
Conducting
Transdisciplinary
Research
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Preface

We dedicate this book to the 20th anniversary celebration of the Academy of Transdisciplinary Learning and Advanced Studies (ATLAS). Started in Austin Texas back in 2000, The ATLAS non-profit organization has grown significantly. The ATLAS success was a result of years of dedication and hard work. Now is the time to take a step back and celebrate what our team has achieved. This success would never have been achieved without the contribution of the authors to the Transdisciplinary Journal of Engineering and Science (TJES).

*The main goal of the ATLAS through its R&B TD Research Institute is "**serving students around the world**."*

The editors are grateful to those who contributed chapters to this book and to the Academy of Transdisciplinary Learning and Advanced Studies (ATLAS) for providing support to all the book's publication.

This book contains articles previously published in the ATLAS Journal.

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CHAPTER 1

A Note on Transdisciplinary Thinking

Raymond T. Yeh

This chapter is a follow up on an earlier article[1] in an effort to tackle complex problems: be it economic, social, environmental, etc. by utilizing different examples to explore a transdisciplinary methodological framework based on an interpretation of how Leonardo da Vinci tackled tough problems in his time.[2] The subtitle is a tribute to da Vinci in that he always tried to depict his understandings of nature in art forms. Our interpretation of da Vinci's approach is summarized into four words, namely: ***transcendence, possibility, leveraging,*** *and* ***mastery*** *which we will elaborate below.*

Keywords: Transdisciplinary, self-limiting assumption, transcendence, possibility, leveraging, mastery.

1.1 Introduction

Disciplinary thinking is often self-limiting

Many years ago, I did a workshop for some 50 corporate managers in which I asked them to draw a self-portrait on a large piece of paper. We then had an art show of these self-portraits. Afterwards, about 85% of the people also identified with one portrait during our art show as shown in Figure 1.1.

[1] Raymond T. Yeh, (2019). Towards a Framework for Transdisciplinary problem solving. *Transdisciplinary Journal of Engineering & Science*, Vol. 10, pp. 26-34.

[2] Fritjof Capra,(2013). *Learning From LEONARDO.* Berrett-Koehler Publishers, Inc. San Francisco.

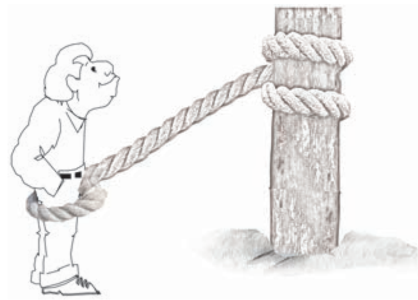

Figure 1.1: Person tied to a post.

The above figure basically says that the person is tied to a post. Well, almost everyone in the workshop identified with this picture though tied to different posts such as family, location, job etc. Each such factor is what I called a *self-limiting assumption (SLA)*. Indeed, almost all of us have *SLA*s. An interesting example is that of Napoleon. The American engineer, Robert Fulton, who was the inventor of the steam powered ships that sailed the Mississippi River. When Fulton tried to convince Napoleon that he could defeat the British Navy by using steam powered ships. Napoleon disconnected and told Mr. Fulton that "What? sail upstream against the wind with a fire under my decks? I have no time for such nonsense."[3] Well, Napoleon's self-limiting view, as an Army general, costed him the opportunity to beat the British Navy.

Consider the story about Charles Darwin and his friend John Gould, a prominent ornithologist. When Darwin returned from his 5-year trip to study geology, he gave his collection of poorly labelled birds, finches, wrens, blackbirds as well as mockingbirds from Galapagos Islands to John Gould, as an expert taxonomist. Gould quickly identified that there were 13 varieties and each variety represented a distinct species, probably one from each of the 13 major islands of the Galapagos Islands. The results confused Darwin. For example, the beaks of finches were used for different functions as some were better to crack nuts while others for pecking insects. While Gould was able to quickly identified the distinct varieties of the birds, it was Darwin to raise the question: "is it possible for a species of birds to split into two or more species if the birds were isolated on separate islands?"[4] This question eventually led Darwin to the discovery of the *Theory of Evolution!* The gist of the above stories indicated the limiting aspect of any disciplinary thinking as both Napoleon and John Gould demonstrated.

A fundamental aspect of TD-thinking is to break the SLAs in order to create new meanings as Lao Tze said well below:

"The mark of a moderate man

[3]Robert S. Block, "Everything is connected to Everything Else", Private communication.
[4]Frans Johansson, The MEDICI EFFECT, Harvard Business School Press, 2004.

Is freedom from his own ideas. . .

Nothing is impossible for him. . .

Because he has let go...”

Learning from Leonardo da Vinci

“One who does not respect life does not deserve it!”

– Leonardo da Vinci –

The above quote pretty much described the essence of this pioneering transdisciplinarian who played different roles: as an artist, scientist, engineer, as well as an eco-designer, in order to understand the nature of life. As Prof. Fritjof Capra elegantly described that “*his science is a science of living forms, and his art served this persistent quest for life's inner secrets. In order to paint nature's living forms, Leonardo felt he needed both a scientific understanding of their intrinsic nature and underlying principles in order to analyze the results of his observations as well as his artistic ability to depict them. I believe that this intersection of needs is the very essence of his synthesis of science and art*”[5]

Based on Dr. Capra's work, I've deduced a framework of Leonardo's work with four concepts as outlined below:

1. **Transcendence:** As a consequence of his deep quest to understand the nature of life. I believe that Leonardo's consciousness level was raised in accordance with his insights obtained from the various projects he worked on which provided inspirations for his other projects. Recall the previous story of Darwin, here is a piece from his autobiography:

   “In October 1838, that is, fifteen months after I had begun my systematic inquiry, I happened to read for amusement ‘Malthus on Population,’ and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favorable variations would tend to be preserved, and unfavorable ones to be destroyed. The result of this would be the formation of new species. Here then I had at last got a theory by which to work.”[6]

   The above insight, triggered by some reading for amusement, seemed to inspire Darwin into a higher level of consciousness and set a clear direction in his research direction.

[5] Fritjof Capra, Learning From LEONARDO, Berrett-Koehler Publishers, Inc. San Francisco, 2013.

[6] Murray Francis (ed). The life and letters of Charles Darwin (p. 83). London, 1887.

2. **Possibility:** According to Capra, Leonardo's work has always been putting life at the center of his work in recognition of the fact that "*all-natural phenomena are fundamentally interconnected and interdependent*".

   By embracing an "interconnected worldview" of seeing nature as a model and mentor. Leonardo was able to see new possibilities previously hidden. This network concept is very similar to the modern notion of *system thinking*[7] which began with the study of cybernetics about *patterns of life* leading eventually to ecological studies of not only nature but also human society with the associated social, economic, environmental concerns etc. Pattern is the result of ordered relationships within an organization or environment. As such, systemic properties are properties of a pattern. For example, the *culture* of an organization is one of its key patterns. Therefore, when a small company is merged into a big one, its cultural pattern is usually destroyed over time while many other components such as buildings, people, etc. may remain.

3. **Leveraging:** Many meaningful connections of ideas for innovation came to view as he tried "to understand a phenomenon meant connecting it with other phenomena through a *similarity of patterns*".

   This concept is most associated with many modern notions of innovation. Consider the former Apple CEO Steve Jobs with his iPod – cited as one of the best examples of innovation.

   Well, the iPod wasn't the first portable music device (Sony popularized the "music anywhere, anytime" concept more than 20 years earlier with its Walkman); iPod wasn't the first device that put hundreds of songs in your pocket (dozens of manufacturers had MP3 devices on the market when the iPod was released in 2001); and Apple was actually *late* to the party when it came to providing an online music-sharing platform. (Napster, Grokster and Kazaa all preceded iTunes.)

   What made the iPod and the music ecosystem it engendered was that it meaningfully leveraged all of these elements into a well-designed (enhanced ergonomics and ease of use) single device, and then tied it into a platform that effortlessly kept that device updated with music. Apple invented nothing. Its *innovation* created an easy-to-use ecosystem that unified music discovery and delivery in a single device. And, in the process, it revolutionized the music industry.

   iPod is a good illustration of oft quoted phrase of Archimedes:

   "Give me a lever long enough and a place to stand,
   and I will move the earth."

[7] Fritjof Capra, The Web of Life, Anchor Books, Doubleday, 1996.

Leveraging on different components via meaningful connections for innovation has been widely used in many fields. More than 20 years ago, my good friend, Dr. Stephen Hochshuler, founder of the Texas Back Institute, showed me one of the key aspects of his institute's practice during a visit to him. Every morning, the doctors will gather together to review some of the more difficult cases together, leveraging on each other's experience and knowledge. Stephen is a pioneer in the modern notion of *precision medicine.* Stephen's approach was similar to NASA-JPL's X-team approach that I also witnessed at the same time framework.

Here is a wonderful architectural example of building an office compound in Zimbabwe with no air conditioning system–a great challenge as the temperature in the African plains can range from 40 degrees at night to over 100 during the day. However, Mike Pearce, architect for the Eastgate Center in Harare, the capital of Zimbabwe, accomplished the mission by basing his design on *how termites cool their mounds of mud and dirt.* Eastgate, a huge office complex, was able to maintain its temperature between 73-77 degrees. [8] Like Leonardo, Pearce's new architectural design derived from the *process of nature.*

Another wonderful example of leveraging came from Dr. Clair Brown, a renowned professor of economics at the University of California at Berkeley, who leveraged Buddhist mindset for some of the toughest economic problems of our time. In her book "*Buddhist Economics: An enlightened approach to the dismal science*"[9] which provided an economic framework that integrates global sustainability, shared prosperity and care for the human spirit. By leveraging on Buddhist philosophy of *compassion* and accumulated lessons of modern economic theory, she developed a holistic approach based on actual national policies that reduce inequality, protect the environment, and Share-Prosperity Index (SSPI) for 50 countries. While it will take courage and political will to implement her suggested policy actions, many of them, however, have already been partially implemented in northern European nations as well as in Nepal, a Buddhist country.

It is interesting to note here that Leonardo's idea of "seeking for similarity of patterns" was rediscovered by Mr. Altshuller, a Russian engineer. He and his colleagues developed a problem-solving methodology called *The Theory of Inventive Problem Solving (TRIZ)*[10] built on the study of the patterns of problems and solution using logic, data, and research ...!

4. **Mastery** By expanding his ability to see new connections as he usually worked on several diverse projects at the same time and when he got some

[8] Frans Johansson, The MEDICI EFFECT, Harvard Business School Press, 2004.

[9] Clair Brown, Buddhist Economics: *An enlightened approach to the dismal science* (Bloomsbury Press), 2014.

[10] Atila Ertas, *Transdisciplinary Engineering Design Process,* John Wiley & Sons, 2018.

insight from one project, he would also update other relevant projects. What Leonardo showed us is that the *journey to mastery is never ending!*

Consider the journey of athletes in the high jump competition. In the early part of 1900s, high jump record stood at just over 6 ft. By 1990, that record has been raised to over 8 feet. During this period, innovative high jumper introduced three radically different techniques, each one a vast improvement over the previous one. The last one, the *Fosbury Flop*[11] was ridiculed by critics who felt the techniques looked sloppy and undignified. But the results are stunning. The introduction of each new technique caused the high jump world to shift to a new paradigm until it reached a plateau and gained maturity. Then, someone will come up with a new innovation for the next leap.

While the above story is an excellent example of mastery for individuals, how do we deal with truly complex issues of our time, e.g. the COVID-19 Pandemic and other important issues on social and economic policies, climate change, social inequality, etc.? In other words, how do we deal in general with the two important issues of mastery, namely; *resilience and sustainability*? Or if we take into considerations of ethics as in the language of ecologists, the question becomes "how can we satisfy our needs without endanger the survivability of future generations?"

In their 2002 book *Cradle to Cradle: Remaking the Way We Make Things*, architect William McDonough and chemist Michael Braungart presented an integration of design and science that provides enduring benefits for society from safe materials, water and energy in circular economies and eliminates the concept of waste.

The book put forward a design framework characterized by the key principle of **Zero Waste** derived from nature. Indeed, in nature, the "waste" of one system becomes food for another. Everything can be designed to be disassembled and safely returned to the soil as *biological nutrients*, or re-utilized as high-quality materials for new products as *technical nutrients* without contamination.

Rather than seeking to minimize the harm we inflict, *Cradle to Cradle* re-frames design as a positive, regenerative force–one that creates footprints to delight in. This paradigm shift reveals opportunities to improve quality, increase value and spur innovation. It inspires us to constantly seek improvement in our designs.

[11]The person jumps backwards over the bar with the legs following the upper body. It is named after the US athlete Dick Fosbury who first used this method at the 1968 Olympics and won a gold medal.

1.2 Examples to Interpret the Methodological Framework

In the following, we shall provide some examples to interpret the methodological framework mentioned above.

1. **The story of North Hawaii Community Hospital (NHCH)**[12]

   Located in the northwest town of Waimoa on the island of Hawaii and serving only 30,000 residents, the hospital nevertheless has developed an international reputation. For example, one Japanese cancer patient who could hardly speak English insisted on being treated at NHCH.

   NHCH is yet another dream come true for Earl Bakken, co-founder of Medtronic, who has long dreamed of a hospital that blended Eastern and Western healing approaches for the benefit of patients. At NHCH, patients are usually under the care of Western physicians, but are free to request the acupuncture and energy healing treatments offered by the Eastern-trained or Hawaiian professionals at the hospital. While the local population and state officials doubted that NHCH would ever open because of the difficulty in obtaining a permit, the hospital defied all odds and opened in 1996. While Bakken is thrilled that the hospital is operational, he knew it's only the beginning. He has a bigger dream. With NHCH, he envisioned a patient-centered, high-tech, high-touch and natural environment in which to practice "blended" or "complementary" medicine. We will provide here a simple description of the essence of NHCH design in terms of the TD-framework mentioned earlier.

   Transcendence – Bakken, always fascinated with healing, seeks to bring a completely new concept of healthcare to the world, called a "Healing Island," a term he coined. Inspired by Hippocrates, the acknowledged father of Western medicine, who established a medical center and school more than 2,000 years ago on the island of Kos, located in the Aegean Sea. Bakken strives to transform the entire island of Hawaii into a vortex for healing, envisioning it as the 21st century Kos of the Pacific.

   Possibility – In the case of NHCH, its vision statement is: "*our vision is to treat the whole individual–body, mind, and spirit–through a team approach to patient-centered care, and ultimately to become the most healing hospital in the world.*" As an example of the above statement, NHCH is located *in the middle of 5 volcanos, benefiting from their collective energy.*

   Leveraging – Figure 1.2 provides a strategy in that the design is the result of blending "high tech", "high-touch" and "ideal environment". While we will not get into the specific "high tech" equipment here, we

[12] Raymond Yeh and Stephanie Yeh, The Art of Business, Zero Time Publishing, 2004.

note that the notion of “high touch” used in the Figure 1.2 has a specific denotation at NHCH. For example, in addition to the traditional physician-patient relationship, the hospital uses the *primary nursing* concept, which assigns a single nurse to a group of patients rather than having different nurses perform separate functions. With primary nursing, each patient has a better chance of developing a trusting relationship with their nurse. In addition, NHCH uses the concept of a “care team,” which brings the primary nurse aides and housekeepers together in groups of five to care for groups of eight patients. This facilitates closer relationships between the hospital staff and patients. It’s concept of an “ideal environment” will be described more in the section below.

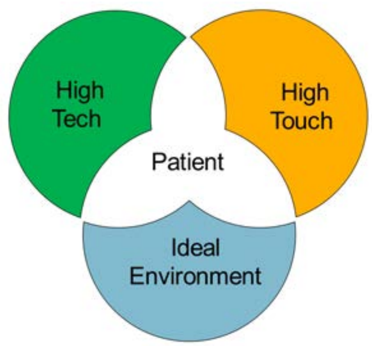

Figure 1.2: Strategy for blending design – “high tech”, “high-touch” and “ideal environment”.

Mastery– Figure 1.3 below provides the patient-centered model for healing. Within the model is the never-ending process of improving the notion of “patient-centered care”. The Internal-External-Physical-Psycho framework creates a healing presence on all relationships for healing each patient who is also a partner.

The vertical axis depicts the patient’s environment, both internal and external, while the horizontal axis depicts the nature of the environment in terms of physical or psycho-social-spiritual aspects. For example, the first quadrant encompasses physical elements of the external environment. At NHCH, windows are easy to open and every room has a sliding door that leads to an outside garden (the hospital is a single floor structure), which gives patients direct access to fresh air and sunshine. Skylights are scattered throughout the hospital’s rooms and hallways, and the décor features pleasing and lively colors. Patients are encouraged to choose specific works of art for their own rooms and closed-circuit “care channels” are programmed with music and video images developed specifically for healing. NHCH offers a wide assortment of fresh foods, as well as education on diet and nutrition.

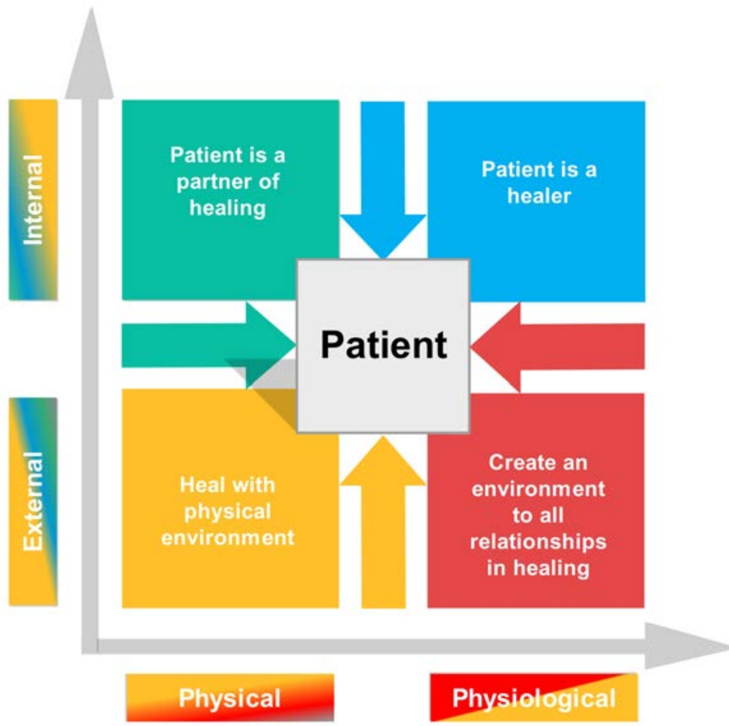

Figure 1.3: Patient-centered model for healing.

The second quadrant of the model looks at the psycho-spiritual elements in the patient's environment. For Bakken, the relationship with others or the "healing presence" is the cornerstone for this quadrant. To facilitate maximum healing, the hospital offers a wide variety of Western and Eastern healing approaches, including acupuncture and energy healing. The third quadrant deals with the patient's internal environment. Contrary to the normal traditional Western physician-patient model, at NHCH the patient is considered a partner in healing. The whole spectrum of wellness, including dietary habits, exercise, smoking, drinking, and drug use fits in this quadrant. Finally, the fourth quadrant addresses the psycho-spiritual aspects within a patient. In other words, what does the patient bring to the table for his or her own healing? Do they have a lot of self-love? Do they feel responsible for their life and their healing process, or do they feel like victims? This quadrant engages the healing potential within each patient, bringing it up to the conscious level to aid in the healing process.

2. **Transforming South African from Apartheid syndrome to a**

democratic Republic?[13]

On April 27, 1994, the world stood back in awe as South Africans of all races stood in long lines to cast their votes in the country's first democratic election. Prior to that election, few could imagine that South Africa, bitterly divided between white power and black oppression, would become a symbol of hope to all nations. In a miraculous moment of perfect timing, all the necessary ingredients came together for the creation of the unprecedented *Truth and Reconciliation process*, which featured forgiveness and reconciliation between races rather than punishment and retribution. Historically, the primarily black African National Congress (ANC) had been supported by the former Soviet Union, leading Western nations to support the opposing white apartheid forces. However, when Mikhail Gorbachev burst onto the world scene and brought the ideas of perestroika and glasnost to bear, the so-called "evil empire" of the Soviet empire began to disintegrate, along with its expansionist support of the ANC. As a result, Western nations could no longer justify supporting white apartheid South Africa. As the dominant Eastern and Western nations began to withdraw their influence from South Africa, Nelson Mandela, imprisoned leader of the ANC, and F. W. DeKlerk, leader of the white apartheid government, both rose to meet the challenge of creating a peaceful future, seizing this single cubic centimeter of chance for reconciliation. DeKlerk had tremendous difficulty in persuading the whites that it was in their best interests to lay down their arms. It required great humility for DeKlerk to fight for a democratic process that would eventually vote him out of office.

But Mandela and other black leaders had a far more difficult time taming the fire of the blacks who demanded vengeance. After 27 years of imprisonment by the white government, though, Mandela stood as the perfect icon to preach and ask for forgiveness, creating the unforgettable process of Truth and Reconciliation. Indeed, during the period between 1990, when Nelson Mandela was freed from prison and the ban was lifted on the ANC and other black and left-wing political parties, and when the first all-race election was held in 1994, a flurry of radical and miraculous events took place that helped the nation to transition away from apartheid toward freedom.

One of these events was the Mont Fleur scenario project, which was sponsored by a group of South African academics, business people, and activists. Adam Kahane was chosen from Shell's strategy department to help them facilitate the forum utilizing Shell's scenario methodology. The group intended to influence the future of the country by developing a set of scenarios that described how events might unfold over the coming ten-year period. The forum consisted of 22 leaders drawn from

[13] Adam Kahane, Solving Tough Problems, Berrett-Koehler Publishers, Inc. San Francisco. 2004.

organizations spread across the political map, including academics, ANC members, members of the old establishment, and businessmen. "*One of the good things about working with a group like this is that they can learn a lot about what is going on from listening to each other. It was as if each of them had a piece of the larger puzzle picture of South Africa."* Using Shell's scenario planning method and guided by Kahane, the team came up with four scenarios:

- **Ostrich:** A story of the white government believing that it could avoid a negotiated settlement with the black majority, burying its head in the sand, and thereby making matters worse in the end.
- **Lame Duck** A story of prolonged transition where the new government was hobbled by compromises built into the constitution and, because "it purports to respond to all but satisfies none." As such, it would not be really able to address the country's problems.
- **Icarus:** A story describing the results of a strong black majority government coming to power on a wave of popular support and embarking on a huge, unsustainable public spending spree that would crash the economy.
- **Flight of the Flamingoes:** A key characteristics of flamingoes is that they take off slowly but they fly together. This scenario is a story about how the new government could avoid the pitfalls of the first three scenarios and gradually rebuild a successful economy.

According to Kahane, the Icarus scenario was the most unexpected and probably exerted the greatest influence. This scenario was created at a time when most leadership attention was focused on achieving a successful political and constitutional transition, not on economics. The Icarus scenario pointed out that the conventional tendency to redistribute resources away from rich whites to poor blacks would not create a sustainable solution for the country. Once the scenarios had been written, the team organized a series of workshops with different political, business, and civic groups, where the stories were presented and the implications discussed. Kahane recalled one particular event: "One of the workshops was with the leadership of the Pan Africans Congress (the PAC), a radical black political party, and at this meeting one of the members of the Mont Fleur team, who was the PAC's head of economics, presented the Icarus scenario. He said 'This is a story about what will happen if our rivals, the ANC, come to power. And if they don't do it, we will push them into it.' That provocation led to one of the most productive of all the workshops. Many years later, in 1999, when another member of the team was appointed to be Governor of the Reserve Bank, he said at his inauguration,'We are not Icarus. There is no need to fear that we will fly too close to the sun."' Kahane believed that economic wisdom and prudence of the post – 1994 South African government has been influenced by the Mont Fleur scenarios, especially the Icarus scenario.

Below is a summary of the above narratives in terms of TD-thinking framework:

Transcendence – to see collectively the possibility beyond each participant's view to reach a solution for all. Indeed, the consciousness of the whole nation was greatly enhanced as Mandela skillfully leveraged the Rugby game to bring the consciousness of the whole nation to a high level after they won the world championship in 1995.

Possibility – scenarios took into considerations of social, political, economic and international considerations. Indeed, after the black government took over, they created the Truth and Reconciliation Commission, a court-like body established in 1995 to help heal the country and brought about a reconciliation of its people by uncovering the truth ab"*The Truth Commission helped us to move away from the past to concentrate on the present and future"*!

Leveraging – involving leaders from most of the key national constituencies and hence facilitated better understanding as well as embracing an interdependent world view. Also, prior to winning the World Cup, the Rugby team had travelled extensively around the country to work with teams in schools to connect on a national basis.

Mastery – The Mont Fleur project clearly made a lasting imprint on South Africa's social, political and economic transition. While the approach was basically transplanted directly from Shell's planning team, Kahane noticed that the effects were much different in South Africa. He said: "*Although the methodology of this project was the same as the one we used at Shell, the purpose was fundamentally different. The Mont Fleur participants were not, like corporate strategists, simply trying to adapt to the future as best they could; they had come together because they wanted to influence the future, to make it better. They were playing on a larger field. When you think about it logically, at least one of the reasons the future is unpredictable is because we can influence it. The team members didn't see themselves as detached observers, but as active participants; most of them had devoted their lives to fighting for a better South Africa. They were aware of how their own thoughts and actions had an impact of what happened around them – they were reflective." In other words, mere analysis lacks the force and purpose to create a desired future. South Africa's almost unimaginable transition demonstrated that co-creating a desired future provided the inspiration which translated into passionate, active participation to serve a higher purpose.*

While the use creative teamwork to identify and influence critical current choices during the workshop, it would not have been enough to change the fate of a nation. In fact, more than 100 such workshops were held later around the country to spread the message. Indeed, it was a miracle to move a nation with apartheid Syndrome to a democratic Republic by overcoming great social and economic barriers to embrace a common world view that they can fly together to create a new order!

3. **The founding and maintenance of the American Dream.**

   On the night of July 2, 1776, words reached the delegates attending the Second Continental Congress in Philadelphia that the British Empire struck, intending to annihilate the budding democracy of its rebel colony. By August there were 32,000 British troops in New York, ready to march on Philadelphia, a city with a population of only 30,000. George Washington's pickup army of 7,000 untrained, ill-equipped farmers stood as the only line of resistance. Each of the delegates who signed the Declaration of Independence was fully aware of the death sentence that awaited them if their bid for freedom failed.

   Transcendence: As Benjamin Franklin said so well, "We must all hang together, or most assuredly, we will hang separately." The dream of freedom, the declaration that "All men are created equal; that they are endowed by their Creator with certain inalienable rights," meant more to these men than life itself. In other words, the collective inner transcendence provides the inspiration and courage to build a new nation.

   Possibility/Leveraging: Opening up the American border to allow wide divergent talents to immigrate to the US to create the opportunities for all as well as to transform the American society. Indeed, as a consequence of the new possibilities, it facilitated the connection of different cultures and talents which form the basis of American innovation in the subsequent years.

   Mastery: The fight for the American dream mentioned above has been renewed time and again by the great leaders in the American history: by Abraham Lincoln during the Civil War, by Martin Luther King, Jr. in the civil rights movement, and by Lyndon Baines Johnson with his vision of a Great Society, etc. Though every fight was different, each of these leaders was guided by the dream of freedom, of creating a society in which, "all men are created equal." While there were many struggles over the years, it proved the tenacity of the new Republic both in terms of its *sustainability* as well as *resilience* time and again.

1.3 Towards A Framework for TD-Thinking

Looking at how tough problems are solved in general; I would suggest that "transcendence" is the essential aspect of any major breakthroughs. In other words, the TD-thinking is a problem-solving mythological framework based on the notion of "*inner transcendence inspired outer transformations*"[1] as shown in Figure 1.4.

In the traditional design thinking (DT) process,[14] they look for three

[14] Tim Brown, Design Thinking, Harvard Business Review, June 2008.

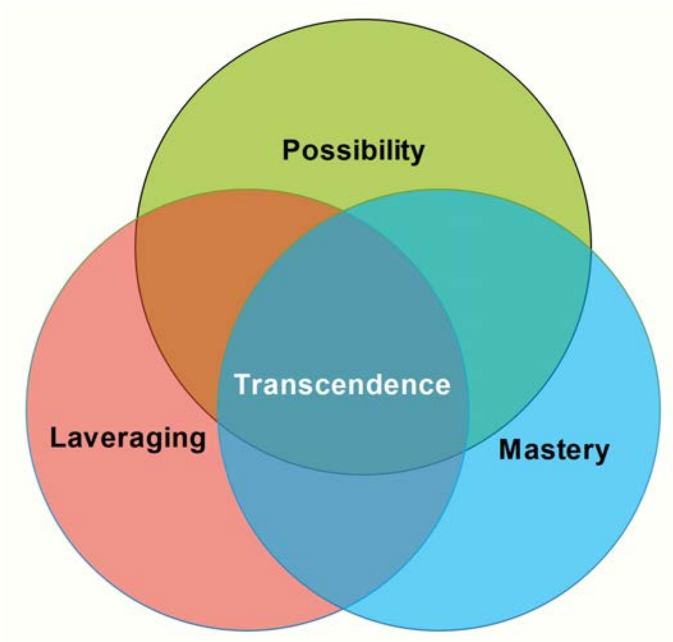

Figure 1.4: TD-thinking problem-solving mythological framework.

things, namely, desirability (does this satisfy the users requirements?), feasibility (can this be done within budget/time or other constraints?) and viability (will this work for the feasible future, etc.?). The three questions above can be answered from the three outer circles of Figure 1.4 above from which a number of possible solutions might emerge. However, from a TD perspective, we need to answer one more question, namely, *should we do this*? This leads to questions such as: "should we get cheaper gas by fracking"? Should we dump millions of tons of garbage or plastics into the ocean, etc.? In other words, the question is whether it is ethical to do this no matter how profitable it is? Indeed, if our consciousness level has reached certain level to embrace that "we are all interconnected" so that if we do something, its ripple effect over time may not be so desirable to our grandchildren. Indeed, these questions lead us to discover an important aspect that traditional Design thinking does not ask the question: "*what's our responsibility*?" By adding this element to the Design Thinking process seems to provide a target for TD-thinking as shown in Figure 1.5. In other words, Figure 1.5 is the desirable outcome of the actions taken based on the outline in Figure 4.

It should be noted, however, that ethical consideration is not the only element of responsibility. Here is a beautiful story.[15] In the middle of the 19the century, Sir Gilbert Scott was hired by the New College at the Oxford

[15]MAX DePREE, Leadership Jazz, Dell Publishing, 1993.

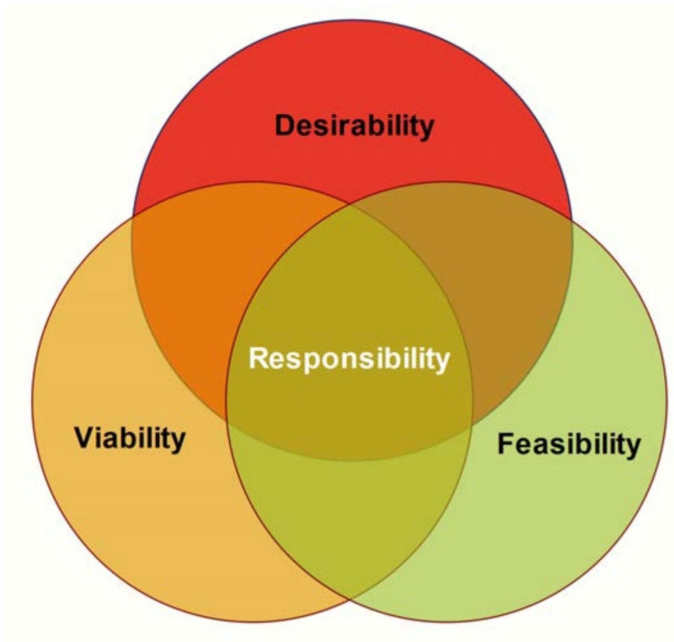

Figure 1.5: TD-thinking.

university, built in the late 14th century, to restore the roof and the great oak beams, which was badly rotten, that supported it. Representatives from the college took Sir Gilbert to visit the Great Hall Woods in Berkshire. Well, the replacements were standing there waiting to be hewn out of the living oaks trees, planted a century before, for just that purpose. A *responsible* leader's promise had been fulfilled!

Figure 5 has two interesting perspectives, namely, *the solution of a design may vary with time as the consciousness level of the designed team or organization changes* as illustrated by the example of the evolution of the United States above. This should come as no surprise based on the hierarchy of needs by Abraham Maslow.[16] The moving up in each hierarchical level implies a "breaking of the SLA" mentioned earlier as the foundation of DT. The story of Prof. Yunus and his Grameen bank,[17] outlined in my previous paper, is a good illustration of such a behavior. It is interesting to note that Maslow had extended his initial 5-level of needs to 7 levels with the top level labeled "*transcendence*".

Given that the framework in Figure 5, it meshes well with the Design Thinking (DT) methodology. We also note an interesting aspect of TRIZ, men-

[16] McLeod, S. A. (2020, March 20). Maslow's hierarchy of needs. Simply Psychology. https://www.simplypsychology.org/maslow.html

[17] Yunus, Muhammad. Banker to the Poor – Micro-lending and the Battle Against World Poverty 1999, Public Affairs, New York.

tioned earlier, in its link with the DT. The principal limitation of DT, however, is in its high subjectivity, which generates some rigidity called psychological inertia observed in the search for a solution within a very well-defined space. Also, DT does not offer strategies or techniques for the detailed solution of the intrinsic problems of the design process. This means that the procedure of the problem-solving that arises during the design process depends on the experience of a team or an individual. Thus, "*TRIZ may assist the requirements of the Design Thinking model. TRIZ contains among its tools, a set of techniques that allow modeling and solving inventive problems. At the same time, TRIZ does not propose any tool or technique to identify the user's requirements, a fundamental aspect of the DT model. As a consequence, the strategy to leverage on both approaches and presents a basic structure to balance the best characteristics of both approaches has emerged"*.[18]

It is also clear that within this framework, *system thinking* is a natural to be deployed as part of the TD- problem- solving processes, especially for providing a holistic view of systems with long feedback loops encountered in ecological and other complex systems.

1.4 Conclusion

The core of TD thinking lies in its holistic view in tackling a problem by first surrendering to a higher purpose via *transcendence* in order to break SLAs of the team so that new possibilities or new connections might emerge.

The ancient Chinese general Sun Tzu understood that an ideal army must have the capability to deal with all kinds of changes, flowing like water to adapt. He asserts:

"For just as flowing water avoids the heights and hastens to the lowlands,

so an army avoids strength and strikes weakness.

And as water shapes its flow in accordance with the ground.

so an army manages its victory in accordance with the situation of the enemy."

When we view an organization, such as an army, as a living organism rather than a machine, we see new possibilities. By treating organizations as machines, we see only transactions, which are the snapshots of dynamic changes occurring within and outside of the organization. However, when we shift from a mechanistic perspective to a more quantum perspective based on relationships and wholeness, we see enterprises as consisting of *flows* of cash, knowledge, work, material, people and information. *Flows* provide the links

[18] Hugo Domingo García-Manilla etc., "Integration of Design Thinking and TRIZ Theory to Assist a User in the Formulation of an Innovation Project" in Managing Innovation in highly Restrictive Environments, Springer. International Publing AG,2019.

between transactions and processes, bringing an organization's environment to a dynamic, adaptable existence.

Similarly, when we view a complex problem as something solid to be decomposed into simpler pieces to be analyzed, we missed all of its intricate *flows/interdependencies* that constitute the *whole* in both space and time. Hopefully, *TD-thinking*, as we proposed above, provides a way to contemplate the *wholeness* of complex problems facing us today. Indeed, such understanding provides answers to the *meaning of life* – living, death, joy, sorrow, ...in the sense that we will not find it by ourselves alone, we find it with another. As we let go of our attachments, *we transcend!* Indeed, *inner transcendence helps to inspire outer transformations!*

Perhaps the following quote from Maryanne Williamson's poem is a proper place to end this chapter:

"And as we let our light shine,

We unconsciously give other people permission to do the same.

As we are liberated from our own fear,

Our presence automatically liberates others."

–A Return to Love –

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CHAPTER 2

Conceptualizing Trans Well-being within Transdisciplinarity

Sue L. T. McGregor

After describing conventional approaches to well-being (hedonic and eudaimonic, subjective and objective) and explaining the four philosophical axioms of Nicolescuian transdisciplinarity (TD), this conceptual research paper identified and juxtaposed four alternative approaches to well-being against Nicolescuian TD: social conception, self-transcendent, intra-active, and relational well-being. The notion of prototypical (lay) well-being was also introduced. What might well-being look like within transdisciplinarity? The paper concluded that ***trans well-being*** *(a new term) would be a process that is situated, contextual and emergent. It would always be unfolding and becoming, arising with and through others. Trans well-being would be a state of being* ***with*** *others (and the environment) and might even be a form of epistemic self-discovery (insights into psyche and self). Upon embracing Nicolescuian TD, perceptions of well-being may have to shift from a* ***state*** *of being to a process of* ***being with*** *others in perpetual evolution.*

Keywords: Well-being, Nicolescuian transdisciplinarity, conceptual research, trans well-being, prototypical well-being, alternative conceptualizations of well-being.

2.1 Introduction

Given the current state of the postnormal world, characterized by chaotic change and crises along with opportunities to mitigate the complex, uncertain situation (McGregor, 2016) [1], humanity's well-being is front and center (Apgar, Argumendo,& Allen, 2009) [2]. Well-being is already a "complex philosophical and political concept" (Smith & Reid, 2017, p. 7 [3]). Enter transdisciplinarity (TD) wherein Efthimiou (2017) [4] referred to "the development of transdisciplinary wellbeing frameworks" (p. 34). McIntyre-Mills (2014) [5] spoke of "transdisciplinarity and a reframed approach to wellbeing" (p. 75). This nascent line of thinking stimulated this paper about what might constitute the conceptualization of well-being within transdisciplinarity.

In particular, this paper reports on conceptual research, which serves to relate specific concepts to particular issues (in this case, well-being to transdisciplinarity) with the intent to both map the research terrain evolving around the concept and better define it (Rocco & Plakhotnik, 2009) [6]. Conceptual scholarship contributes significantly to any discipline's intellectual renewal and evolution (Smithey Fulmer,

2012) [7]. After describing longstanding conventional approaches to well-being and profiling the Nicolescuian TD approach, four alternative conceptualizations of well-being are explained and juxtaposed against transdisciplinarity. The idea of well-being as prototypical is also introduced as one that pushes back against both generic and alternative approaches.

Transdisciplinary and other scholars are encouraged to critically reflect on and engage with the ideas shared in this paper. Mitstifer (1996) [8]appreciated the intellectual angst that can arise during this sort of philosophical exercise, cautioning that reframing "well-being . . . will take time, suspended assumptions, and collegial regard for the development of a free flow of meaning and of windows to new understandings" (p. v). As caveat, the word can be hyphenated (well-being) or not (wellbeing) depending on usage in different parts of the world (Grammarist, 2013) [9]. The author used the hyphenated version while respecting the version used in sources cited.

2.2 Conventional Approaches to Well-Being

There is no firm agreement on what constitutes well-being (Gasper, 2004 [10]; Hone, Schofield, & Jarden, 2015 [11]; McGregor, 2010b [12]). But generally speaking, compared to wellness, which is a dynamic process, well-being is a state of being, a condition of being happy, healthy and prosperous at a particular time (King, 2007) [13]. To illustrate, well-being is "a state of being where [people] have economic security; are respected, valued and have personal worth; feel connected to those around them; are able to access necessary resources; and are able to participate in the decision-making process affecting them" (Marshall, McMullin, Ballantyne, Daciuk, & Wigdor, 1995, p.1 [14]).

Two overarching approaches to well-being have emerged in the literature and practice: (a) hedonic, also called subjective well-being (SWB) and (b) eudaimonic or objective well-being (OWB) (Belzak, Thrash, Sim, & Wadsworth, 2017 [15]; McMahan & Estes, 2011 [16]). These conceptualizations need to be understood before considering alternative approaches that can be aligned with transdisciplinary tenets.

2.2.1 Subjective and Objective Well-being

Subjective well-being concerns people's assessment of their own state of being at a particular point in time. They evaluate and then judge both their life satisfaction (cognitive *state*) and happiness or unhappiness (emotional *state*). The different circumstances and conditions of a person's life determine their resultant self-assessment. *Objective* well-being focuses on third-party assessment of other people's quality of life and the good life including the latter's access to both (a) material resources (e.g., income, food, housing) and (b) social attributes (e.g., education and health) and connections (i.e., social networks, political voice and inclusion) (Smith & Reid, 2017 [3]; Western & Tomaszewski, 2016 [17]).

In more detail, the objective approach assumes that people have basic needs and rights that can be objectively (third person) observed so as to discern the extent to which they are being satisfied. Measurable indicators include income, employment, health, housing and education. Lists of objective well-being measures are well established in the literature. Things appear or not on the list because researchers have assumed that they are good and bad for well-being causing this approach to be characterized as paternalistic. The subjective approach tries to eschew paternalism by directly asking people what *they* think and feel about their own state of well-being; this involves self-reporting how satisfied people are with their lives (Qizilbash, 2009 [18]; Smith & Reid, 2017 [3]; see also Sianf's (2011) [19] blog posting at the United Kingdom's Office of National Statistics' wellbeing consultation site).

2.2.2 Hedonic Well-being

Hedonic is Greek hedone, "pleasure" (Harper, 2019) [20]. The hedonic approach (SWB) equates well-being with pleasure, happiness, satisfaction and utility (Gasper, 2004 [10]; McMahan & Estes, 2011 [16]; Smith & Reid, 2017 [3]). It is referred to as "a life of gratification" (Smith & Reid, 2017, p. 4 [3]). "In short, the hedonia tradition frames being well in terms of feeling good" (Belzak et al., 2017, p. 123 [15]). "Well-being [equates to] what is good for me" (Crisp, 2017) [21]. It "focuses on happiness and defines well-being in terms of pleasure attainment and pain avoidance" (Ryan & Deci, 2001, p. 141 [22]). The current state of well-being is "the totality of one's hedonic moments" to date (Ryan & Deci, 2001, p. 144 [22]). Some argue that achieving hedonic well-being (i.e., a life of gratification) depends on "selfishness, materialism, objectified sexuality, and ecological destruction" (Smith & Reid, 2017, p. 4 [3]).

2.2.3 Eudaimonic Well-being

In contrast, the eudaimonic approach (OWB) focuses on "the processes which enable self-fulfilment, meaning and purpose [to realize] human potentiality" (Smith & Reid, 2017, p. 4 [3]). Eudaimonic is Greek eu, "good" and daimon, "guardian, guide" (Harper, 2019 [20]). The term arises from what Aristotle called daimon, one's true self or true nature (Qizilbash, 2009 [18]; Smith & Reid, 2017 [3]). While hedonic refers to the experiences of pleasure, eudaimonic pertains to the experiences of meaning. Hedonism is the pursuit of pleasure as a matter of principle. The eudaimonic approach refers both to contributing to the greater good and cultivating personal strengths by living a life of purpose (rather than instant gratification), vitality, self-actualization and integrity (McMahan & Estes, 2011[16]; Ryan & Deci, 2001 [22]). It envisions people achieving well-being by "pursuing meaningful, valuable and exemplary lives" (McMahan & Estes, 2011, p. 105 [16]).

For clarification, the eudaimonic approach holds that although some desired outcomes may be pleasurable, they are not necessarily good for the person and thus will not promote well-being (McMahan & Estes, 2011 [16]; Ryan & Deci, 2001 [22]). With its OWB bend, the eudaimonic approach has also been criticized for being too paternalistic meaning those espousing it are trying to protect people for their own good possibly infringing on the latter's personal liberty (Crisp, 2017 [21]; Qizilbash, 2009 [18]; Smith & Reid, 2017 [3]).

2.3 Transdisciplinarity

Reframing well-being in light of transdisciplinarity requires an explanation of *trans*, which is Latin for across, beyond, back and forth, zigzagging (lateral movements), moving through, passing beyond the limits to a new space (Harper, 2019 [20]; Nicolescu, 2002 [23]). As push back to the limitations of disciplinarity, multi and interdisciplinarity, transdisciplinarity was first coined as a term in 1972 (Apostel, Berger, Briggs & Machaud, 1972 [24]; Bernstein, 2015 [25]). A world movement subsequently developed with two main schools of thought: Zurich and Nicolescuian (McGregor, 2015a [26]). Two other underutilized approaches were tendered by Erich Jantsch and Joseph Kockelmans (McGregor, 2010a [27]).

The Zurich school of thought emerged from a 2000 conference in Switzerland. Adherents to this approach assumed that science is the main research methodology but it has to be done differently within social constraints and with societal input (Klein et al., 2001) [28]. The approach informing this paper was initially formulated and advanced during the late eighties by Basarab Nicolescu (2002 [23], 2014 [29]). He views transdisciplinarity as a new methodology for creating knowledge (a companion to empirical, interpretive and critical methodologies) (see McGregor, 2018b) [30]. Nicolescu (2006) [31] characterized his approach as theoretical and the Zurich approach as phenomenological (i.e., application in context).

In more detail, after observing the world, Nicolescu concluded that there is both (a) too much fragmentation of knowledge (i.e., too many specializations in too many disconnected disciplines, over 8000) and (b) a strong penchant to privilege science over life-world knowing (Klein, 2014 [32]; Nicolescu, 2002 [23], 2014 [29]). Humanity faces a plethora of complex, vicious and aggressive psychological, social, political, economic and environmental messes: unsustainability, climate change, health pandemics, poverty, non-renewable resource management, violence, uneven development, and uneven income and wealth distribution. Addressing these complex problems requires a *unity of knowledge* - a joining of disciplinary and other-sector knowledge (Nicolescu, 2002 [23], 2014 [29]).

Nicolescu thus called for the "fusion of knowledge and being" (2014, p. 212 [23]) referring, respectively, to objective science and subjective life (hearken objective and subjective well-being). With this in mind, he conceived of and 'worked out' (formulated) transdisciplinarity based on three conventional philosophical axioms: (a) ontology - what counts as reality, (b) epistemology - what counts as knowledge, and (c) logic - habits of the mind considered acceptable when reasoning and drawing conclusions and insights (Nicolescu, 2002 [23]; Rohmann, 1999 [33]). Cicovacki (2004) [34] and McGregor (2011 [35], 2018b [30]) added the fourth axiom of axiology - the role of values in research - respecting that Nicolescu (2014) [29] asserted it is not necessary, to be discussed (see Figure 2.1).

2.3.1 TD Ontology

Nicolescu's (2002 [23], 2014 [29]) formulation of transdisciplinary ontology positioned it as multiple levels of Reality whose interface is mediated by the unifying force of the Hidden Third. These multiple Realities exist on two levels: (a) internal where human consciousness and perspectives flow (the TD-Subject) and (b) external where information flows (TD-Object). This collection of Realities (he capitalizes the word) corresponds to levels of understanding that deepen when reasoning moves from one level to and through another. Movement amongst these levels is lubricated with culture and art (aesthetics), religions and faiths, spiritualities, and the Sacred (Nicolescu, 2014 [29], 2016 [36]) (see Figures 2.2 and 2.3). Eric Reynolds creatively called these "spirit-opening modalities" because they enable knowledge and perspective

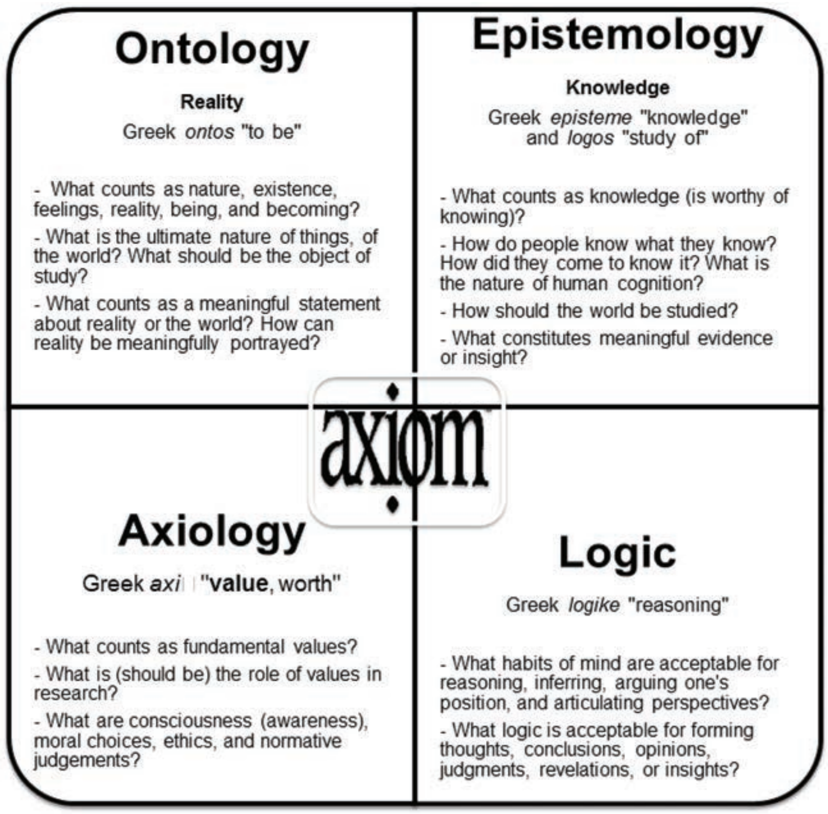

Figure 2.1: Nicolescuian transdisciplinary axioms.

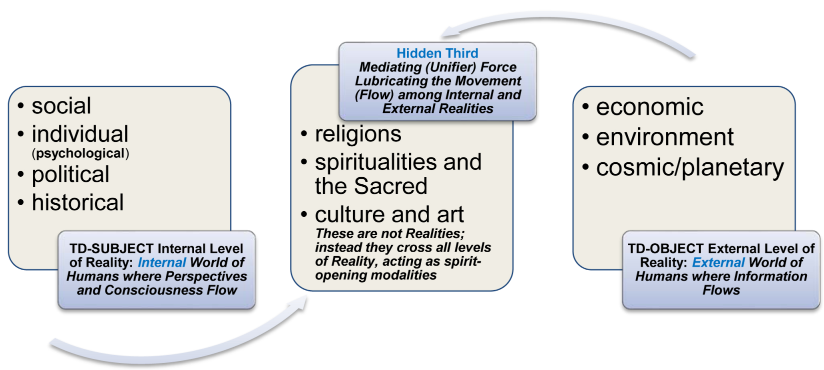

Figure 2.2: Nicolescuian transdisciplinary ontology.

integration to occur by serving as nonresistance-enabling forces (personal communication, August 15, 2018).

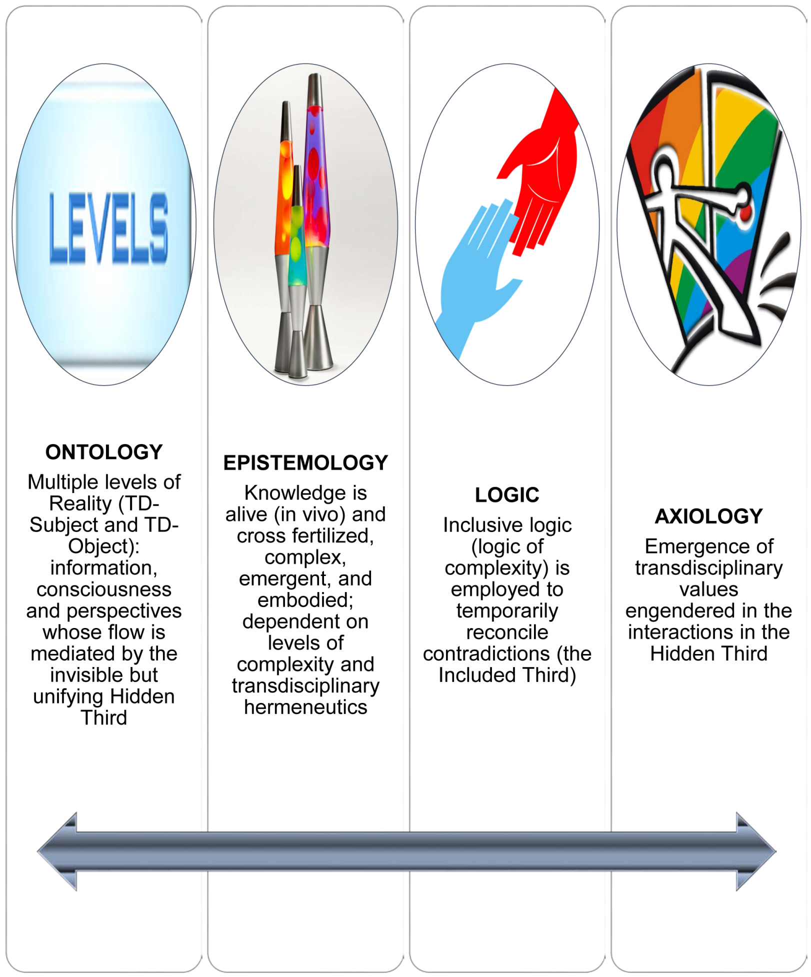

Figure 2.3: Nicolescuian Transdisciplinary Axioms.

This conceptualization of reality eschews the Newtonian idea that there is one Reality out there waiting to be discovered using the scientific method. There are many, many Realities rife with resistance to each other but - to mock the Borg - resistance cannot be futile; contradictions and incongruities must be accommodated in order to create the TD knowledge required to address the messy complexities of the world (McGregor, 2018b [30]; Nicolescu, 2014 [29]).

2.3.2 TD Epistemology

Respecting this imperative (Star Trek pun continued), Nicolescuian epistemology (called complexity) understands knowledge to be alive and always in-formation (far beyond mere information); it is *crossfertilized* (many disciplines and sectors), *complex* (can adapt and self-organize), *emergent* (always coming into being) and *embodied* (made whole by and owned by everyone) (Nicolescu, 2006 [31]). All of the diverse people from the academy (university) and civil society (businesses, governments, citizens, and non-governmental organizations) co-create this knowledge, which they then co-own and shepherd (McGregor, 2018b [30]). McGregor (2015b) [37] used a lava lamp metaphor to explain the dynamics of this powerful fusion of intellects and horizons (perspectives) - this reconciliation of disparate mind sets so new TD knowledge can emerge.

Also TD epistemology encompasses transdisciplinary hermeneutics, which concerns what happens when people cross boundaries while engaging in TD work and *how* this happens. At issue is what conditions have to be in place for true understandings to emerge about each other and the emergent knowledge. When people's mental perceptions of something can be expanded, even transcended (to a new space), the unity of knowledge is more likely. The fusion of perceptions and prejudices leads to more powerful understandings of self, others and the emergent TD knowledge (Nicolescu, 2014 [29]; van Breda, 2007 [38]).

2.3.3 TD Logic

Nicolescu formulated that TD knowledge creation happens through the use of *inclusive logic*, which means nothing is excluded even if it is antagonistic, contradictory and tension forming. All input has the potential to lead to new knowledge with people meeting in the fecund space (i.e., *fertile middle ground*) between the academy and civil society to share and co-create it. Nicolescu (2002) [23] based his formulation of this space on the quantum notion of a vacuum, which is not empty but at its lowest energy level, ripe with potential. In this *included middle* (e.g., the undulating floor of the lava lamp), diverse perspectives can temporarily be set aside so people can become open to others' ideas and viewpoints leading to the emergence and creation of something new.

They do so by employing the *logic of complexity* leading to complex TD knowledge (Nicolescu, 2014) [29]. Complexity is Latin *complexus,* "that which is woven together" (Harper, 2019) [20]. The opposite of complex is not simplicity but that which is not woven; it is independent (Alvira, 2014) [39]. Complexity logic lets people cross and connect different ways of knowing in creative and coherent ways (Nicolescu, 2014) [29]. Combined with inclusive logic, it is a powerful way to create new TD knowledge.

2.3.4 TD Axiology

Axiologically, this emergent TD knowledge creation process entails both the respect and management of actors' values as well as the emergence of new *transdisciplinary values* that did not exist before. Nicolescu believed that a separate axiology axiom is not necessary because values derive (originate) from epistemology, ontology and logic. TD values arise from, are engendered in, the interactive region of the Hidden Third (McGregor, 2018b [30]; Nicolescu, 2002 [23], 2010a [40]). He further argued that these TD values matter more than each individual's value schemata in place when entering and sustaining activities during TD knowledge creation. He claimed that these derived "values are engendered by Trans-Reality. They are not human-made" (Basarab Nicolescu, personal communication, June 9, 2010). They arise from the primordial soup so to speak.

In contrast, McGregor (2009) [41] posited that people's value schemas matter and cannot be dismissed; instead, initial value positions *can* shift over time during people's engagement in the included middle thereby creating the "potential to converge into an integral collection of values that privilege transdisciplinary tenets." It is called integral because what emerges from this rich interaction 'is what it is' because this *particular* constellation of TD values jelled. If something is integral, it is absolutely essential and indispensable - the new whole would not 'be what it is' without it (McGregor, 2018a) [42]. TD values, in effect, transcend individual values moving to a unique arrangement that reflects the dynamics of a *particular* problem solving engagement. This unified knowledge becomes part of the world's knowledge base for all to use.

2.4 Alternative Perspectives of Well-being

Much like Nicolescu (2002) [23] took issue with the fragmented subject and object, Smith and Reid (2017) [3] urged well-being scholars to move beyond the prevailing dichotomy between subjective (hedonic) and objective (eudaimonic) well-being. This transition will be especially necessary if people choose to align well-being with transdisciplinarity, which, in summary, encompasses complexity, emergence, multiple perspectives, aliveness, and openness to new ways of thinking. It requires the integration of human consciousness and perspectives with external information - the soft with the hard. What emerges must be owned and stewarded by everyone involved. Transdisciplinarity embraces inclusiveness, joint collaboration and inventiveness, intellectual and perspective fusion, modes of reasoning (logic) that accommodate weaving together disparate viewpoints, and the birth of TD-steeped values.

In the TD context, the concept of well-being has to broaden and deepen. Focusing on individual *states* of being (whether hedonic or eudaimonic) is not enough when so many actors are intricately and integrally involved in the fluid and emergent process of addressing complex issues in search of plausible solutions and implementing and living with those solutions so humanity's well-being is enhanced. It is a given that human well-being is a central feature of the dynamics of complex systems and interactions; hence, well-being must remain a central aspect of addressing complex problems (Apgar et al., 2009) [2].

By association, well-being scholars need to respect "people in their complexity, in their social and historical contexts" (Gasper, 2004, p. 30 [10]). Well-being should be conceived as "an open-ended phenomenon [that resists] the imposition of pre-established categories" (Smith & Reid, 2017, p. 11 [3]). Such an approach would "offer an appreciation for the emergent complexities of human-ecological relations" (Smith & Reid, 2017, p. 11 [3]). Indeed, McIntyre-Mills (2014) [5] claimed that instead of associating well-being with individual or aggregate economic prosperity, well-being scholars should embrace the idea that "wellbeing rests on mindfulness of our relationships with others and with the environment, not on status or ability to live [consumerism-fuelled] lifestyles of our own choosing" (p. 75).

Others concur, agreeing to the need to reframe well-being as 'being with other' as well as with the environment (Gough & McGregor, 2007 [43]; Millennium Ecosystem Assessment, 2005 [44]). Armitage and colleagues defined well-being as "a state of being with others and the natural environment that arises where human needs are

Social Conception	Self-transcendent	Intra-active	Relational
• Well-being is both outcome (state) and process • Well-being is a state of being *with* others made possible because of the processual interface of material, relational, and subjective components	• A higher range of well-being exists when people are open and have the chance to transcend beyond their psyche to another space or level after experiencing 'the transcendent' (different from normal experiences) • Well-being is an *epistemic self-discovery* not of one's own volition (aha! awe-inspiring moments)	• A process-oriented approach concerned at the micro level with how entities and relationships come into existence relative to the transient, transpersonal, and contextual nature of well-being • World is considered to be in perpetual process of becoming so well-being also has to be *always becoming and unfolding*	• Well-being is an emergent process by which something appears over time through the interplay of relational self (always in relationships), societal structures, and the natural environment • Well-being is *situated and emergent* • Relationality is generative meaning *relations shape well-being* • Well-being *arises through and with others*

Figure 2.4: Alternative conceptualizations of well-being.

met, where individuals and groups can act meaningfully to pursue their goals, and where they are satisfied with their way of life" (Armitage, Béné, Charles, Johnson, & Allison, 2012, p. 3 [45]). White (2017) [46] also framed well-being as arising through and with others. She claimed that relationships are "intrinsic to the constitution and experience of well-being" (White, 2017, p. 128 [46]); well-being is dependent on relationships, which are essential to the quality and character of each person's well-being.

The following text identifies and explains four alternative conceptualizations of well-being and juxtaposes them against transdisciplinarity: social conception, self-transcendence, intra-action, and relational well-being (see Figure 2.4). These nascent constructs were culled from the literature both by using Boolean search techniques based on the concepts of well-being (wellbeing) and transdisciplinarity and following leads emergent from particular articles. The search process was especially inspired by the early find of Smith and Reid's (2017) [3] article titled *Which 'being' in well-being*? This ontological play on words resonated with Nicolescu's (2002) [23] especially formulated ontology (concerned with Reality, coming into being, becoming, existing). These four approaches represent the only ones found in the search process using the parameters explained herein.

2.4.1 Social Conception of Well-being

Armitage et al. (2012) [45] envisioned well-being as both a process and an outcome, which is a shift from conventionally viewing well-being as a state of being (i.e., just the outcome). They created a social conception of well-being by nesting individual basic human needs within social-psychological and cultural needs. Understanding the *process* of well-being (i.e., a series of steps toward a particular end or outcome) entails viewing it as human agency and capabilities that "emerge [at] the interplay of the objective (e.g., people's circumstances shaped by material and relational dimensions) and the subjective (e.g., values and perceptions)" (Armitage et al., 2012, p. 4 [45]). White (2017) [46] also positioned well-being as "anchored in material and relational contexts" (p. 128). In short, well-being emerges during the interplay of the subjective and objective much like TD knowledge emerges from the interplay of TD-subject and TD-object (see Figure 2.2).

In more detail, Armitage et al. (2012) [45] explained that the material component of social-focused well-being encompasses both physical and financial assets considered essential to well-being: income, health, assets, wealth, and public and private services. The relational component focuses on social and collective interactions, reciprocity, and a sense of self-identity in concert with community connections all shaped by state and societal structures. The subjective component includes values, beliefs, norms, perceptions, and notions of self - "a sense of . . . contentment with [their] 'way of life"' (p.4). Armitage et al. (2012) [45] believed that knowledge of the processes involved in three dimensions coming together to create the outcome of "a 'life well lived"' (p. 4) is a valuable way to conceptualize well-being. Put simply, a social focus respects that "'well-being is a state of being with others"' (p. 4).

Transdisciplinarity is all about social connections, interactions, processes and emergence (McGregor, 2018b) [30]. Conceptualizing well-being through a social lens, which is concerned with basic human needs, cultural needs and social-psychological needs, provides a way to deal with material realities, relational dynamics, and values, beliefs and norms. Transdisciplinarity cares for material circumstances, relationships and values all of which shape problem posing, addressing and solving. Considering how the needs of people, society and culture affect 'being with others' is a valuable shift in how to view well-being. From a TD perspective, solving complex problems requires entering and working within the fertile middle ground where mindsets are temporarily set aside so all voices can be heard and integrated using inclusive and complexity logics. The resultant well-being that emerges would be a new "state of being with others" that arose from a rich process; well-being is both outcome and process (Armitage et al., 2012, p. 4 [45]).

2.4.2 Self-transcendent Well-being

Transdisciplinary knowledge is alive and always in formation, changing with insights, innovations and inspiration (Nicolescu, 2014) [29]. In their discussion of whether inspiration falls under the hedonic or eudaimonic well-being traditions, Belzak et al. (2017) [15] created the new concept of *self-transcendent well-being*. Self-transcendent people are inclined to reach out beyond themselves. They have "the capacity to expand self-boundaries *intrapersonally* (toward greater awareness of one's philosophy, values, and dreams), *interpersonally* (to relate to others and one's environment), *temporally* (to integrate one's past and future in a way that has meaning for the present), and *transpersonally* (to connect with dimensions beyond the typically discernible world)" (Reed, 2003, p. 147 [47]). This is possible because these people tend to be open to experiences and exhibit energetic, powerful behaviour (De Fruyt, Van De Wiele, & Van Heeringen, 2000) [48].

In practice, this form of well-being exists when people, who are open to experience, *actually* experience revelatory encounters *with* the transcendent (something that is apart from normal human experiences) evident in a-ah, light-bulb, awe-inspiring life moments. Self-transcendent encounters help people to move beyond their conscious self to a new place of insight and inspiration (Belzak et al., 2017) [15]. This is possible because they have been open to and actually encountered an experience or phenomenon that pushed them even beyond self-actualization to a place where they are transcenders, "*instruments* of the transpersonal" (Maslow, 1993, p. 282 [49]). To be discussed, transpersonal refers to people stepping outside their personality, beyond their own psyche, to a new space (Kelly, 2005) [50].

Self-transcendent well-being is "a 'higher' range of well-being experiences" (Huta & Ryan, 2010, p. 739 [51]). It is "triggered by illumination," which is possible when people are "open to aesthetics, absorption [and] self-forgetfulness" (Belzak et al., 2017, p. 135 [15]). This is exactly the type of well-being that needs to be engendered when people enter the fertile middle ground to engage in TD work. They need to become open to others' world views and perspectives, an openness that is lubricated by the spirit-opening modalities of aesthetics enabling people to become absorbed in the emergent TD knowledge-creation process. They would not lose themselves but find themselves.

This is different from eudaimonic well-being, which is a "kind of volitional self-expression" (Belzak et al., 2017, p. 135 [15]) (i.e., purposeful expression of will). Instead, self-transcendent well-being is an "epistemic self-discovery" (p. 135) (i.e., new insights into self). This resonates perfectly with TD epistemology and ontology wherein new knowledge (episteme) emerges from employing inclusive logic in the lubricating and illuminating Hidden Third (the transcendent process of becoming) (Nicolescu, 2002) [23].

2.4.3 Intra-active Well-being

Transdisciplinary work is dependent on interactions among people during the process of co-creating TD knowledge (Nicolescu, 2002) [23]. Accordingly, Barad's (2003 [52], 2007 [53]) quantum notion of intra-active, employed by Smith and Reid (2017) [3] to conceptualize intra-active well-being, opens interesting ontological doors for TD work. Both Nicolescuian TD and Barad's intra-active concept are grounded in some combination of the new sciences of complexity, chaos and quantum physics (e.g., embeddedness, emergence, entanglement).

Inter means between and among and *intra* means within and inside (Harper, 2019). Barad (2003 [52], 2007 [53]) believed another concept was needed beyond interaction, which assumes that entities pre-exist and can relate. Barad was interested in what is involved in the process of these entities coming into existence or materializing in the first place. Concerned with "the materialization of all bodies - 'human and nonhuman"' (2003, p. 810 [52]), Barad argued that "all phenomena are ontologically primitive relations [; that is, there are no independent entities only] entities within relations" (2003, p. 815 [52]). Similarity, Nicolescuian ontology assumes that all levels of reality are what they are because they are in relation with each other (Nicolescu, 2014 [29], 2016 [36]).

The intra-action concept (i.e., what happens within) concerns how relations and entities (e.g., knowledge) materialize; ontologically ignoring how these relations 'come to be' means people "will miss all of the crucial intra-actions among these factors" (Barad, 2003, p. 810 [52]). Inspired by Barad's (2003 [52], 2007 [53]) focus on, what could be called, the imperceptible but very real intra context of entities and relationships, Smith and Reid's [3] conceptualization of intra-active well-being "attends to the more transient, transpersonal and contextual aspects of wellbeing" (2017, p. 1). This attention to imperceptible but influential processes resonates with TD work.

Respectively, people who are engaged in TD work are *transient* - they have a foot in their academic home while roaming the connections available in a network of relationships and contexts, iteratively staying in each place for short periods of time (Smith, 2003) [54]. TD work is *transpersonal* meaning people transcend (i.e., climb beyond existing limits) their individuality and personality so they can engage in complexity work with others (Kelly, 2005) [50]. Although TD is all about *context*, Smith and Reid (2017) [3] (geographers) maintained that well-being scholars have neglected to take into account the impact of context, space and place on the conditions that shape well-being.

From a transdisciplinary standpoint, intra-active well-being is a very useful ontological acknowledgement of the dynamics behind, between and beyond relationships and new knowledge becoming a reality within the included middle while disparate people *interact*. The micro, intra dynamics of the formation of these emergent entities (i.e., relationships and knowledge) is an intriguing approach to well-being within transdisciplinarity. Said another way, *well-being comes into being* during TD work and there is a rich, micro process behind this phenomenon. In effect, well-being may be better conceived "as relational practices rather than [a] stable foundation of . . . life" (Smith & Reid, 2017, p. 10 [3]).

To reiterate, Smith and Reid (2017) [3] created intra-active well-being as a way to deal with the more process-oriented transient, transpersonal and contextual aspects of well-being that are shaped by intra-active forces; this takes well-being far beyond a static 'state of being.' Instead, the formation of well-being is contingent upon and inseparable from the micro context within which it is embedded and entangled (Barad, 2003) [52]. The well-being as intra-active approach (i.e., well-being is "never stable, never the same") sheds light on the dynamics often concealed when well-being is defined as already existing "as stable and measurable" in a person's mind (Smith & Reid, 2017, p. 4 [3]). Similarly, TD knowledge is alive, never the same, always evolving (Nicolescu, 2002) [23] making these two approaches quite compatible.

Smith and Reid (2017) [3] also ingeniously referred to the world as being complex and full with this "fullness in a constant process of becoming" (p. 12); by association, they rationalized that a vibrant conceptualization of well-being is warranted, one that views it as a fluid process. This is especially relevant within the context of transdisciplinarity where knowledge is deemed alive and the world's future depends on the fusion of disciplinary and life-world knowledge so the world can remain complex and always becoming (McGregor, 2018b [30]; Nicolescu, 2002 [23]). Well-being as intra-active scaffolds this basic transdisciplinary premise in that it respects the micro processes behind the materialization of entities, both human and nonhuman (e.g., knowledge). To reiterate, this construct intimates that 'well-being comes into being' during TD work.

Finally, TD work also involves many different people temporarily letting a part of themselves go to make room for others' perspectives (McGregor, 2018b) [30]. This eventuality benefits from a conceptualization of well-being that presumes people are "part of the world becoming [which involves] the unfolding of well-being" (Smith & Reid, 2017, p. 14 [3]). In fact, Gasper (2004) [10] used the term "well-becoming" to accommodate the idea that people "must be created, formed, emerge [so they can] exist in time" (p. 6.). To complete the circle, their well-being is linked to well-becoming and well-dying. Smith and Reid's (2017) [3] conceptualization of intra-active well-being draws on concepts that are the bedrock of transdisciplinarity: letting go (mini dying), unfolding, becoming, and emerging along with embeddedness, processes, and complex dynamics.

2.4.4 Relational Well-being

Well-being is a process and has a relational dimension (Armitage et al., 2012) [45]. In that spirit, relational well-being concerns "the terms and qualities of relationships" while individual or personal well-being refers to how "well-being is thought [about], felt and experienced" (White, 2017, p. 128 [46]). Important to Nicolescu (2002 [23], 2014 [29]), "ground[ing] wellbeing in a relational ontology ... can challenge discourses that result ... in the fragmentation of the self" (White, 2017, p. 129 [46]). Theorized and developed by White (2017), relational well-being is grounded in three factors. "Relational selves, societal structures and the natural environment [each has] some relative autonomy with its own structures and processes [while concurrently] being interdependent and in tension with each other" (White, 2017, p. 131 [46]).

In more detail, the term *relational self* refers to people's inclination to define their own personal well-being from "the sense of being in relationship" with others (White, 2017, p. 130 [46]). Reciprocity is key with the imperative being to sustain relationships instead of worrying about who will benefit, how or when. Although these are unknown, people are confident that help and support will be forthcoming because the relationships have been nurtured and sustained (White, 2017) [46].

White's (2017) [46] second notion of *societal structures* involves respecting the power inherent in having *established* (solid) structures instead of privileging the tenets of "openness, flow and flexibility," which intimates fluid structures (p. 130). People pattern their life narratives through these societal structures so the former "should not be under emphasized" (p. 130) [46]. Third, relational well-being includes the *natural environment*, the local context, and the larger concept of place. She [46] maintained that the rhythms, flows, processes and tipping points of nature have to be accorded due respect because they influence human well-being as well as humans' relationship with nature.

White (2017) [46] concluded that relationality is central to well-being. Relationality is generative, meaning it is capable of generating and producing something. With this in mind, she framed relational well-being as an *emergent process*, "something that *happens* [emphasis added] in and over time through the dynamic interplay of personal, societal and environmental structures and processes" (p. 133 [46]). She [46] believed that relations come first, not people; relations shape well-being. Accordingly, well-being is not always quantifiable, either there or not. Instead, it is "situated and emergent" (Smith & Reid, 2017, p. 11 [3]). Likewise, TD knowledge is situated and emergent suggesting a plausible alignment between relational well-being and transdisciplinarity.

2.5 Prototypical Well-being

As discussed earlier, the classical approach to defining the concept of well-being relies on researchers identifying a collection (list) of necessary and sufficient features that all have to be present in order to measure or experience well-being (Hone et al., 2015) [11]. This section elaborates on Rosch's (1975) [55] challenge to this assumption. She [55] suggested that the concept of well-being is not generic; rather, it is a prototype developed and used by *each* person (it may or may not align with scholars' conceptualizations of well-being). Given that TD work depends on a fusion of disciplinary and lay knowledge (Nicolescu, 2002) [23], lay notions of well-being deserve attention here.

A prototype is the preliminary form from which other forms are developed. It is also considered to be a typical example of something, ideally a good example. In the field of innovation and design, a prototype is built to test a concept; it is a fully working model. A prototype approach to well-being involves people categorizing things in terms of their similarity to a good example of well-being. In contrast, a classical approach to well-being assumes there are essential elements in a list that *must* be present for well-being (Rosch, 1975) [55].

Rosch [55] further theorized that in order for people to have a prototype of well-being, they must be able to (a) compile a list of dimensions or features of well-being, (b) rate the centrality of (i.e., agree upon) each feature relative to how it helps *them* understand well-being, and (c) illustrate that this centrality affected how they think about well-being (i.e., their cognition). Rating each feature contributes to the creation of an internal structure of well-being in their mind, a prototype they can then turn to when needed (Rosch, 1975) [55]. They do not rely on third-person conceptualizations of what 'being and living well' look like (i.e., eudaimonic); instead, they make up their own.

Rosch (1975) [55] further explained that, from a prototype approach, the well-being concept has both content and a structure. Content pertains to, what well-being scholars often call, dimensions or features of well-being such as economic, social, emotional, political, cultural, environmental, spiritual, and existential (see McGregor & Goldsmith, 1998) [56]. Structure refers to whether the person deems specific dimensions as essential (i.e., central) or less essential (peripheral) to their understanding of well-being (Rosch, 1975) [55].

In more detail, central features are strongly associated with the concept while peripheral ones are not. The latter are of secondary importance and less essential to one's understanding of what constitutes well-being; one's are not an integral part of the concept but they do inform it (Rosch, 1975) [55]. The prototype approach accepts that for well-being to be experienced, the features deemed by that person to be central (i.e., the *core* of the prototype) must be there rather than all critical features identified in an arbitrary list having to be there. The prototype approach allows for 'degrees of well-being' rather than an all-in approach (Kearns & Fincham, 2004) [57].

Why does this matter? Hone et al. (2015) [11] opined that the proliferation of so many different conceptual definitions of wellbeing supports their assertion that there *are* lay prototype structures. Put simply, lack of researcher agreement of what constitutes well-being (i.e., what should be in the list) indicates that some features are central and others are peripheral with this scenario called *prototypical* for each person rather than generic or theoretical. To illustrate, Kearns and Fincham (2004) [57] showed that each person has a prototype of the concept of forgiveness that she or he can activate and use; this lay prototype may or may not align with theories of forgiveness. They confirmed that this finding also holds for the concepts of love and commitment with Hone et al. (2015) [57] intimating the same for well-being.

Each person's well-being prototype *typically* has both central and less-essential features; it is prototypical (unique) for *that* person. By "activating the prototype," people can assess their well-being or that of others (Kearns & Fincham, 2004, p. 851 [57]). Following their [57] lead for the forgiveness concept, people are encouraged to heed prototypical lay conceptions of well-being because the latter may augment and advance well-being conceptualization. A prototypical approach has merit. If, as transdisciplinarity assumes, a diverse collection of people is coming together to address and hopefully solve complex societal problems, a diverse collection of lay perspectives on well-being makes sense with prototypical well-being augmenting, maybe transcending, conventional and alternative conceptualizations.

2.6 Discussion and Conclusions

After explaining the conventional approaches to well-being, four alternative conceptualizations were profiled and juxtaposed against transdisciplinarity: social conception, self-transcendent, intra-active, and relational (see Figure 4). After careful consideration, the key takeaway of 'What might well-being look like within transdisciplinarity?' is that well-being is emergent and relational; it is about *being and becoming with others.* This analytical insight prompted the new term *trans well-being* (not to be confused with the well-being of trans people, Ashley, 2018 [58]).

A working definition of *trans well-being* embodies specific aspects of the four approaches that nourish the new definition. These include a sense of well-being that *transcends* conventional hedonic (SWB) and eudaimonic (OWB) approaches, which focus respectively on self-assessment or third-party assessment but not conjoined creation and assessment of well-being by both researchers and lay people (prototypical). Dichotomizing subjective and objective well-being makes no sense when the entire premise of transdisciplinarity is to unite the TD subject with the TD object (Nicolescu, 2002 [23]). Trans well-being would thus respect the axiomatic tenets of Nicolescuian transdisciplinarity (see Figures 2 and 3). It would especially focus on relations, processes, context, transcendence, and being and becoming.

The first four factors are key tenets of Nicolescuian transdisciplinarity (McGregor, 2018b [30]; Nicolescu, 2002 [23]) and reinforce the notion of augmenting TD with alternative conceptualizations of well-being. Regarding being and becoming, Smith and Reid [3] posed the existential "unspoken question of which 'being' is implied when researching well-'being"' (2017, p. 2). Gasper (2004) [10] raised a parallel concern when commenting that "too much work on well-being has been based on insufficient evidence and theory about *be*-ing" (p. 29). Given that ontology is the most contested TD axiom (Nicolescu, 2010b) [59], the ontological observation that the *being* part of well-being has been shortchanged is even more compelling.

Fortunately, a cursory analysis revealed that alternative well-being scholars are respecting the call to focus on the dynamic, processual being and *becoming* part of well-being. Specifically, focusing on italicized entries in Figure 4, trans well-being, relative to transdisciplinarity, would be a *process* that is situated, contextual and emergent. It would always be unfolding and becoming, arising with and through others. Trans well-being would be a state of being *with* others (and the environment) and might even be a form of epistemic self-discovery (insights into psyche and self). These suppositions inspire further ontological and theoretical investigation to generate insights that could help advance "transdisciplinarity and a reframed approach to wellbeing" (McIntyre-Mills, 2014, p. 75 [5]).

In closing, transdisciplinarity is concerned with how to "better understand the world, the contemporary human situation, and the meaning of human life" (McGregor, 2010a) [27]. Reversed, this equates to eudaimonic (meaning), hedonic (current state) and trans-well being (unified understandings via melding of subjective and objective). This conceptual research mapped the nascent research terrain evolving around alternative conceptualizations of well-being and better defined the concept in the context of transdisciplinarity (Rocco & Plakhotnik, 2009) [6]. Alternative conceptualizations of well-being were shown to positively align with transdisciplinarity's four axioms (see Figure 3). This conceptual alignment proves promising for future research and practice. Trans well-being would involve a shift from viewing well-being as a *state* of being to a *process of being* with others in perpetual evolution.

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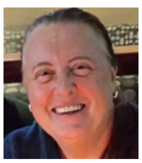

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CHAPTER 3

Complexity and Transdisciplinarity: The Case of Iconic Urban Megaprojects

Gerardo del Cerro Santamaría

*The nature and the shaping of urban megaprojects owes to the socio-economic, developmental, institutional and geographic context where they emerge. However, megaprojects, regardless of context, constitute **disorderly, disruptive and contentious complexity** and have an intrinsic potential (often realized) to elicit substantial controversy and criticism that fundamentally questions the parameters of the projects as envisioned and publicly presented by their promoters. As a result, it is possible to highlight – as will be done in the conclusion to this paper – some suggestions for future research and policy practice aiming at urban sustainability that can be applied to the planning, design, management, implementation and development of megaprojects worldwide. Our proposal converges around transdisciplinary research on urban megaprojects. From the vantage point of transurbanism, the complex nature of megaprojects can be justly observed and assessed. In fact, the concept of complexity, which is salient in transdisciplinary approaches, suits research on urban megaprojects as characterized by disorder, disruption and contention.*

Keywords: Urban megaprojects, complexity, transdisciplinarity, disorder, disruption, contention.

3.1 Introduction: Transurbanism and the Outside

Transdisciplinary urbanism is a proposal to focus on the reality of the outside both as a dimension of human experience and as a research strategy. This entails an ethical stand, that of *noblesse d'espirit*, that ought to drive our quest for knowledge and social change. The "reality of the outside" is not only the physical reality that embraces the city outside of urban megaprojects, but also the phenomenological reality of the knowing subject "being-in-the-world," and political reality outside of the priorities of elites that are never going to make the necessary efforts to improve society. The urbanism of the outside is a transdisciplinary endeavor enacted from multiple agencies, from the bottom up, from the margins to the center.

In recent years, citizen participation in urban planning processes has become both a demand and a reality. As the result of major economic crises around the world and growing awareness of the exploitation of the environment and climate change, disenchanted citizens have demanded to be more hands-on in deciding about and influencing their living environments, while public authorities retaliate by drawing lines of jurisdiction. In the field of architecture and urbanism, some have advocated for a radical change aimed at expanding design practice into a socially and politically relevant field. Here the idea, put forward by Rizzo and Galanakis, is to develop a new urbanism education curriculum to include public-service practice, similar to the long-established curricula in law and medicine [1].

At the same time, in the heterogeneous field of urban studies, many are starting to side with urban activists and artists to bring about the change that mainstream planning has failed to deliver. According to this view, public space has become the focus and location to organize artistic and cultural interventions that aim at questioning, amongst others, the current land use program, social and political injustice, and ultra-liberal privatizations of public commons. However, many questions arise about the use of art in urban studies, such as, how the extensive critical theoretical work on urban space and processes of urbanization of recent decades may further inform artistic practice, performance and intervention.

Within urbanism, several attempts have been made towards less reductive approaches to space and design; approaches that no longer choose between theory and practice as the ideal locus for critique, but, instead, allow critique to be processed in ways that are more complex and more entangled; approaches that advocate **hybrid modes of inquiry**. One can think of the hybridisation of nature and technology, engineering and the social, facts and values, human and non-human, and the explicit attention to agency in Science and Technology Studies (STS) and Actor-Network-Theory (ANT). Such approaches have in common their suggestion to approach urban issues not according to predefined ideologies or (critical) theories but to study them **as a problem of the outside – as situated, complex gatherings of all sorts of agencies, where the notion of transdisciplinarity can be applied meaningfully.**

We believe with Doucet and Janssens that, when countering the idea of design practice as a mere applied theory, and instead considering the architectural and urban question as hybrids, complex gatherings, and “messy undertakings,” we should nevertheless not content ourselves with doing this alone. Both accountability and designerly, complex ways of understanding urbanism’s agency in the world should be confronted with the fact that, no matter how well we develop tools to deal with it, and thus account (take responsibility) for such complex engagements, we will always be facing the contingency of design, a “leap in the dark.” Namely, we can never entirely predict what the design itself will result in and what effect a design outcome will have, which unexpected agencies may enter, and what surprises we can enjoy [2].

Urban designers, despite insecurities about the effects of their actions, nevertheless act in a concerned manner and be held responsible for their actions. They ought to engage with the world in an irreductive, complex, and problematising manner rather than in a reductive fashion. In other words, they need to allow for surprises and with it “other possibilities” and, thus, “hope” as necessary elements for the enhancing of urbanism’s projective capacity. No matter how well our design methods may become in order to deal with the complexity of the world, as soon as it starts to aim to control that complexity and contingency again, chances for the unexpected, for events to emerge, are constrained, and with it, any possibility for change. The answer to these challenges may be a transdisciplinary approach to urbanism that takes into account both the discovery (knowledge) dimension and the design (creation) dimension [3].

The common denominator of all approaches is an attempt to reconcile, **exact sciences, social sciences, design and philosophy and advocate for a new transdisciplinary paradigm.** The transdisciplinary framework envisioned here is similar to that suggested by Gibbons et al. in their "Mode 2" of knowledge production, i.e. a dynamic framework in which multiple players combine empirical and theoretical knowledge to solve applied problems: a combination of knowledge and design, as discussed by Rizzo and Galanakis [4]. Dosse notes that the social sciences are witnessing "a genuine transformation" where terms such as chaos, process, meaning, complexity, and self-organization are slowly replacing the classic concepts of structure, static, combinatory, and universal. In this new framework, Dosse claims that the task of the transdisciplinary-scholar is to clarify, rather than dissect, the "judgments of fact" from the "judgments of value" [5].

Rizzo and Galanakis see Transdisciplinary Urbanism as a new, emerging methodological framework according to which social and action researchers from multiple fields, artists, animators, performers, activists, and local communities come together to study uncertainty, chance and open-endedness, and to transparently renegotiate power structures in urban space. Transdisciplinary Urbanism builds upon the social, philosophical and design aspects of Urbanism; it connects different theories and practices, and crosses disciplines in order to study and improve everyday life. The disciplinary crossovers entailed by such practices push inhabitants and professionals out from their comfort zones, encouraging co-operation and co-creation in non-predetermined ways [6].

Indeed, the exponential growth of both web-based interaction tools, physical sites where knowledge is created, and the recombination of extremely specialized fields in new knowledge entities have facilitated the emergence of a new form of knowledge production that Gibbons et al. have labeled "Mode 2," as mentioned earlier. As the opposite of "Mode 1", in which knowledge is eminently a contribution to compartmentalized disciplines, Mode 2 of knowledge production is characterized by transdisciplinarity, i.e. working within an evolving and dynamic framework in which empirical and theoretical knowledge are combined with design creativity and where multiple players (e.g., universities, research agencies, informal agencies, private firms, NGOs, etc.) contribute to the creation of such knowledge [7].

Transdisciplinarity can also be seen as an evolution of multi- and inter-disciplinarity. However, unlike these latter, transdisciplinarity does not seek to solve the paradoxes generated by the endless dissection of knowledge in smaller disciplinary units. Rather than aiming to the "unity of knowledge," by acknowledging the inherent complexity of the subject, transdisciplinarity directs to master the paradoxes. Building upon this, Transdisciplinary Urbanism (TU), urban studies and design provide the theoretical and empirical foundation to conduct proactive (but not pre-determined) investigation of the effects of change in urban space. TU researchers and the many actors working and living in the city work within the dynamic framework that is represented by contemporary polities, this latter shaped by unpredictable, constructive and destructive cycles.

3.2 Transdisciplinary Research

The process for transdisciplinary research in urbanism consists of three phases: problem identification, problem analysis, and bringing results to fruition. The designerly aspect has to do with the fact that these three stages do not necessarily occur in the given order, and with the fact that "bringing results to fruition" is not the same as problem-solving, and does not necessarily occur at the end of the research process. Rather, it takes place in the course of the research process in order to enable learning processes and is achieved in the form of a real-world experiment, which is, indeed, what an urban design can be considered to be.

In a context of hybrid knowledge among the exact sciences, the social sciences and philosophy, integration between theory and practice, ethical concerns, and the importance of experimental, designerly modes of inquiry become key to transdisciplinary urbanism. Transdisciplinary modes of knowledge production are characterized by hybridization, i.e. the loss of dependency from a specific disciplinary compartment. Transdisciplinary research includes at once what stands between disciplines, across disciplines and beyond any discipline. Transdisciplinarity is about the articulations, rather than the relations, between disciplines: the whole is more than the sum of its parts.

Because urbanism engages, both as a discipline and as a profession, with broader societal concerns (e.g. situated knowledge, participatory design, everyday practices), it therefore seems obvious that hybrid modes of inquiry are part of the knowledge landscape. In the context of this chapter we have used the broad understanding that, whereas *inter*disciplinary knowledge is located in scholarly environments, *trans*disciplinary knowledge production entails a fusion of academic and non-academic knowledge, theory and practice, discipline and profession.

Transdisciplinarity is a mode of inquiry, practice, and learning that places ethics, aesthetics, and creativity inside, not outside, of disciplinary and professional work. It brings new objects into view, places practices into new configurations, contextualizes and re-situates theory and learning, and incorporates social, political, and ethical questions once deemed beyond the proper sphere of research and education. The boundary work of transdisciplinarity is decidedly plural. It is generative, formative, and interrogative, catalyzing critique and transformations of our modes of inquiry, practice, and education.

Transdisciplinary urbanism ought to be inquiry-driven rather than exclusively discipline-driven; meta-paradigmatic rather than intra-paradigmatic; informed by thinking that is complex, creative, contextualizing, and connective, following Edgar Morin [8]. Inquiry here is a process of creativity combining rigor and imagination. Transdisciplinarity is an attitude towards inquiry in urbanism, informed by certain epistemological presuppositions, and an effort to frame inquiry as a creative process that recognizes as central the subjectivity of the inquirer and challenges the underlying organization of knowledge. Problem-driven transdisciplinary urbanism investigates the interactions between the knowing subject and the object of knowledge. It encompasses discovery and creation, knowledge and design, science and creativity for a holistic interpretation of consciousness, space and social forces that includes theoretical, phenomenological and experimental concerns.

3.3 Complexity and Transdisciplinarity

The notion of "strategic urban planning" has become paramount in efforts to address a variety of challenges in urban environments. This notion involves a holistic approach to problem-solving that implies placing the idea of complexity at the forefront of analysis and action. Complex thought, education and knowledge, in Edgar Morin's understanding, take into account contextual, global and multidimensional factors to desvise strategy conducive to more fruitful action.

> "Pertinent knowledge must confront complexity. Complexus means that which is woven together. In fact there is complexity whenever the various elements (economic, political, sociological, psychological, emotional, mythological ...) that compose a whole are inseparable, and there is inter-retroactive, interactive, interdependent tissue between the subject of knowledge and its context, the parts and the whole, the whole and the parts, the parts amongst themselves. Complexity is therefore the bond between unity and multiplicity. Developments proper to our planetary era confront us more frequently, ineluctably with the challenge of complexity." [9]

Complex knowledge also factors in the centrality of the knowing subject in analytical endeavors, the uncertainty of the knowledge enterprise itself and the incompleteness and undecidable nature of *homo complexus*'s human action. Through complex knowledge, the holistic quality of urban planning neturally leads to a transdisciplinary conception of theory-building and practice development.

Thus, a possibly fruitful way to apply this notion of strategic urban planning would be to propose a transdisciplinary paradigm to address urban challenges that places complexity at the forefront of inquiry. Strategy by itself is insufficient if it is based on traditional approaches to knowledge generation. A global and transdisciplinary strategy of sustainable development that frames megaproject development is required.

The global problems of sustainable development consist not only in some of the environmental problems (generally known as climate change and loss of biodiversity), but also in socio-economic issues. Regardless of the possible and multiple interpretations of sustainability, it involves politics, resources and power. Most current attempts to solve sustainable development are not conducive to sustainable development; they are mostly contradictory, inconsistent and inefficient. This contrasts with the nature of the behavior of sustainable development systems, which is non-linear and holistic.

A transdisciplinary way of thinking is in order. Such a way of thinking would cross traditional disciplines and would modify the classical notion of science. A new vision fostering sustainable principles requires a rethinking of human values, and a reconsideration of the integration among the flow of perception, experience and consciousness. It is impossible to imagine a single solution to the problem of sustainability, but many complex, interrelated and evolving solutions. To avoid current destructive human behavior, we need to develop a new collective perception of human relations towards the valorization of a new set of attitudes and behaviors or towards a different prioritization of the set of current values. Holistic and unified knowledge can deal with complex global problems such as megaproject development within a sustainable development framework.

3.4 Urban Megaprojects

For the past few decades, scholars have tried to make sense of an "urban moment" of increasing global attention to the relevance of cities for the evolution and development of nations. The unstoppable population growth in the cities of the planet has only intensified this interest in the urban realm. Cities are today analyzed as lenses through which we can observe and study the main socio-economic phenomena tied to globalization, which marks the evolution of humankind in the beginnings of the 21st century. Further, cities are no longer understood exclusively as individual and discontinuous places, but rather as nodes in networks and flows of transnational capital, matter (goods and services), energy, information and people. Strategically positioning cities in the global network has become a major strategy of economic development for urban elites.

In order to increase their global visibility, many cities have undertaken in the past two decades strategies of revitalization and re-development that in many cases include the construction of emblematic megaprojects, often iconic buildings from an architectural point of view. The expectation was that such iconic buildings and structures would internationalize the city, put it "on the map", attract global investments, visitors and tourists, and thus contribute to solve the perennial problem of improving the welfare and prosperity of urbanites. The city of Bilbao, Spain, is a legendary example (one that is more successful than others) of this focus on urban development via construction of spectacular architecture in times of globalization.

We are heirs to the globalized city, in which it is not possible to conceive anything but the regeneration of areas adjacent to rivers and bays, the recovery of zones previously dedicated to storage and manufacturing, the construction of new transportation infrastructures or the extension of existing ones, as well as the renewal of historical centers. However, the Manhattanization of the world – and the urban political economy that sustains it – also presents difficulties and can create several structural obstacles with direct consequences for the design and implementation of megaprojects in globalizing cities and regions.

3.5 Disorderly, Disruptive and Contentious Enterprises

A case in point is Dubai, a megaproject set in crisis after the recession that started in 2008. After years in which one could regularly find news about the new architectural marvels of the world constructed in Dubai (including sets of artificial residential islands), the situation has been one of hypertrophy for this onetime urban vision. The bubble burst, and the model of Dubai became yesterday's news. Beginning in September 2008, real estate prices fell, and those who had gotten accustomed to positive news on the emirate were rubbing their eyes in disbelief. The glowing reviews about a permanent acceleration in megaproject construction – when Dubai was considered to be the dynamic and innovative center of the Arabic Peninsula – had turned into disbelief, first, and an admission of defeat not exempt of irony, later. The Emirate was bailed out by Abu-Dhabi, and the economic situation has improved in recent years, but a big weakness for Dubai remains: the city lacks a consistent concept of society, with more than 90% of its immigrants having very limited rights and unlikely to reside there permanently [10].

Situations of economic recession are only one of many obstacles faced by megaproject construction. Another is of a political nature, in particular the lack of strong metropolitan governments provided with the necessary instruments to undertake big projects that can transform the urban image and the urban fabric. Such is the case of Mumbai, which is determined to "Shanghaize" itself, although major challenges loom. Unlike in China – where the redistribution of local, regional, and national power has not been a zero-sum game in which the local governments have gained power at the expense of the central government – the deliberate "Shanghaization" of Mumbai has seen the competition between different scales of government result in the concentration of power and resources at the metropolitan level, creating a power gap for the development of urban megaprojects. In China, the redistribution of power has taken place between the different levels, enabling the country to proceed with UMP construction and generally to better adapt to the requirements of the global economy [11].

The organizational obstacles in megaproject development are not minor. Bent Flyvbjerg (2003) already warned of these problems in *Megaprojects and Risk* with examples of big infrastructure projects in Europe [12]. The development of an urban megaproject is usually completed in various phases, and therefore many rearrangements, corrections, additions, and errors occur, not to mention the usual incapability by developers to limit the final expenses to the initial budget (so-called "cost overruns"). All this produces a lack of transparency that is increasingly difficult to support in view of the increasing activity of civil society, which organizes itself to face the ambitions of the political and economic elites. To cite some examples, megaprojects under construction in Budapest, New York, Paris, and Sao Paulo all illustrate the idea that, in the absence of clear and diaphanous planning – and although the state and the promoters try to explain the genesis and the impacts of the megaprojects – the whole process is perceived as dark and secret. Sometimes, this circumstance is used by the state to violate agreements and contracts of public interest and to reverse previous decisions, as has happened with the National Theater of Budapest, according to Judit Bodnar and Judit Veres (2013) [13].

We cannot forget either that sometimes UMPs develop in conflict situations – as shown by Alexandra Miller's work on the Afghan Ring Road (2013) – and that organized resistance to megaprojects can be of such a caliber that the state and the promoters fail to carry them out. This happened to Mexico City's proposed international airport project, which has been defeated because of the divisions between and within the political class and citizens initially triggered by the progressive democratization, decentralization, and globalization of the country. Diane E. Davis and Onésimo Flores Dewey (2013) argue that, in the Mexican case, it is also necessary to bear in mind the increasing power of the local state, which favors the civil opposition. The authors also underscore the importance of factors such as cultural identity, historical allegiances, and the geographical location in the mobilization of a wide array of local, national, and international allies against the airport [14].

A lesson of the Mexican case can be that bureaucratic ambiguities and tensions exist with regard to who is responsible for the principal projects of infrastructure in countries that experience a democratic transition. Such ambiguities and tensions can debilitate the proponents of a project and reinforce its opponents. This political and institutional baggage can also prevent urban planning authorities from learning how to respond to past experiences with citizen participation and civil opposition. Thus, the authors argue that the defeat of the airport megaproject in Mexico City was as much a reflection of a precarious moment in the political and economic development of the country as it was of the validity and legitimacy of the protests against the project itself.

Another contentious aspect of megaprojects is the planning, design and implementation of their iconic character, and the benefits that are assumed to be associated with such iconicity. Capturing a share of the world's mobile wealth is foundational to the justification of megaprojects. Protagonists embrace a narrative of international competitiveness, framing a project discourse that is dominated by the rhetoric of economic competitiveness for survival and development.

From an urban-spatial perspective, this entails that cities need to become "visible" and attractive to international capital. The "icon project" (Sklair, 2017), that is, the widespread construction of architectural icons in globalizing cities around the world, accomplishes these goals [15]. The construction of iconic urban megaprojects (IUMPs) has grown into a standard policy choice by urban and regional elites in globalizing cities. Politicians, business leaders and others in local and regional growth machines fulfill their personal and professional ambitions by investing in and promoting iconic urban megaprojects, aspiring to reach global status and positive economic change for their cities.

In what follows, we discuss contentious aspects in the planning and development of megaprojects in three cities around the world: Bilbao, Istanbul and Hong Kong. Our purpose is to lay out the variety of controversies, difficulties, obstacles, negative impacts and civic opposition associated to the construction of urban projects. We will show that the nature and the shaping of projects owes to the socio-economic, developmental, institutional and geographic context where they emerge. However, we will also see that urban megaprojects, regardless of context, constitute *disruptive and contentious complexity* and have an intrinsic potential (often realized) to elicit substantial controversy and criticism that fundamentally questions the parameters of the projects as envisioned and publicly presented by their promoters. As a result, it is possible to highlight – as will be done in the conclusion to this paper – some suggestions for future research and policy practice that can be applied to the planning, design, management, implementation and development of megaprojects worldwide.

3.6 Shadows of the *Bilbao Effect*

Many urban elites worldwide have been greatly influenced by the so-called "Bilbao effect" – the perception that the Guggenheim Museum Bilbao resulted in a "Cinderella transformation" of the Northern Spanish city and economic capital of the Basque Country. In the dominant discourse concerning architecture's surrender to capitalism's commercial goals, the Guggenheim Bilbao has been and remains to be mistakenly and repeatedly portrayed as the "catalyst" for the city's radically successful transformation from industrial powerhouse to regional service center. This case of disorderly, disruptive and contentious complexity (conceptual, planning, design, institutional and media complexity) has had many followers around the world.

For example, the new Ordos Art Museum in Inner Mongolia, beautifully designed by MAD, a prestigious firm of Beijing architects, suggests (not too surprisingly) that just building a terrific museum is not enough to ensure success. The city of Ordos has sprung up fast and is relatively wealthy, thanks to discoveries of oil and gas, but the museum has no collections and precious few plans for exhibitions. No wonder it is devoid of visitors. As Michael Kimmelman put it:

> "The truth is, the Bilbao effect is largely a myth. Frank Gehry's museum alone didn't turn around that city. It capped decades of civic renewal. Flashy, even brilliant buildings rarely rejuvenate neighborhoods or guarantee crowds and cash just by virtue of their design [...] Sadly, museums, like cities, have squandered fortunes praying to this false idol. They still do." [16]

As I have shown elsewhere (Del Cerro, 2007), the Guggenheim Bilbao has been a positive addition to the city, but far from the 11miracle" that would turn Bilbao into a successful urban economy [17].

The debate on the "Bilbao effect" (how iconic megaprojects can successfully bring about urban transformation, development and competitiveness), however, continues. The Guggenheim in Abu Dhabi, scheduled to open in 2017 but still pending as of March 2019, will be twice the size of the museum in Bilbao, twelve times the size of the Frank Lloyd Wright Guggenheim in New York. Carol Vogel in The New York Times refers to this Gehry design as "a graceful tumble of giant plaster building blocks and translucent blue cones." [18] The outcome of the Guggenheim Helsinki's international competition was known in June 2015, with the winning project going to the Paris-based firm Moreau Kusunoki Architectes (by Fall 2016, the city of Helsinki voted against the project and construction never started).

These two projects have attracted significant criticism; they have been questioned along three main lines: (1) iconic architecture is no longer the hegemonic visual discourse in urban revitalization; (2) the franchise model imposed by the Guggenheim means that local officials have no autonomy to make major decisions on matters from exhibition calendars, to budgets and investments; and (3) local cultural identities are usually neglected under a foreign global arts model. In addition, the environmental impacts of the projects may not be negligible. The Abu-Dhabi project has also been controversial around issues of workers's rights and labor conditions. In spite of mounting criticism, if the new Guggenheim Museum in the United Arab Emirates results in even half the impact of that of Bilbao's, the term "Bilbao effect" will continue to carry weight on both sides of the debate.

Despite the media success of the Bilbao Guggenheim, the Bilbao effect has proven to be difficult to replicate in most places, even for Frank Gehry. On the other hand, some architectural icons, such as Gehry's Stata Center at MIT, work well with no Bilbao effect – most MIT scientists working in the building praise its playful and inventive feel (Campbell, 2007) [19]. Cooper Union alum Daniel Libeskind's jagged edges, sharp angles and complex geometries (the extension to the Denver Art Museum, the Royal Ontario Museum in Toronto or the Danish Jewish Museum in Copenhagen) have not had the universal acclaim of his Jewish Museum Berlin, an illustration that success, impact and visitor attraction are not necessarily a function of a building's spectacular design. Many works by Shigeru Ban or Tadao Ando are excellent examples of highly admired and successful architecture in the antipodes of iconic buildings designed to stun.

The jury is still out in 2019 regarding not only Gehry's highly anticipated Guggenheim Abu-Dhabi but also the massive West Kowloon Cultural District (WKCD) in Hong Kong, which stand among the most prominent cultural megaprojects in recent years. The WKCD is a project of such scale and ambition that it could "define the nature of the public realm in the 21st century," according to a rather hyperbolic statement by Rem Koolhaas (Koolhaas, 2013) [20]. The WKCD has met significant criticism from the planning to construction phases. Though a Guggenheim is not part of the project, the WKCD replicates all the expected controversies associated with IUMPs, including cost overruns, negative environmental impacts, gentrification risks, drawbacks of top-down cultural engineering, neglect of local cultural identities, and uncertain economic success, as we discuss below. None of these externalities bode well for cities that are counting on instant icons to salvage them during times of economic malaise.

3.7 The Controversial Rebuilding of Istanbul

Complexity in the Istanbul case involves not only the intricacies of city regeneration, but also, and fundamentally, the dialectics of political and economic power at the national level with the global image of Turkey and its chances at economic development being at stake. The process included local citizen resistance, political confrontations and the realignment of political options along the lines of a more environmentally-friendly Istanbul under Vision 2023.

When the Haliç, or Golden Horn, a major urban waterfront and the primary inlet of the Bosphorus in Istanbul, started to be developed, there were views that the project would not yield significant economic benefits nor improve the quality of life of the residents, but would rather create a risk for gentrification of the urban area. The emphasis on creating shopping malls, parks, luxurious hotels and convention centres to attract tourists led to the demolishment of housing and the displacement of local populations. The Fener and Balat Rehabilitation Project is a good example of this phenomenon. The aim of this project was to improve the housing quality of the residents in the Fener and Balat area by providing 225 buildings with basic levels of comfort over a four-year period. It was started in 1997 with a joint intervention by the Fatih District Municipality, UNESCO and the European Union (Bezmez, 2008) [21]. Seventy percent of the buildings needed to be demolished due to their physical conditions, resulting in the removal of 900 families [22].

3.7.1 Resistance from the Local Population

In the Fener Balat Rehabilitation Project, although there have been measures taken by the government to prevent gentrification, such as excluding buildings that were bought after 1997 from the rehabilitation project and preventing owners from selling their properties within five years of completion of the restorations, the measures were vague and hence the local community still voiced out their dissatisfaction against the government. As Bezmez explains, there were several reasons for their protest. First, the idea that their houses were restored without any contribution from their part seemed unrealistic, making them fear that they were going to be gentrified and forced to cover the expenses. Second, most residents transformed the buildings such that a house could fit several families, therefore a return to the original building would provide them with much inconvenience. Third, a restriction that the residents could not sell their house in the next five years seemed impossible given their financial situation. Fourth, there were rumors that the project started with the intention to revive Istanbul's non-Muslim past and not to improve the living standards of the residents. Due to opposition of the project, the rehabilitation was halted and delayed [23].

3.7.2 Political Confrontations

When different mayors and parties were in charge of the Istanbul Metropolitan Municipality (IMM), the central government embraced different values and views towards the development of the Golden Horn, hence affecting the effectiveness and efficiency of development. In Mayor Dalan's term, the Turkish Clothing Manufacturers Association was interested in Feshane, a historical site of textile factories around the Golden Horn. The association was planning to use the building as an exhibition centre for the products of the association's members and also to rent out to exhibition organizers. The IMM would retain ownership of the building and rent it to the association on a long lease, therefore enjoying part of the profit. Dalan approved of this project hastily and even started restoration work before an initial agreement was signed.

However, the social-democratic mayor Nurettin Sozen was elected before Dalan could sign an official contract with the association, even if the association had already incurred significant expenses. As a result, Sozen called the operation to a halt by delaying the project with "every possible obstacle." At last, the association decided to give up the project. In the 1990s, the Eczacibasi Group, an industrial group in Turkey, wanted to turn Feshane into Istanbul's Museum of Modern Art. Similar to The Clothing Manufacturers Association, the Eczabasi Group was supposed to sign a long lease with the IMM and cover all the financial expenses of the redevelopment. Yet tension rose between the IMM and the industrial group after a plan including substantial expenses was put forward to restore Feshane. The project was abandoned [24].

3.7.3 Vision 2023: Environmental Issues

In 2017, Unesco declared Istanbul a "design city," pursued by the Turkish government as part of their "Vision 2023," which aims at the centennial of the proclamation of the Republic of Turkey. The threefold mega-development in Istanbul associated with the government's "Vision 2023" defines a set of goals centered around the further economic growth of the city and its nomination as a global hub. The first part of this development is Istanbul's Third Bridge in conjunction with the Northern Marmara Motorway. The second part consists of the Third airport situated in the North-West of the city, which is to become the world's biggest airport. In the same part also falls a plan concerning the development of a new city near the airport including multiple facilities (e.g. hotels, retail and commercial office space and logistic centers), which is to be connected with the existing city via high-speed underground and aboveground fixed-track infrastructure. The third part is Kanal Istanbul, located west of the Bosporus Strait, providing an alternative passage for vessels. This canal essentially bisects the European side of Turkey and creates a new island between Asia and Europe [25].

The above megaprojects represent serious challenges ranging from huge funding requirements, mostly undertaken by taxpayers, to significant impacts on urban structure, the natural environment and the community. As far as impacts on urban structure are concerned, according to Dogan & Stupar, they are probable to be adverse by spoiling the visual and structural uniqueness of the city's environment and intensifying urban activities, leading to a further rise of population as well as a shift in urban density. The latter is expected to have synergetic effects with the construction of the Third Bridge, concerning the exacerbation of traffic congestion caused by the promotion of private vehicles [26].

The environmental issues are probably the biggest concern of this mega-development. The Third Bridge and its associated motorway passes through the northern border of the Belgrad Forest (adjacent to Istanbul) at the European side and the Bosporus Biodiversity Area, creating serious threats for a wide range of local habitats and intensifying the heat island effect. At the same time, noise and air pollution are expected to increase due to Istanbul New Airport (set to start in March, 2019, and with no official name yet due to political controversy), which is also to be placed on the migration routes of birds. The Kanal Istanbul is likely to trigger irreversible environmental disaster, taking into account the inversion of the hydrologic balance between the cold and fresh waters of the Black Sea and the warm and salty waters of Mediterranean Sea. Finally, the lack of community engagement as shown by the low level of public awareness of the above risks as well as the potential need for expropriations in order to empty lands for construction are characteristic of the impacts of this mega-development on the local community [27].

3.8 The Business of Culture in Hong Kong

Turning a city into a cultural capital is a complex endeavor. Complexity is here marked by image change, global media and the usual obstacles of design, planning and construction of facilities and infrastructure. Confrontations around contradictory political discourses with no convergence between stated objectives and actual intentions adds to the complexity surrounding cultural capital design and development. Moreover, damage to the environment by construction was a major factor that added to an already disruptive, disrderly and contentious scenario.

In spite of oficial statements about the focus on culture for Hong Kong's motivation in the West Kowloon Cultural District (WKCD), the project is viewed as largely focused on economic values, emphasizing tourism. The development of tourism has not been intended to promote culture, but instead to enhance Hong Kong as a 'traditional economic stronghold' as declared by the first Chief Executive of Hong Kong Special Administrative Region (HKSAR) Tung Chee-wah. He stated in his 1998 policy speech, during an economic crisis in Hong Kong, that it was the government's plan to distinguish Hong Kong as 'Asia's world city' and "Asia's entertainment capital' through megaprojects. After the Asian financial crisis in 1997-99, the "promised" outcomes of megaprojects, as shown in Bilbao, Pittsburgh, Baltimore and other cities attracted Hong Kong leaders [28].

3.8.1 Developers and Politicians

Populist politicians in Hong Kong denounced the early versions of the plan as too generous to developers. Tung Chee-hwa, the Chief Executive of Hong Kong, initially planned to hand over the entire project to one large developer as expressed in his annual policy address. The plan was decried as a subsidy to the city's wealthiest developer, Li Ka-shing. Even many of Tung's longtime allies among business leaders did not support him in his plan for the WKCD. The plan was revised in October 2005, calling for a lead developer to build half of the residential and commercial real estate on the WKCD Peninsula, while other developers could bid for the rest. The revised rule was objected by the three wealthy developers who submitted proposals under the initial rules [29].

The project was also criticized as property development rather than cultural project due to its connections to the large scale retail industry as well as commercial and residential development interests (Sum 2010). The government funding primarily supports shopping, dining and entertainment facilities with expectation of revenues, which is beneficial to the city's wealthy developers. Not surprisingly, raising prices of properties in the neighborhoods could be detected as early as 2010, and continue today [30].

3.8.2 Academic Opinions of the Project

The WKCD project is a controversial megaproject, which seeks to globalize Hong Kong as an art hub city. Professor Tai-lok Lui, as many scholars who criticize the WKCD project, describes the proposal as an example of entrepreneurialism and neo-liberalism:

> "The proposal was a typical package of urban entrepreneurialism, with an emphasis on chasing after mega-projects, iconic buildings and media visibility. But it avoided questions concerning the substance of the entire project, consensus from below and the vision of cultural development. Its failure shows that, without addressing these basic questions, city competition by means of developing global architecture, mega-projects and fabricated urban culture is inevitably futile." [31]

Helen Siu and Agnes Ku, Sociology professors at the Hong Kong University of Science and Technology, examined the WKCD project and the Hong Kong's attempt to build a "global city." They explain the relationship among different sectors involved in the project with the local institutional structure and processes, defined by "the cultural policy and institutional framework in colonial times – characterized by non-interventionism and top-down drive under a fragmentary yet centralized structure." [32] Siu and Ku articulate that top-down decision-making structures and the lack of voice from cultural practitioners under globalization has undermined cultural citizenship and civil society in the dominant discourse of globalization. For instance, the People's Panel on West Kowloon (PPWK) was set up by activists in the cultural sector and civic organizations to re-examine the project, seeking cooperation among government, property developers, and civil society. Yes, this Panel never became operative.

Moreover, some scholars point out that the WKCD has already failed to "globalize" Hong Kong, as the project has largely ignored the history, culture and identity of the city. The Brand Hong Kong program of which WKCD is part bears the mission "to provide a greater focus to the international promotion of Hong Kong as 'Asia's world city."' The marketing strategy of the city's Brand Hong Kong program has, in its preoccupation with these values, marginalized others, according to Stephen Chu. The Donald Tsang administration was keen on developing Hong Kong into a hub of Asian creative industries, but not a base for local creative industries to grow in. As long as the development of creative industries is being framed by the "Brand Hong Kong" concept, vernacular hybrid cultures and spaces cannot surface (Chu, 2010) [33].

> "The overwhelming emphasis on branding Hong Kong has ironically led to the loss of Hong Kong's intrinsic uniqueness: the blending of the global and the local into a hybrid emerging culture which is significantly

> 'glocal."' [...] "It attempts to assess the implications of the Brand Hong Kong program's failure in recognizing that the distinguishing characteristic of Hong Kong was its emergent community where genuine cosmopolitanisms found the space to emerge." [34]

3.8.3 Environmental Impacts

The WKCD is constructed by reclamation of the Victoria Harbor. It was initially a trading harbor, and eventually became a tourist spot and an important transit path between the Kowloon Peninsula and Hong Kong Island. The Victoria Harbor provides a natural scenic asset to Hong Kong, claiming itself to be the "Pearl of the Orient" by the panoramic view seen from airplane windows or skyscrapers in Hong Kong. The Victoria Harbor has attracted 55% of the tourists coming to Hong Kong in recent years (Chan, 2000) [35]. Reclamation activities became intensified since the 1980s. The amount of land reclaimed from 2000 – 2005 is equivalent to the amount of land reclaimed in the last 100 years, and significant pieces of land reclaimed include 250 hectares of land for container terminals in the port.

The West Kowloon Project has reclaimed 40 hectares of land around the Victoria Harbor [36]. During the construction phase it was expected "construction site runoff, pumped groundwater discharge, drainage diversion, sewage effluent and accidental spillage that contain high levels of suspended solids and chemicals such as oils, solvents and cement-derived materials." [37] The process of dredging is needed to remove unsuitable foundation and replace with large volumes of dredged sand, exacerbating water pollution in Hong Kong. Dredging reduced primary productivity in the sea, affecting the marine ecosystem since they are dependent on plants for sustenance [38]. There is also a loss of sensitive species such as filter-feeding organisms, including scallops, mussels and oysters, which are essential to a vibrant seafood business around Hong Kong. There is also evidence that the Chinese White Dolphins, which is an endangered species unique to Hong Kong, is threatened since dredged materials compromise the well-being of Dolphin Sanctuary neighboring to East Sha Chau Contaminated Mud Pit, where the dredged contaminated mud is disposed of. There are only 85 Chinese Pink Dolphins out of the original 300, and those that survived were not expected to survive further reclamation [39].

3.8.4 Poor Air Quality

The WKCD is located next to the Western Tunnel Crossing, which connects West Kowloon across the harbor to Hong Kong Island and is one of the busiest locations in Hong Kong. It has one of the worst air qualities with average PM 2.5 concentration around the tunnel crossing at 63 micrograms/cubic meter, which far exceeds the World Health Organization's (WHO) air quality maximum threshold of 25mg/m^3. During construction, activities such as excavation, stockpiles, the movement of vehicles, concrete batching and the activities of other plants during the loading and unloading operations added onto the already poor air quality around the area [40].

Other major infrastructure construction, such as the Western Harbor Crossing portal, the additional roads and car parks with the WKCD are also affecting the air quality surrounding the area. Since the newly reclaimed land would also accommodate for large number of people during mega events, the resulting pollution, traffic congestion and over-concentration will also aggravate the existing air pollution problem [41].

The project promised to build better landscape in the surrounding area of WKCD, including additions of ornamental plants, a piazza, park and avenue through innovative design. Yet, the effects of greening the space might not be able to compensate for the other landscape impacts. For instance, along with the nearby Kowloon MTR station, Elements Mall International Commercial centers and several enormous apartment buildings are being constructed. Further plans show the construction of skyscrapers in the WKCD, further obstructing the view of the Victoria Harbor [42].

3.9 Conclusions

This paper has presented and discussed evidence in three cities (Bilbao, Istanbul and Hong Kong) showing that megaprojects are disorderly, disruptive and contentious enterprises triggering important economic, socio-political and environmental challenges that are often hard to resolve for the benefit of urban communities. The list is long: cost overruns, negative environmental impacts, gentrification risks, drawbacks of top-down cultural engineering, neglect of local cultural identities, an uncertain economic success, population displacements, the spoiling of cities´visual and structural uniqueness, rise of congestion and overpopulation, political gridlock, threats for ecosystems, environmental risks of many kinds, etc.

In view of all of these drawbacks, it seems reasonable to think that better investment opportunities exist for cities, but very often these opportunities are not priorized given the hegemonic neoliberal urban discourse that focus on growth, international visibility and competition in the global arena.

Under the "green capitalism" label, recent megaprojects are presented as "sustainable." However, it remains unclear under what conditions these allegedly sustainable megaprojects can foster widespread growth and shared prosperity. Will they simply symbolize, once again, the grandiose vision of political and economic leaders in their attempta at nation-building to effectively compete on the global board? Will those megaprojects yield economic benefits to the cities that host them and not only to the promoters who build them? We do not know yet, although there is growing evidence that the benefits could be very limited (as is increasingly the case with Olympic mega-events).

Growing skepticism about spectacular and large-scale urban development, as well as the multiple impacts of the Great Recession of 2008, have triggered a rethinking of urban revitalization strategies in the West, and new paradigms, such as "smart cities," have come to the forefront of the discussions. Advocates of the "smart city" idea, who rightly stress the importance of digitalization and technology for a better management of urban areas, seem to overlook the fact that it is the governance models, not just the tools, that need to be improved.

What is truly fundamental for urbanites is to ensure that their leaders (and themselves as creators and re-creators of the places they inhabit) work to organize sustainable urban ecosystems from an ecological, environmental and socio-economic perspective. The good form and efficiency of the city are not enough to guarantee a good urban life. Improving macro-economic magnitudes is not enough if there is no effort at achieving higher levels of social welfare. Urban visibility (megaprojects) and urban connectivity (smart cities) strategies, by themselves, present as many risks as benefits for urban populations.

Jane Jacobs rightly reminded us almost half a century ago that cities are organized complexity that can not be addressed as a conventional problem of hierarchies and visual or mechanical order planned exclusively by leaders and experts (her diatribes with Robert Moses, the great modernizer of New York, are legendary). Jacobs understood cities as a complex problem of interrelated factors in an organic whole, and recommended urban planners and architects to show respect for the intrinsic order of the city and discard the demiurgic, spectacular and traumatic interventions that they often put into practice.

Today, the science of complexity applied to urbanism is proposing some postulates based on scientific evidence and the multidisciplinary study of cities that echoes the thought of Jacobs. The first is that cities have the capacity to promote creative and dynamic growth and at the same time reduce the destruction of resources. It has long been known that the city is more efficient than other types of human settlements from the point of view of energy, consumption of resources and emission of greenhouse gases. The reason is that urban ecologies are organized through exchange networks organized in spatial proximity whose synergies have positive and multiple effects. In other words, cities are complex, dynamic and variable human clusters that can favor efficiency, competitiveness and ecology.

Likewise, we know that networks and proximity flows and casual encounters in defined spatial environments foster multiplier effects and thus explain the impact of creativity on the economic strength of cities. We are not advocating for the presence of a creative class that allegedly serves as as the engine for urban prosperity, but rather for valuing and promoting the configuration of the ecological character of the city as a place for the exchange of knowledge, information, experiences and affections. This area of exchange needs public or semi-public spaces, and hence the crucial importance of preserving squares, sidewalks, parks, terraces, cafés and other meeting places where economic rationality does not prevail. Online connections can supplement, but not replace, this primary network of face-to-face human exchange.

Like any network, cities benefit geometrically from the number of existing connections. If the economic disparity between urbanites condemns certain citizens and neighborhoods to socio-spatial segregation, the prosperity of the city as a whole will be compromised. For reasons of social welfare, economic prosperity, and, increasingly, for reasons of survival of the planet and our species, it is essential to advance in the planning of integrated cities on a human scale that respect the close and multiple interaction of their neighborhoods. This constant process of human interaction – the intrinsic order of the city – allows urbanites to shape their own identity by appropriating their environment and endowing it with meaning, a fundamental factor that contributes to individual and collective well-being, and indirectly also to prosperity.

Cities need to ensure that the above ideas, which flesh out the urban order as organized complexity, become the driving force behind megaproject planning and implementation. When urban ecologies are organized through exchange networks organized in spatial proximity, when urban planning values and promotes the configuration of the ecological character of the city as a place for the exchange of knowledge, information, experiences and affections, and when planning aims at advancing integrated cities on a human scale that respect the close and multiple interaction of their neighborhoods, then megaprojects could possibly work for the welfare of the community; at a minimum, they would turn from disorderly, disruptive and contentious enterprises into feeble artifacts.

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CHAPTER 4

Process of Measuring the Maintainability of Commercial Off-the-Shelf (COTS) Based Systems: A Complexity Approach

Smith M., Lawson D. W., Ertas, A., and Surles, J.

This paper defines a process of predictive approach to evaluate the maintainability of a Commercial Off-the-Shelf (COTS)-based system (CBS) by analyzing the complexity of the deployment of the system. The approach integrates architectural dependencies and the system's concept of operations to derive a network-based representation of the software system. A greater understanding of the deployment complexity is gained by using a Design Structure Matrix (DSM) to determine the number of architectural dependencies on a COTS product, or in-degree, for each COTS product in the system. The arithmetic mean of the in-degree for all nodes in the system is then compared with the perceived effort to maintain the system. The resultant measure – the in-degree mean – is useful in evaluating the maintainability of the operational system while the system is being designed and throughout its lifetime. Architects can use the approach to assist in COTS product selection and to make product trades to optimize the maintainability of the system. Integrators can use the approach to optimize product deployment and to determine the upgrade strategy for deployment. Finally, maintenance engineers can use the approach to estimate the effort required to maintain the system and to identify areas in which extensive product expertise is required. Because the approach requires only basic information about the system, it can be applied early in the design process and used until the system is decommissioned.

Keywords: COTS, complexity measures, system design, system maintenance, system integration.

4.1 Introduction

This paper describes a process to evaluate the maintainability of Commercial Off-the-Shelf (COTS) based systems (CBS) during the design and operational phases of a software development project. The approach integrates complexity theory, graph theory, Design Structure Matrix (DSM) theory, network theory, and systems engineering to derive a single predictive measure of the maintainability of a CBS, the in-degree mean. The approach enables all disciplines involved in the development of a CBS to work from a single maintainability metric to deliver a cost-effective solution.

Little evidence exists to suggest that current prediction techniques for software maintainability are effective [1,2] for CBS. The effort associated with maintaining CBS is not generally part of the development and costing models that are popular today; therefore, the effort to deploy and integrate these products is rarely bid or scheduled appropriately. Instead, most existing models are focused around the effort for software engineers to maintain glue-code or custom code, i.e., the non-commercially derived components of a CBS. Even when costing and scheduling models account for COTS integration, they are generally focused on the front-end of the development cycle where the effort is expended on fulfilling mission-specific requirements. Therefore, a useful measure of maintainability is required for CBS that encompasses effort in all phases of development.

While this problem may seem trivial, particularly in the modern design paradigm where a single machine instance is used for a single COTS product, the complexities driven by the dependencies between COTS products increase costs in the system development and deployment timeframes and eventually in the maintenance timeframe. The costs in the maintenance phase of the system are often the most significant since the engineers who are most knowledgeable about the dependencies and interactions of the products are no longer available because they have moved on to other development efforts or because the maintenance team is a completely separate team without reach-back to the development team. Additionally, a traditional divide exists between the operations and development engineers, and the relationship is often antagonistic [3]; therefore, a cultural opportunity also exists to enable the two groups to work more closely and, together, develop a more cost-effective solution. For example, the recently popular DevOps, or Development Operations, system delivery paradigm attempts to accomplish this pairing with software engineers developing and delivering custom software solutions in a rapid-fire series of small incremental deliveries [4].

Existing measures of the maintainability of CBS are focused on the number of COTS products that are part of a system [5,6]. However, as with biological systems, it is not only the number of components that create complexity, but instead the interactions between the components [7,8]. The measure of maintainability described herein is a metric that is based on the interactions of the components.

In this work, the in-degree mean model - a measure of the effort required to maintain the COTS installation - is described as well as the steps necessary to create a network-based model of the CBS. The model is compared to the perceived effort required to maintain 13 operational CBS. The advantages of the approach are discussed along with who can benefit from the information derived from the model. The paper includes conclusions along with a discussion of future work.

4.2 Current Approaches for Measuring System Maintainability

Multiple models exist to determine the costs associated with developing systems utilizing COTS components in combination with custom development. The BASIS technique, the COCOTS Model, the COTS Lifespan Model (COTS-LIMO), and the Maintenance Delta are four examples. Three of these models primarily focus on the front-end of the development lifecycle or are focused on cost measurement alone.

This section provides background on the definition of a COTS product. The development phases of a COTS-based software system are defined in order to indicate the applicable program lifecycle phase where each of the available models is used. Following these level-setting sections, current modeling processes are explored to understand the state-of-the-art in estimating effort associated with developing, deploying and maintaining CBS.

4.2.1 Commercial Off-the-Shelf Components

COTS, as defined in the Constructive COTS (COCOTS) model, is a component that has the following attributes [6].

- The component is sold, leased, or licensed for a fee that includes fixes for defects.
- The source code for the component is unavailable to the end user.
- The component evolves over time through periodic releases of the product (upgrades) containing fixes and new or enhanced functionality, and
- Any given version of a COTS component will eventually reach obsolescence after which it will no longer be supported by the vendor.

COTS-intensive systems depend on many different COTS applications to provide the business functionality of the overall system. No single COTS product fulfills a significant amount of the requirements [6]. Instead, many products are integrated together to fulfill the business requirements of the system. The CBS design approach relies on glue code or custom code to ensure that COTS products communicate with each other utilizing their documented interfaces. CBS typically deliver functionality more reliably and quickly than custom software development approaches [9,10,11].

In CBS, the developer relinquishes control of the release cycle of the COTS product [12]. A third party controls when bug fixes and new functionality are introduced into the product. The third party's timelines are rarely coordinated with the users of the COTS product. So, users either accept the functionality as is or find other ways to fulfill the business logic that are not provided with the COTS products that are part of the system. Usually this entails creating custom code to provide missing functionality or to work around a bug in the COTS product. Sometimes, to work around a bug in a COTS product, it is necessary to change the way the system is used until a bug fix is released by the vendor. Similarly, a new version of a COTS product may change the functionality of an interface while introducing a fix to a bug (related to the interface or not). The developer may need the bug fix, but the change in an interface may cause rework in the custom code around the COTS product. Since the CBS developer does not control what is in the release from the COTS vendor and what is not, the COTS vendor has the potential to cause rework simply by the way a new release is bundled.

For CBS, the developer can no longer fully coordinate every aspect of the system delivery [13,14] and may have to deal with dependencies that complicate the system deployment without adding value to the system's functionality. These problems are amplified when products from multiple COTS vendors are deployed in the system and incompatibilities between the architectural requirements of the vendors cause conflicts in the deployment of the system [15]. For example, if one product requires Java version 1.5 and another requires Java 1.6 to operate correctly then the overall system must have two different versions of Java installed for both of these products to function correctly. Having two versions of a product in the same system results in complexity around configuration management, deployment and integration of the entire CBS.

In today's large government system architectures, it is typical to have more than 50 COTS products [16,6] and not unusual to have more than 100 COTS products in the final CBS architecture. The architectural dependencies between these products, that is, dependencies on specific product versions, libraries or common variables, complicate the initial deployment, the integration and the on-going maintenance of the system once the system transitions into operations. Often, because of the COTS delivery cycle, the use of COTS products increases the rate of change in a system versus a custom-developed solution [17]. COTS products also increase the risk of change in a production system and contribute to complexity in replacement or upgrade attempts with a resulting failure percentage as high as 70% [18]. The complications associated with the rate of change increase the costs associated with maintaining the CBS, have the potential to strain the schedule and costs associated with integrating and maintaining the CBS, and have the potential to cause a complete project failure if not accurately estimated and understood.

The problem of maintaining the COTS deployment is not one that is relegated to the O&M phase of the system lifecycle. A typical COTS vendor releases a new version of its product every eight to nine months, and only supports the last three releases of the product [19]. This means that a COTS product may only be supported for 27 months once it is configured into the system unless steps are taken to install an updated version of the product. Changes associated with the product update cycle are in addition to changes introduced by vendor's patch releases that fix bugs. Patch releases only increase the number of changes in the configuration. Today's large system development cycles are often multiple years long with many large systems taking longer than five years to develop [6]. The comparatively brief update cycle of individual COTS products suggests that many products will require updates before the system leaves the development phase of the system lifecycle. And, more importantly, because of this rapid update cycle, a plan to upgrade COTS components in the architecture must be part of a sustainable O&M plan. The vendor upgrade cycle and the need to keep the delivered system in a supported configuration with each individual vendor makes it necessary to consider and understand the architectural interactions of COTS products in the earliest phases of the system design to ensure that the system is maintainable for its planned lifecycle. Additionally, interoperability issues have the potential to paralyze the development of the project if they are not understood and incorporated into the applications requirements [20], so it is helpful to understand these complexities introduced by COTS dependencies early in the project and track them through the project's entire lifecycle.

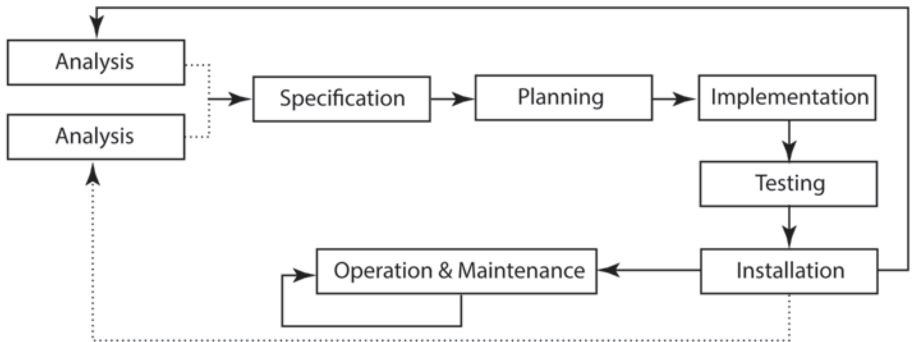

Figure 4.1: CBS development cycle process (modified from [1]).

4.2.2 Software Development Lifecycle

Several of the existing maintainability metrics for CBS are based on complex measurements of COTS interfaces. Others are based on subjective analysis of the COTS product and how easy it is to use in a development environment. These measures are appropriate for the front-end of the product development lifecycle where software developers are designing and interacting with the products. However, because the maintenance phase of a project is significantly more expensive than the development phase [21], measurements are needed that account for maintainability in the planning, installation, and operations and maintenance phases. Figure 4.1 highlights the areas of a typical development cycle where maintainability efforts have the most impact on effort for CBS.

4.2.3 Measuring the Cost of COTS System Developments

The BASIS Technique [22]

The Base Application Software Integration System (BASIS) technique is an integration approach that assists in selecting COTS products and defining the order in which COTS applications should be incorporated into the delivered system [22]. The technique is used in the first stage of project development - the planning stage - to determine which COTS products introduce the most risk into the system design. Once these products are identified, they are integrated into the system starting with the most complex and progressing to the least complex. An iterative integration process is proposed in the technique implying a spiral development process. The BASIS technique is a small part of the Phase-Integrated COTS (PIC) approach for the entire software development lifecycle. The model considers COTS a portion of the custom software development cycle.

The BASIS technique is used at the start of the design process and is used to select the best COTS candidates to fulfill the requirements of a project. There are three basic evaluation steps to the BASIS approach [22] – (1) how each COTS product fulfills system requirements, (2) the provider's viability and (3) the complexity of the product's external interfaces for integrating with the custom code. The BASIS technique requires extensive knowledge of the COTS products being evaluated. While there is an effort in the technique to account for the order in which COTS products should be integrated into a system, the focus of effort is to minimize the development risk of the project. Specifically, the BASIS technique minimizes the risk associated with developing and integrating custom code and estimating the effort associated with custom code development instead of the effort to maintain the overall COTS installation for the CBS.

The BASIS technique differs from the in-degree mean method proposed herein in that the in-degree mean requires less intimate knowledge of the interfaces associated with each COTS product. Further, the in-degree mean enables the architect to consider the maintenance phase of the program during the design process instead of simply choosing products that are favorable in the development phase. Instead of requiring knowledge of each external interface, the in-degree mean method requires only the installation requirements and the architectural requirements.

COCOTS Cost Model [3]

The Constructive COTS Integration cost model (COCOTS) is a cost estimating tool that recognizes that COTS integration has become a significant portion of modern computing systems. The model attempts to account for the integration of COTS components in the cost estimation of the system design.

COCOTS accounts for four initial integration costs associated with the effort to perform (1) assessment - candidate COTS component assessment, (2) tailoring – work required to configure and integrate the COTS component into the system under development, (3) glue code - the development and testing of any custom integration code needed to plug a COTS component into a larger system, and (4) volatility – the increased system level programming and testing due to volatility in incorporating COTS components. The model accounts for testing in each of the phases. By design, it is focused on the front-end of the development process. The COCOTS model, and its extensions, is used as a software-costing tool; therefore, it is primarily used in the system design and development phases of a program. However, the COCOTS model is being expanded to include maintenance costs in the future [9].

In the assessment process, the COCOTS model defines rating criteria for determining the integration complexity of each COTS product. The rating is subjective and gives a point rating for the complexity associated with a product in each of the following areas: parameter specification, script writing, I/O Report Layout, GUI screen specification, Security / Access protocol initialization and setup, and availability of COTS tailoring tools. The complexity scores for each of the COTS products in a system are combined to determine an overall complexity rating for a project. The model requires an engineer to be familiar with the development interfaces of the COTS product. The knowledge associated with the development interfaces is often gained through years of experience with the product.

The COCOTS model is different from the in-degree mean process because it is estimating the effort associated with development instead of the costs associated with the deployment, integration and maintenance of COTS products. The complexity ratings and integration approaches associated with the in-degree mean assist the costing of the integration effort in a similar way as the COCOTS model assists the development team in determining costs and schedules. The two models are focused on different ends of the program lifecycle as shown in Figure 4.1. As with the BASIS technique, the COCOTS model requires knowledge of the development interfaces of each COTS product whereas the in-degree mean process only requires information from the COTS installation manuals and the system CONOPS.

COTS-LIMO [1]

There is a widespread belief in the COTS integration community that the number of COTS components in a CBS has a strong impact on the maintainability of a system. Each COTS product in the system requires unique knowledge to support the integration and maintenance effort. Additional costs are associated with tracking COTS product upgrade roadmaps and licensing costs as well as the support effort required to interface with the vendor to report bugs as they are identified in the CBS. And, the independent release schedule of each COTS product in the system creates a maintenance tail to simply track the compatibility between COTS product versions.

Because of the additional costs associated with CBS, the COTS Lifespan Model (COTS-LIMO) model attempts to identify a break-even point where maintenance costs increase disproportionately to the number of COTS products in a system. According to the model, the break-even point exists regardless of the efficiencies gained. This point is called the maintenance equilibrium. The COTS-LIMO model presumes that it is possible to determine the number of components that exceed this maintenance equilibrium. The COTS-LIMO model acknowledges that the costs associated with maintaining a single COTS component decrease over time as the maintenance staff becomes more familiar with the product. But, even with these efficiencies, the complexity of maintaining multiple COTS products in a single system reaches a point where the costs associated with tracking and maintaining the COTS components exceed those efficiencies gained [5,23] by using COTS products instead of custom-developed components.

The COTS-LIMO is intuitive. As more products are added to a CBS, the maintainer of the system reasonably expects that effort to maintain the system will increase. However, the COTS-LIMO model has one significant drawback; namely, that no process or method currently exists to determine the appropriate number of COTS components that exceeds the maintenance equilibrium for a given CBS design. The model falls short in practical application because it is not possible to determine when there are too many COTS products in a CBS. So, it is not possible to make architectural decisions about whether to fulfill a system requirement with a COTS product or custom development.

Maintenance Delta [24]

The theory of the Maintenance Delta asserts that the Power-Law distribution is a standard for the number of architectural interactions in a system and, therefore, represents an ideal on which the maintainability of real-world systems can be measured.

In network theory, scale-free networks hold a unique position in that they have been found to describe many large networks. This holds true for both naturally occurring networks (cellular metabolism) and for man-made networks (learning networks, the Internet, etc.) [25,26]. The scale-free network is a network where the degree distribution of the nodes follows the power-law distribution [27] – a probability distribution, pk, of degree k with the form

$$p_k = Ck^{-\alpha} \tag{4.1}$$

for integer values of k where $k_{min} > 0$, where C is a normalization constant, and α is a constant parameter of the distribution known as the exponent or scaling parameter. α typically lies in the range $2 < \alpha < 3$ [28]. The number of nodes in each dependency group differs with the size of the network; therefore, the scale-free model is intended to accommodate networks of various sizes.

The maintenance delta is the numerical difference between the distribution of a CBS and a power-law distribution of similar size. A CBS with a distribution that is below, or less than the power law distribution, would have a negative maintenance delta indicating that the level of effort to maintain the system is less than normal. A CBS with a distribution that lies above, or has more interactions than a similarly sized scale-free network, has a positive maintenance delta and, thus, requires more effort than normal to maintain the COTS installation.

The maintenance delta is intended to be a comparative measure of the maintainability of two systems. By deriving the maintenance deltas of the two competing architectures and comparing the results, it is possible to make design decisions based on the maintainability of the overall solution. The maintenance delta and the in-degree mean process both explore maintainability for the O&M phase of the CBS development lifecycle.

4.3 Maintainability and Complexity of CBS

Like software maintainability, COTS maintainability is based on complexity; therefore, maintainability should be accounted for by the interactions between the components. A process for measuring the maintainability that combines the unique qualities of a COTS-based system along with the interactions between those products is needed for CBS to appropriately measure their maintainability. The concept of maintainability is focused on the operations and maintenance phase of the program and focused on the maintainers of the system, not the consumer of the system's functionality. The focus on the O&M phase is distinctly different than software models where most effort is focused on the development phase of the program (see Figure 4.1). Similarly, other software models focus on the effort for software engineers to maintain the custom code, including glue ware, of the system instead of the effort required to maintain the components for which there is little visibility into the internal structures of the software and little influence on the delivery roadmap [29,16]. For these reasons, a CBS maintainability measure should focus on the interactions between the components and the effort associated with changing the components and the effort required by maintenance engineers to upgrade and maintain these components.

The in-degree mean model presented herein complements the existing models by filling a gap in the available models. By covering the aspects of system deployment, the integration effort associated with that deployment, and the maintenance effort in the Operational and Maintenance (O&M) phases, the model adds a more detailed investigation of an area of the CBS lifecycle that has been overlooked in other models.

4.3.1 Process of System Maintainability

The maintainability of CBS is defined by how much effort is expended in the various phases of the program; however, as the O&M phase is typically the longest in the program lifecycle, the effort associated with this phase has the highest impact on the maintainability of the system. Maintainable systems minimize the effort required to achieve five maintenance activities associated with COTS-based systems [14]

1. Product reconfiguration
2. Testing and debugging
3. System monitoring
4. Enhancing user-level functionality
5. Configuration management

Table 1 shows these five maintenance activities along with a description of common general activities that comprise each category. Product reconfiguration is the replacement of given product with an upgrade to the same product or replacement with another product that performs a capable functionality. The other attributes of the systems that require effort – testing and debugging; system monitoring; enhancing user level functionality; and configuration management - are somewhat self-explanatory. Other factors influence the cost of maintaining COTS-intensive systems [6]. However, each of the influencing factors can be categorized into one of the five identified maintenance activities.

Extensive research has been done on complexity and on measuring complexity of software development [30,31,32,33,34]. Much of this research, particularly around component based software development, is pertinent to this work. With component-based software development, the interaction between components becomes the focus for creating maintainable solutions instead of the internal workings of each individual component [35]. However, this present study aims to be complimentary to these models for custom software development and cover an area of maintenance that is not typically included – that associated with maintaining the COTS products.

4.3.2 Complexity

Identifying Dependencies

In a large system, the individual products combine to deliver the system's defined functionality; however, to deliver the functionality, the components must be integrated into a single system. Each COTS product requires additional components and characteristics to function as desired in the system. These requirements are defined as COTS dependency attributes [36] and include such items as the need for a specific version of another COTS product or the definition of an environment variable in the system where the product is installed. Behavioral dependencies - the interaction between the two components that may only be certified for specific versions of the two products [14] - are included in COTS dependency attributes.

Architectural mismatch is another similar area of study that has received much attention in the literature [37]. As with the COTS integration effort [38,12,15], the architectural mismatch research has focused on the front-end development of programs. This research has generally focused on the interfaces between COTS products, the interfaces that are used by software developers to interact with the COTS products, and the software architecture in which the components are functioning. A fourth area, assumptions about the construction process, is closely linked to dependency attributes in that it recognizes that software components (including COTS components) have underlying assumptions about the order in which the system is built or about previously existing capabilities that must be in place for the components

Table 1. Maintenance activities that drive significant effort in CBS.

Maintenance Activity	Description	Implication of COTS usage
Product Reconfiguration	Updating COTS products with new versions Replacing products with competitors offerings Adding / deleting products as requirements evolve	Update schedule determined by COTS vendors Updates uncoordinated between vendors Features, bug-fixes and adaptations driven by market force of COTS products rather than system requirements
Testing and Debugging	Identifying causes of failure Running tests Monitoring system performance and resource utilization Logging system behavior and activity	COTS products are black-box: no access to source code Documentation often incorrect or incomplete Done in collaboration with COTS support organizations COTS suppliers do not accept responsibility for problems without proof (and maybe not even then)
System Monitoring	Logging system behavior Analyzing logs for failure, performance problems, etc.	Lack of visibility into behavior of individual COTS products
Enhancing User-Level Functionality	Modifying functionality as requirements evolve	No / limited access to source code of systems Dependent on tailoring facilities provided with COTS product Glue code and wrappers are major means of tailoring
Configuration Management	Tracking available versions of COTS products Tracking change history of products Recording set of compatibilities and incompatibilities between sets of products Tracking current configuration of products at each deployed site Tracking change history of products of each deployed site Managing license and service agreements for each product	Versioning controlled by the COTS distributor Licensing and support agreements must be managed Management of COTS configurations Compatible versions of COTS products must be determined

to function correctly. However, as the proliferation of COTS products increases in computing architectures, the architectural mismatches caused by requirements from disparate COTS products is an area that has not been covered by previous research.

Architectural dependencies and dependency attributes are traditionally acknowledged as creating interactions in a CBS. But, architects also create interactions in the CBS by choosing which products fulfill specific requirements and by defining the system's concept of operations (CONOPS). These two types of interactions contribute to complexity in testing and debugging the system by creating additional interactions within the system [39]. For instance, if a single product is chosen to fulfill five different functional requirements in the system, changing that product requires more functional testing than if the product only fulfilled a single functional requirement.

The concept of operations creates interactions by introducing interactions between components that are not necessarily intended by the vendor [24]. One COTS product may not require another to install and operate, but the two may be required to interact and provide the required functionality of the system. This interaction is not covered by the architectural or behavioral dependencies and is, therefore, missing from the current models that are in use. Combined, architectural dependencies, COTS dependency attributes, architectural mismatch, and the system's concept of operations create a more complete view of the architectural interactions in the CBS.

Architectural interactions themselves create complexity in the CBS that must be managed. And, because each COTS product vendor follows its own independent development and upgrade schedule, the innate complexity in a CBS is worsened by the need to upgrade individual components on their own individual time scales to remain in a supported configuration. The time-dependent combinatorial complexity created by multiple independent upgrade paths must be eliminated from the system in order for the maintenance lifecycle of the system to be successful and avoid degenerating into a chaotic state [40]. This emergent behavior is one of the aspects of a complex system [8,40,41] and must be anticipated and understood in the design phase of the CBS in order to achieve the appropriate maintenance equilibrium of the system in the deployment and maintenance phases. Without appropriate sustainment, the system has the potential to devolve into disorder [42]

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	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]
[1]	■											■	
[2]		■											
[3]	■		■	■	■	■	■	■	■	■			
[4]		■	■	■	■	■	■	■	■	■			
[5]		■	■	■	■								
[6]		■	■	■		■							
[7]		■	■	■			■						
[8]		■	■	■				■	■	■			
[9]		■	■	■				■	■	■			
[10]		■	■	■				■	■	■			
[11]											■	■	
[12]											■	■	
[13]		■									■	■	■
# of dependencies (in-degree)	2	9	8	8	3	3	3	5	5	5	3	4	1

Figure 4.2: DSM showing interactions between COTS products and the in-degree for each product.

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Mapping Dependencies

The Design Structure Matrix (DSM) has been in use for decades to show dependencies between tasks in design and manufacturing of large engineering systems [43]. The DSM has proven to be a valuable tool in understanding and managing complexity in sophisticated design projects in the automotive and other industries. Recently, the DSM has been used to create the foundation of a network to study the task interactions in a product development process [44] and modularity in software development [45]. Based on this work, it is straightforward to leverage the DSM tool to map the architectural interactions and assist in managing the complexity associated with maintaining a CBS.

Figure 4.2 shows an example DSM. The numbers along the top and side of the DSM represent COTS products in the system – a total of 13 in this case. Each product is listed in the same order on both sides of the DSM resulting a square matrix. A mark in the square where two products intersect indicates a dependency that the COTS product in the row has on the COTS product designated in the column. For example, in Figure 2 product 1 is dependent on itself and product 12. Similarly, product 3 is dependent on products 1, 4, 5, 6, 7, 8, 9, 10 and itself. Product 2 is unusual in this DSM because the only dependency it has is on itself. This relationship is directed. It may or may not be true that the product in the column has a dependency on the product in the row. For this reason, the DSM is not symmetrical once it is fully populated. Each product has a dependence on itself; therefore, the diagonal is fully populated in the DSM. Looking at Figure 2, the row for COTS product [1] shows the dependency that the product has on itself in column [1] and another dependency on the COTS product in column [12].

In CBS, DSMs assist in scheduling decisions and identify architectural dependencies. They also provide a visual representation of the system. It is sometimes convenient to transform the DSM into a network or graph where the system can be analyzed using graph theory [45]. When the DSM is converted to a network, each connection other than the link the COTS product has to itself is a link to another node in the network.

Graph theory is used frequently in computer science and system design to represent software and architectural designs, computer networks, and even the Internet [46,47]. Graph theory is a useful mechanism to study networks as it offers a common language to label and represent the network as well as mathematical notions and operations with which network properties can be quantified and measured. The graph, or network, consists of nodes and connections between the nodes. Degree, degree sequence, and degree distribution are three of the common graph theory attributes that give information about the network [48]. Because directed graphs give information about the relationships between two nodes that is not available in undirected graphs, directed graphs present a more accurate representation of the structure of the network [49,50]. In a directed graph, *in-degree* refers to the links coming into a node, and *out-degree* refers to the number of links coming out of a node. In the DSM for CBS, the in-degree refers to the dependencies that other COTS components have on a node. Out-degree refers to the dependencies that a node has on other COTS components.

Measuring Complexity and Maintenance Effort

Looking at Figure 2 again, the in-degree for each COTS product in the system is obtained by simply summing the number of entries in each of column where each column represents a single COTS product. The in-degree is the number of products that depend on the COTS product identified by the column in the DSM. Therefore, some products have an in-degree of 1 because no other products depend on that product to provide functionality in the system. Conversely, each product depends on an operating system, so the operating system column has multiple in-degree dependencies. Figure 2 identifies the in-degree for each COTS product, computed and shown at the bottom of each column.

The arithmetic mean of the in-degree of the nodes, or average in-degree, is a characteristic of the network. The average, shown in (2), defines the *in-degree mean*. The mean (average) in-degree, c, in a directed graph is

$$c = \frac{1}{n}\sum_{i=1}^{n} k_i \tag{4.2}$$

where the in-degree of node i is denoted by k_i and n is the number of nodes in the network [51]. The arithmetic average is straightforward to calculate and it incorporates the contribution from every node in the network; however, strong outliers may heavily influence the average [52]. Components with many connections require significant effort to test and maintain compatibility with all of the other products with which they interact. Also, in dynamic networks where nodes are continuously being added (e.g., the Internet), the average degree of the network appears to be increasing [53]. In the case of CBS, the architecture of the system is static, so the average degree is constant for each network under evaluation.

4.4 Measuring Complexity and Maintainability

The in-degree mean model is proposed as a predictive measure of the effort required to maintain a CBS through the O&M phase of the CBS development cycle. To empirically assess the model, data for CBS were gathered from multiple sources [54].

4.4.1 Sample Population

The population of systems available for assessment with the model included CBS from one large company (> 10,000 employees), two medium sized companies (> 100 employees and < 10,000 employees) and one small company (< 100 employees). Projects selected for this study were not required to satisfy criteria other than their sponsor's willingness to participate. Therefore, nothing was known up-front about the number of COTS products in each system or the effort required to maintain each system. Using multiple data sources strengthens the study by eliminating engineering design bias introduced by standardization in an organization [55]. A request for participation was sent to program managers and leaders from each of these organizations. During introductory conversations, each organization provided an approximate number of systems on which they would provide information. 53 responses were expected; however, only 17 responses were received.

While 17 represents a significant reduction from the expected 53 systems, each organization experienced unique challenges in providing the details of the systems

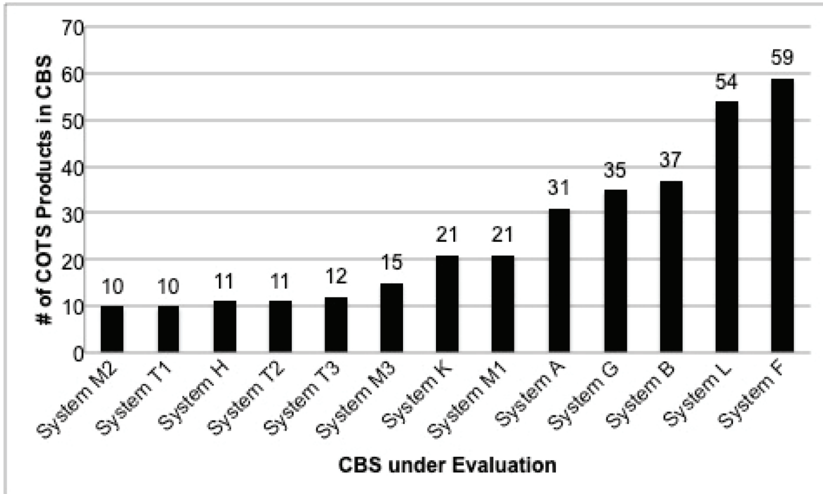

Figure 4.3: Number of COTS products in each system in the sample set.

they had architected and delivered. Some sources were concerned about program security and releasing company-sensitive information and were unable to provide the requested information. Others suffered from staff shortages and were not able to provide the information because of timeline constraints from other deadlines. One company outsourced the entire Information Technology (IT) department and did not retain the expertise required to provide the information about their systems.

From the 17 responses, three were eliminated during the evaluation period because the systems were cancelled before entering the O&M phase of the program or because the supporting personnel were not available to participate in the questionnaire. One system was eliminated because two different contractors developed and maintained the system. This system is different because in all the other systems in the response set, the same contractor developed and maintained the CBS. Instead of introducing another independent variable associated with the separation of the development and maintenance contracts, the system was excluded. An item was added to the future work (Section 7.4) relative to adapting the model to address cases where the developer and maintainer of the CBS are different.

After these exclusions, the model was tested with a sample size of 13 systems. All of the evaluated systems except one were in the operational stage of the lifecycle. The one remaining system was being decommissioned; therefore, it had already been through its operational lifecycle. The final sample set ranged from ten to 59 COTS products (see Figure 4.3) representing systems from small to large numbers of COTS products [6].

The sample size is larger or similarly sized to other published studies related to CBS maintainability. For instance, in IEEE, only four published empirical studies were identified, these having two [56], five [16], eight [48] and thirteen [13] systems surveyed.

The following sections explain how the dependencies for the 13 systems in this study were derived (a measure of complexity) and how effort to maintain these systems was evaluated (a measure of maintainability).

4.4.2 Identify Complexity in CBS

To establish architectural interactions in the subject CBS, a request was sent to system architects and program engineers asking for a list of COTS components in the system for which they were responsible. A follow-up interview to understand the CONOPS associated with the system and to identify any additional dependencies was also requested as part of the initial contact with the system subject matter expert (SME). This part of the process was challenging for some of the programs because of concerns with revealing sensitive program information or because knowledgeable personnel were no longer available. This suggests that for operational programs, the information required to create the in-degree mean model may be difficult to obtain. However, for systems under development, knowledgeable personnel should be readily available for determining the information required for the model.

For most of the projects, the follow-on interview lasted less than one hour. Architectural data flows were helpful in ensuring that all dependencies were identified and to refresh the program SME on project functionality that was used less frequently.

Dependencies in Existing Documentation

After receiving the COTS list from the program representative, COTS installation dependencies were identified by reading the vendor documentation for each of the products in the CBS. Many installation and configuration dependencies are recognized in literature [57,14] and are straightforward to define. With this process, the mapping of installation and configuration dependencies relied on the accuracy of vendor documentation to ensure that it was complete and up-to-date.

The availability and quality of vendor documentation varied significantly as there is no standardization in installation guides for COTS software [58]. When COTS vendors document their installation dependencies, this takes many forms. The installation guide is the most common place where vendors document installation prerequisites. Figure 4.4 shows how one COTS product, Hummingbird's Exceed – a COTS application that lets the user access Linux or UNIX applications from a Windows-based workstation – documents its dependencies on the operating system and on the Java Runtime Environment.

Hummingbird's Exceed notes dependencies in at least two ways. First, depending on the product used in the system (four different products are covered in the embedded table), the operating system is noted in the second column of table and additional requirements are noted in the fourth column. Because multiple operating systems are supported, it is necessary to know the baseline operating systems, including versions, used in the system under evaluation. Once the operating system is known, a dependency is noted in the DSM at the intersection of the row for Exceed and the column for the operation system. The same process is used to document the dependency on TCP/IP and Microsoft C/C++ (from the fourth column in the embedded table in Figure 4.4) in the DSM. Additional third party dependencies are noted depending on how the product is to be used in the system.

The "Third Party Software" portion of Figure 4.4 indicates another dependency on the Java Runtime Environment (JRE). This dependency is written out instead of included in the embedded table; however, the dependency must still be captured

Installation Requirements

The following table outlines installation requirements for Hummingbird connectivity products:

Product	Operating System	Disk Space	Other Requirements
Exceed	Windows 95 Windows 98 Windows Me Windows NT (service pack 4 or later) Windows 2000	78MB	Winsock compliant TCP/IP
Exceed XDK		219 MB	Winsock compliant TCP/IP Microsoft Visual C/C++ (MSVC) 4.2 or later, for X Client development
Exceed 3D		6 MB	Exceed – to Open GLX Exceed XDK – to display Open GLX Microsoft Visual C/C++ (MSVC) 4.2 or later, for X client development
Exceed PowerSuite		96	Winsock compliant TCP/IP An assigned IP address and the ability to communicate with other computers on the network (Windows NT) A HOSTS file if a domain server is not available

Third Party Software

Certain third party software must be installed to run some Hummingbird products. The Sun Java Runtime Environment (JRE) is required to run Java programs.

For example, you must install JRE before installing the following product sub-features:

- Systems Administration—Jconfig (client)
- Systems Administration—Jconfig Daemon
- Exceed (Tools)—Xdis

Hummingbird Master Setup lets you install third party add-on(s) such as:

- Adobe Acrobat Reader
- Sun Java 2 Runtime Environment
- Microsoft SNA Server (for Windows NT/2000)
- IntranetWare for SAA Client

Figure 4.4: Example installation prerequisites for Hummingbird Exceed (COTS product) [47].

in the DSM. It is important to recognize that vendors document installation dependencies in multiple ways even within a single vendor's documentation.

For the CBS in the dataset, determining the dependencies took about one hour per product. The vendor documentation that lists the installation dependencies must be located. The Internet is a valuable resource for these documents as most vendors make their documents publically available. Once the appropriate manual is located, the installation dependencies are relatively easy to find in the manual. They are generally called out in the Table of Contents or found with keyword searches. Most vendors make installation dependencies clear even when the product installation is dependent upon another company's product. For instance, many products are dependent on a database for storing information. In these cases, the vendor is clear on which vendor's databases are supported along with the required versions of those databases.

Many products are commonly used across projects. For instance, Internet Explorer and the Oracle database are typical components in many systems. The commonality of these components accelerated some of the investigation of dependencies but only when the same versions of the components were used between systems. When different versions were used, it was not possible to leverage previous work because of the potential mismatch of the versions of dependencies.

Dependencies from the CONOPS

In addition to dependencies introduced by the COTS products themselves, CBS also include dependencies derived from the system CONOPS. Combined, these are called architectural interactions. The dependencies from system CONOPS were derived during an interview with the system architect or other SME who was knowledgeable of the overall design principles and concepts of the system. During the interview, the architect identified dependencies that were introduced by the system data flows or system design. Such dependencies are sometimes related to the way application workflow states are preserved or to concepts related to application fault tolerance and failure recovery. Similarly, in many systems, the database is used to preserve processing state information for web applications. It is possible that no vendor's installation guide recognizes this dependency; however, for the system to function as the architect has designed, the dependency between the products must be recognized and maintained throughout the lifecycle of the system. In the DSM, these dependencies are noted with a mark on the web application row in the column for the database. Dependencies derived from the CONOPS are unique to the design of the CBS; therefore, they can only be determined by the architect and will not be documented in the vendor requirements for each individual product.

The process of documenting dependencies between COTS products (whether installation or CONOPS) continued until all of the known dependencies were identified with a mark in the DSM. The diagonal of DSM is always marked as the dependency that each product has on itself. Once complete, the DSM documents all of the architectural interactions of the CBS and becomes the basis of the model for determining the maintainability of the CBS.

Because there is some ambiguity in the dependencies that are known at the beginning of a project, the DSM is a living model of the system. As new dependencies are introduced or knowledge of the existing dependencies matures, the DSM is updated to increase the fidelity of the model.

4.4.3 Real-World Assessment of Effort – the Survey Questionnaire

In order to validate the accuracy of the in-degree model of maintainability is it necessary to compare the measure against the effort required to maintain actual deployed systems. Ideally, the effort associated with integrating and maintaining the COTS products in a system would be captured by some direct means such as charge numbers, billing information, etc.; however, in surveying commercial companies, academia, and government organizations, none of the organizations kept billing metrics at the granularity needed to isolate the maintenance effort associated with only the COTS solution. Therefore, a survey of system architects was determined to be the best means to determine the perceived effort required to maintain each COTS based system. While not as accurate as direct measurement based on billing information, *perceived effort* gives a notional measure of the effort to maintain a CBS.

The construction, execution, and evaluation of the survey questionnaire was accomplished through several steps.

Constructing the Questionnaire

1. Closed ended questions
2. Clear items
3. Only single questions (no double-barreled questions)
4. Only relevant questions
5. No negative questions
6. Non-biased items and terms
7. Short answers (when possible)

All survey items were created to evaluate the perceived effort associated with maintaining the COTS components of a CBS as defined in previous research [14]. As there are five major areas that contribute to the effort – Product Reconfiguration; Testing and Debugging; System Monitoring; Enhancing User-Level Functionality; and Configuration Management - the questionnaire was organized with five major question groups corresponding to each area of effort. Within each major question group, a single survey item addressed each of the individual maintenance activities. Combined, these items comprise a measure of the perceived effort associated with each major category. A sample section of the survey questionnaire is shown in below.

Your role on the project: (e.g., architect, COTS manager, etc.)
Current phase of project: (e.g., development, production, integration, etc)
How long has the project been in this phase? (years or months)

Estimate the effort associated with activity as it relates to the COTS (Commercial Off-the-Shelf Products) in the architecture. If the program or project has not experienced the described type of COTS product change, please mark N/A instead of estimating the effort.

Product Reconfiguration

1. Updating COTS products with new versions. i.e., updating Oracle 10.1 to 11.0, or Internet Explorer from version 7 to 8.
   Effort (from 1-10, or N/A)
2. Replacing a COTS product with a competitor's offering. i.e., replacing DB2 with Oracle.
   Effort (from 1-10, or N/A)
3. Adding or removing COTS products from the architecture as requirements evolve.
   Effort (from 1-10, or N/A)

Testing and Debugging

1. Identifying causes of failure in the system. i.e., isolating the fault to a COTS product and logging the case with the vendor.
   Effort (from 1-10, or N/A)
2. Running tests to validate requirements and verify changes in configurations. i.e., effort associated with testing requirements fulfilled by COTS products.
   Effort (from 1-10, or N/A)
3. Monitoring system performance and resource utilization of COTS products. i.e., validating system performance requirements and resource utilization of COTS products.
   Effort (from 1-10, or N/A)
4. Analyzing logs associated with COTS products to determine system behavior and activity. i.e., utilizing COTS logs to debug or determine system functionality.
   Effort (from 1-10, or N/A)

System Monitoring

1. Logging system behavior. i.e., the effort associated with finding logs associated with COTS products.
   Effort (from 1-10, or N/A)
2. Analyzing logs for failures, performance problems, etc. i.e., the effort associated with determining information about a particular COTS product's failure and performance based on the logging provided by the vendor.
   Effort (from 1-10, or N/A)

Enhancing User-Level Functionality

1. Changing system functionality as requirements evolve utilizing the current COTS in the system. i.e., delivering additional or different system requirements with the COTS products that are already part of the system.
   Effort (from 1-10, or N/A)

Configuration Management

1. Effort associated with tracking the available versions of COTS products. i.e., effort associated with determining when newer versions of a COTS product are released.
   Effort (from 1-10, or N/A)
2. Tracking the change history of COTS products. i.e., tracking the versions placed into the system including reasons driving the change.
   Effort (from 1-10, or N/A)

3. Recording set of compatibilities and incompatibilities between sets of products. i.e., determine compatibility between a new version of a COTS product and the existing versions of the other products in the system. e.g., determining the (in)compabilities of all the COTS products in a system with a new version of the operating system.
   Effort (from 1-10, or N/A)
4. Tracking current configuration of products at each deployed site. (assumes that multiple instantiations of the system exist and that it is possible to have different configurations at each location).
   Effort (from 1-10, or N/A)
5. Tracking change history of products at each deployed site. (as with #4 above, assumes that there are multiple instantiations of the system and that each system can be updated / changed independently).
   Effort (from 1-10, or N/A)
6. Managing license and service agreements for each product. i.e., tracking the licensing and service agreements with each of the products in the project configuration. (assumes that at least one COTS product in the configuration requires a license and/or service agreement.)
   Effort - (from 1-10, or N/A)

Additional Notes / Thoughts: (Please indicate the question the note pertains to.)

The survey items were scored using a single numerical rating of the effort in each category (a Likert scale [60,61]). Short answers enabled quicker analysis of the data from the questionnaire and allowed the respondent to easily rate the system while maintaining the integrity of the measure. An ordinal scale (where 1 represented minimal effort and 10 represented maximum effort) was used to compare the perceived effort of maintaining of the evaluated system. Each item allowed the respondent to answer with a "not applicable" (or N/A) response in the event that the system under evaluation did not experience any effort associated with a maintenance activity. The "N/A" response allows each of the items in the questionnaire to be exhaustive – enabling all known answers to the question [62]. The "N/A" response is particularly relevant in systems that only have a single instantiation or where the maintainers of the system have not encountered error conditions where COTS vendor support is required.

The face validity of the survey items was based on previous research identifying all of the areas in a CBS that contribute to the effort in maintaining the system [14] and by having three SMEs analyze the survey instrument [63] to ensure all areas of effort associated with maintaining the COTS components were captured. The questionnaire was initially issued to a small sample of respondents to improve upon its clarity and readability. After two revisions, the third and final version was submitted to all of the respondents.

Human Subjects

To help ensure that the respondents had sufficient experience in the field to make an accurate assessment of the effort to maintain the CBS, only senior engineering

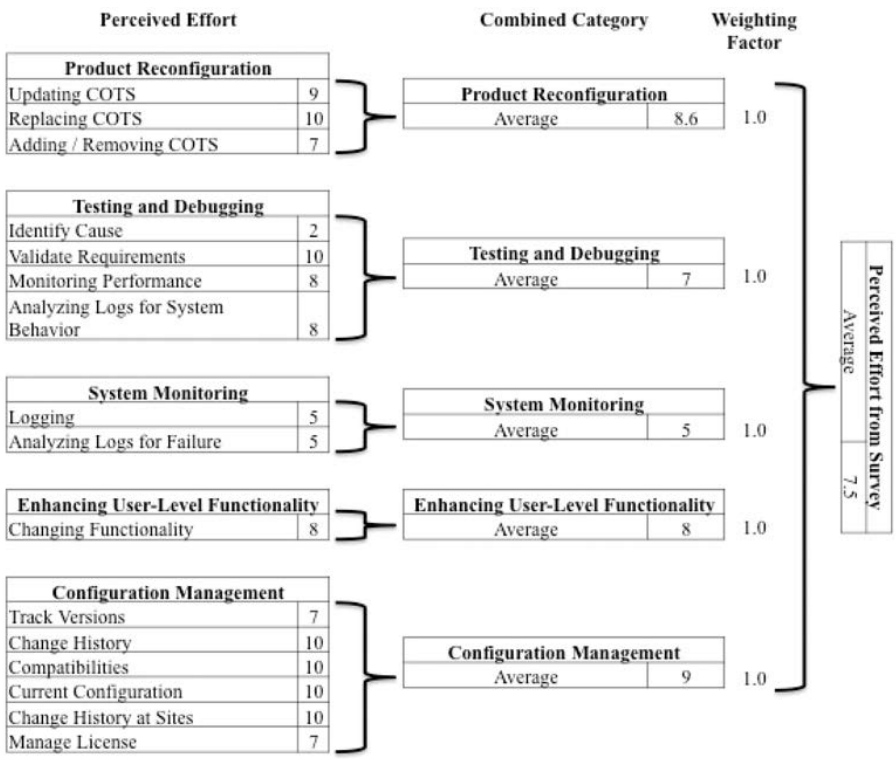

Figure 4.5: Method for computing the effort for maintaining a CBS from the questionnaire.

leaders participated in the survey. This minimized the chance of a respondent having a limited experience on which to evaluate the system under test. Each of the engineers or sustainment personnel completing the questionnaire had over 15 years of experience in the field with five of the 13 having more than 25 years of experience.

Evaluation (scoring) of the Survey

The result from each response in the survey was treated as an ordinal value. While a rating of 7 means more effort was exerted in maintaining the system as compared to a rating of 6, it is not valid to attempt to distinguish gradients between the two scores [64]

Maintainability Index

The overall maintainability index of each system was obtained by averaging the scores from the five maintenance activities known to comprise effort to maintaining CBS (see Figure 4.5). When computing the maintainability index, all items were weighted equally [7]; therefore, the overall rating of the perceived effort associated with each maintenance activity was obtained by averaging the responses in that activity's area.

Table 4.2: Summary of results.

Systems ↓	**Perceived** (from questionaire)	**Normalized Perceived** Effort((Perceived Effort-5)/10)	**In-Degree** Mean (from DSM)
System A	4.10	-0.09	2.68
System B	7.53	0.25	4.65
System F	5.40	0.04	3.39
System G	2.75	-0.23	2.69
System H	4.05	-0.10	2.45
System K	4.75	-0.03	2.29
System L	5.67	0.07	3.04
System M1	1.67	-0.33	2.76
System M2	1.42	-0.36	2.30
System M3	2.29	-0.27	2.80
System T1	4.75	-0.03	3.30
System T2	4.65	-0.04	2.64
System T3	5.50	0.05	3.17

The computation of perceived effort associated with system maintenance activities had to accommodate the "not applicable" (N/A) response. The approach to dealing with missing data is not standardized and is unique to every situation [59]. In this study, the maintainability index for the system where one area of effort was not pertinent was computed as if the question did not appear in the survey. Essentially, the number of survey items for the specific maintenance activity was decremented and the item simply was not scored in the average. While this has the side effect of increasing the significance of the effort of those items in the maintenance activity that do contribute to the effort in maintaining the CBS, it is the most straightforward way of accommodating those systems that do not have every aspect of maintenance involved in their sustainment. The option of substituting a nominal value (e.g., 5 since a rating of 5 represents typical effort) for the question with the "N/A" response was considered; however, this artificially changes the effort estimation by adding a contribution for an activity that is not part of the system. Alternately, dropping the item for all of the systems under evaluation was considered; however, because the sources of effort in maintaining systems is already established in literature and many of the systems under evaluation reported effort associated with every aspect of maintainability, it did not seem reasonable to exclude effort associated with these activities for those systems for which effort was expended.

4.5 Results

The results from the survey questionnaire (a measure of perceived effort) and the in-degree mean computation (a measure of CBS complexity) are summarized in Table 4.2. The perceived effort (maintainability index) score has been normalized to transition normal effort to 0 on the scale; therefore, negative effort represents effort that is less than normal to maintain a system, and positive effort indicates a system that requires more effort to maintain than normal.

The model for the in-degree mean asserts that the mean of the in-degree of the

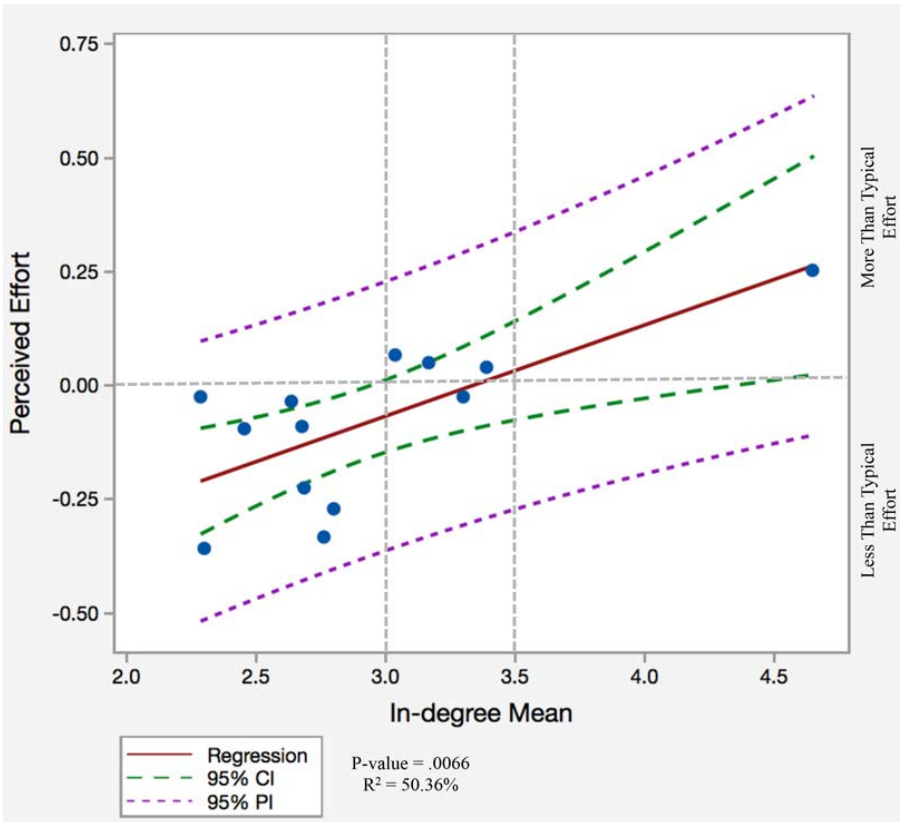

Figure 4.6: Plot demonstrating a relationship between the perceived effort and the in-degree mean.

nodes in a CBS predicts the effort required to maintain the CBS in the operational phase of the system. To better visualize this relationship, it is helpful to plot the computed in-degree mean from each CBS as it relates to the perceived effort derived from the survey for the same system (Figure 4.6). The regression model in Figure 6 suggests a statistically-significant relationship exists between the two measures of effort to maintain the CBS. The p-value for the relationship is 0.0066, within the significance level of 0.05, and the coefficient of determination (R2) value is 50.36%.

Not withstanding evidence that a predictive relationship exists, it can be observed that the 95% confidence interval bands become wider as the in-degree mean increases, and the 95% predictive interval bands are quite wide. This bandwidth relates to the size of the dataset, the fact that the dataset contains few systems having high in-degree mean values, and that measurements of perceived effort are noisy. As has been noted, empirical studies of this type are rare and face many challenges. The promised dataset for this study which began as 53 systems yielded only 17 systems, 13 of which were useable. Even so, the dataset for this study is larger than or similar in size to datasets from other published empirical studies. The same can be said for the number of systems with high in-degree mean values – such systems were not well represented and only one made it to the final dataset. While this particular system does influence the empirical model, the data reveal no evidence to suggest the measured parameters for this one system are anything other than valid.

To further explore the strength of the relationship, Kendall's tau coefficient was calculated to assess the association based on ordinal ranking of the data. Kendall's tau is less sensitive to the magnitude of outlying values and has more robust statistical properties. In this study, Kendall's tau was calculated as 0.374, with a p-value of 0.087 for the null hypothesis test, H0: tau = 0. The p-value is marginally significant, but if we accept this, Kendall's tau suggests a relationship exists between the in-degree mean and perceived maintenance effort, albeit a weak one. Collectively and within the limitations of the dataset, both the regression analysis and Kendall's tau suggest the in-degree mean can be used as an indicator (weak predictor) of the effort required to maintain a CBS in the operational phase of the system

Descriptively, Figure 4.6 further shows that the effort required to maintain a CBS crosses from less-than-typical to more-than-typical effort in between 3.0 and 3.5 for the in-degree mean of the system. Systems with in-degree means lower than 3.0 have lower than average maintainability scores indicating that they require less perceived effort to maintain than those systems with a high in-degree mean. Conversely, those CBS with in-degree means above 3.5 exhibited more perceived effort to maintain. While this is a relative measure, it is an indicator early in the design phase that an architect should consider other COTS products or different COTS product arrangements to design a system that is easier to maintain in the O&M phase of the program and reduce the overall lifecycle cost of the system.

4.6 Analysis and Discussion

From the results, it is possible to derive observations about the relationship of the perceived effort to maintain the CBS and the architectural interactions of the systems. Further insight can be gained by evaluating the in-degree model relative to the existing COTS maintainability approaches.

4.6.1 BASIS Technique

The BASIS technique is a three-step process to assist in COTS selection. The third step is most like the in-degree mean process; however, the BASIS technique requires significant knowledge of the COTS component's external interfaces and how those interfaces interact with glue code. The BASIS technique is not focused on the O&M phase of the program nor the effort associated with maintaining the COTS installation base. Instead, it is focused on choosing the COTS products to meet the system requirements and minimize development costs.

The in-degree mean process and the BASIS technique are complementary and, together, can be used to develop a CBS that meets the system requirements and delivers a maintainable system. The BASIS technique can be used to select the COTS components that most accurately meet the system requirements, and the in-degree mean process can assist in choosing between multiple COTS components that meet the requirements but require different levels of effort in the maintenance phase. The two approaches do not significantly overlap.

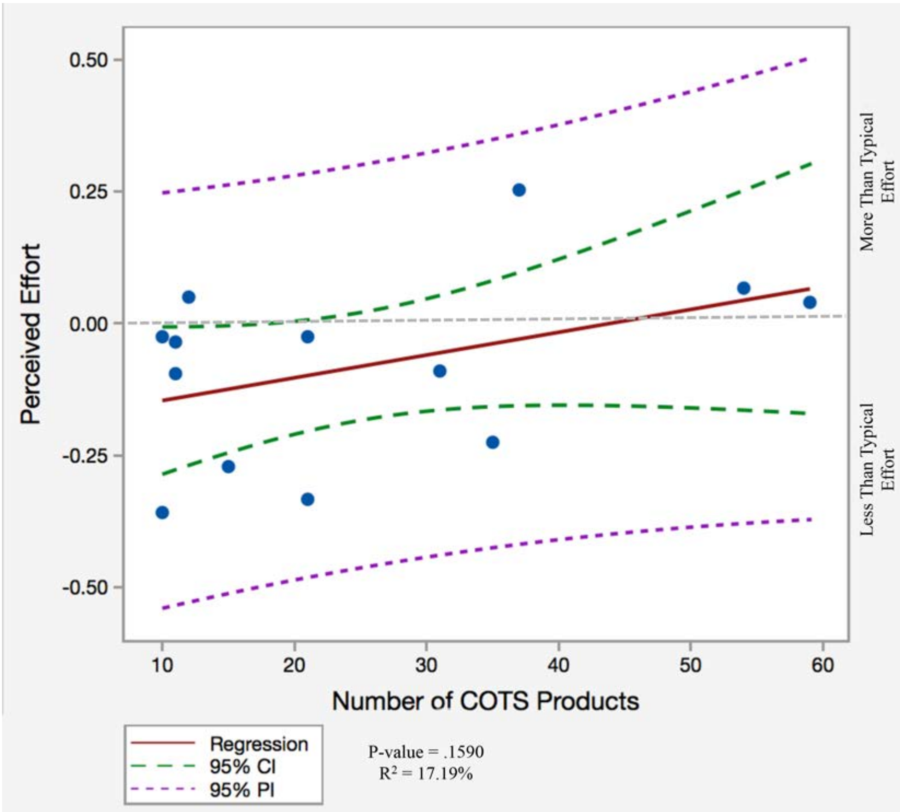

Figure 4.7: Plot demonstrating relationship between perceived effort and the number of COTS products in a CBS.

4.6.2 COCOTS Cost Model

The COCOTS Cost Model is used primarily as a software-costing tool; therefore, there is no significant overlap with the in-degree mean model. COCOTS is focused on the effort to interface custom software with the external interfaces of the COTS products including the glue code that is often used to link multiple COTS products together. While the model is planned to extend into the maintenance phase, the work is not yet complete; therefore, the in-degree process adds to the areas currently covered by the COCOTS Cost Model.

4.6.3 COTS-LIMO

The COTS-LIMO model attempts to identity a break-even point where maintenance costs increase disproportionately to the number of COTS products in the system. The theory is that there is some number of COTS components beyond which the system is simply unmaintainable because the effort associated with that number of COTS products is too great. This study tested the COTS-LIMO on the CBS dataset.

Figure 4.7 shows the comparison of the perceived effort (normalized) to the system size (number of COTS products). The plot suggests the expected form of relationship between the number of COTS and the perceived effort to maintain the CBS, which aligns with intuitions about COTS maintainability. But this relationship is not statistically significant (p-value = .1590) nor is the level of explained variability high ($R^2 = 17.2\%$).

From the empirical data, it may be inferred that the number of COTS in a CBS is only a portion of the story. The data show that the number of interactions between the COTS components has a stronger influence on the effort to maintain the CBS than just the number of COTS in the system.

4.6.4 Maintenance Delta

The theory of the Maintenance Delta asserts that there is a relationship between the Power-law and the number of architectural interactions in a CBS. Specifically, the theory states that the difference in the Cumulative Distribution Function (CDF) for the system and the CDF of a Power-Law distribution indicates the maintainability of the system [6]. For each of the systems under evaluation, the Kolmogorov-Smirnov goodness-of-fit test [65] demonstrated that the system does not follow a power-law distribution. The α from equation (1) associated with each system is less than 2, and typical power-law distributions have $2 \leq \alpha \leq 3$ [28]. So, the systems in the current sample set do not follow a power-law distribution. It is possible that the sizes of the CBS under evaluation are simply too small to demonstrate power-law characteristics. However, for systems with a single operating system, the hub of the node (the operating system) is connected to every other node. This one node in a small system does not allow the system to follow the power-law curve: it causes α to be less than 2 and beyond the typical range of the power-law interval.

4.6.5 Discussion

The results support certain observations. First, there are some products that have almost as many dependencies as the operating system: Java is one of these products. Because of the high number of dependencies, the operating system and those products with almost as many dependencies as the operating system must be treated with special care when planning maintenance. For instance, careful planning must occur when upgrading products with many dependencies simply because of the testing that is required ensuring that all architectural interactions are satisfied. It has been the lead author's experience that Java is treated as a product that can be updated with little planning or coordination. The data suggest that the number of architectural interactions involved with Java and similar products requires that either they be upgraded only when complete system testing can be performed or that mitigation strategies be implemented to reduce the number of architectural interactions with these individual products during the design phase to make the CBS maintenance activities require less effort.

Second, the data suggest that system architects rarely have a comprehensive list of COTS products that comprise the system; therefore, the understanding of the architectural interactions in the system is incomplete. For example, in the data section for System T3, the architect only listed seven COTS products in the response to the request for a list of COTS products that comprise the system. But, as all of the architectural interactions were mapped, an additional five COTS products were discovered in the underlying dependencies. System T3 was not unusual in this finding. Every other system had at least two additional underlying COTS products that were not identified in the original request. Without a complete understanding of the COTS products in the system, it is more difficult to maintain the system. Additionally, without understanding the way the COTS products interact with each other, maintenance activities associated with the COTS products may have unintended consequences which may result in system outages or additional effort to properly manage changes to the system. The data also suggest that personnel with the knowledge required to apply the knowledge are often not available in the later phases of the development lifecycle.

Third, basing the CBS on a single operating system generally reduces the overall maintenance effort. Systems A, F, K, M1, M2, M3, T2 and T3 are all based on a single operating system, and the average perceived effort for these systems is 3.7. The systems with more than one operating system, including a hypervisor as an operating system, have an average in-degree mean of 5.0. While this observation is intuitive, even CBS based on a single operating system can exhibit high levels of perceived maintenance effort. Systems F and T3 score high on both the in-degree mean and the average perceived effort even though they are based on a single operating system. So, the selection of COTS products and the CONOPS of the system still must be considered even when utilizing a single operating system.

4.7 Conclusions

4.7.1 Conclusions

The in-degree mean process offers a straightforward way for architects, integrators and maintainers to determine the maintainability of a COTS deployment based on information available early in the development phase of a CBS. The model is intuitive as maintainers of the system expect that the more interactions between COTS products, the more effort changing those products will require. The maintainability of the COTS deployment in a CBS is an area that has received little attention, so the approach offers a way to understand the complexity of the deployment through design structure matrices and network analysis. The combination of these well-known tools provides a framework to compute the in-degree mean, a measure of maintenance effort for a CBS. The in-degree mean can be used to compare deployments for competing architectures or simply as a measure of the maintainability of the CBS architecture.

The perceived effort associated with maintaining 13 systems was compared to the in-degree mean of the CBS derived from the architectural interactions of the systems. The comparison yielded a practical, intuitive and statistically-significant result indicating that the in-degree mean does correlate to the effort to maintain the systems.

The measure is useful in the beginning of the design phase to determine the maintainability of the COTS installation. The artifacts derived from the model are useful throughout the CBS lifecycle to assist in maintenance activities and to determine the level of effort required to maintain the COTS product installation base. As the system matures, the architectural dependencies of the COTS installation can be updated to increase the fidelity of the model.

4.7.2 Contributions

This work makes two separate contributions to the body of knowledge around CBS – the in-degree mean model and a clearer definition of design attributes that contribute to complexity in the COTS installation of a CBS. The in-degree mean model builds on existing models and gives additional insight into the maintainability of a CBS in the O&M phase of a project. No other CBS metrics or models currently consider this phase of the lifecycle when assessing effort associated with the development of a CBS, and the most developed models are only focused on the effort to maintain the custom code that is written to be delivered along with CBS instead of the effort to maintain the COTS-based installation. Because the O&M phase of a project is the longest and most expensive portion of the system's lifecycle, considering the maintainability of the CBS during this phase can help lower the overall lifecycle cost of the system. Additionally, the in-degree mean model enables architects to create systems that require less effort to maintain which should increase the success rate of the development and deployment of CBS.

Second, the work adds the system CONOPS to the list of design attributes that add complexity to the COTS installation. Previous research identified dependencies that COTS products create themselves through their installation requirements; however, system architects create additional dependencies in the COTS installation in the way data flows are designed in the system and the way information is stored in the CBS. Including the system CONOPS in the design characteristics that add to complexity creates a more complete understanding of the dependencies between COTS products and enables the system architect, integrators and maintainers to make more informed decisions on the maintenance activities associated with the CBS.

4.7.3 Practical Implications and Application

The in-degree mean is a straightforward calculation that gives the architect, system integrator and system maintainer knowledge of the dependencies between the COTS products in a CBS. With this information, many decisions can be made related to the design and maintenance of the CBS.

The in-degree model is also applicable to Free and Open Source Software (FOSS), Government Off-the-Shelf Software (GOTS) and Research Off-the-Shelf (ROTS) Software. The only difference between these software products and COTS is the method of procurement. The other attributes of COTS software are the same and the dependencies between these types of software products and COTS are identical. For this research, FOSS and COTS were treated identically and combined as a single product type. As an example, Figure 4.4 shows Java, a FOSS product, included with other software dependencies. Including FOSS and other types of software products is important as they are increasingly used to build modern CBS.

System architects can use the in-degree model to determine if the COTS installation for the project can be maintained within a typical range of effort. Because the model only requires the system CONOPS and the installation manuals of the COTS products, the architect can compute the in-degree mean early in the design phase and make COTS product decisions or CONOPS changes to decrease the effort to maintain the system. In a system proposal, the architect can use the model to predict the level of effort required to maintain the overall system design in the maintenance phase with a view to lowering project bid metrics. Or, the architect can use the in-degree mean to demonstrate to a customer that one design is more robust than another design assuming information about both systems is available.

System integrators can use the artifacts derived during the creation of the in-degree model to focus effort on the COTS products that create the most complexity in the design. The DSM is a tool with decades of research demonstrating its applicability in managing system complexity [56,66]. Because all architectural interactions are mapped into a DSM in the creation of the in-degree model, the system integrators can use the DSM to determine which products have the most dependencies and then employ SMEs on those products to reduce the risk to the COTS installation.

Having a better understanding of the maintainability of the CBS allows the system maintainer to fine-tune project bids associated with effort to maintain the system. A low in-degree mean indicates that a system maintainer can lower the effort in a bid to maintain the system. Similarly, a high in-degree mean indicates that the system maintainer should bid a high level of effort to maintain the system. Higher fidelity bidding models decrease the financial risk to the system maintainer and assist in determining the appropriate level of support for the O&M phase of the project.

4.7.4 Limitations / Topics for Further Study

The systems in this study ranged from ten to 59 COTS products and were gathered from three separate and unrelated sources. While the sizes in the sample set are typical, larger systems exist. For example, two additional systems with more than 150 COTS products were excluded from the analysis because no one with current knowledge of the system was available to assist with understanding the architecture and assessing maintenance effort. Future work should include these "super systems" to determine if the in-degree mean applies to the very large systems.

The current approach combines multiple systems with various lengths of time in the operational phase of the program– some over 13 years. It seems reasonable that these systems have been updated over their lifecycle to lower the effort associated with maintaining the system. If one area of the system required significant effort to maintain early in the project's operational phase, changes could have been made to decrease the effort and create a more maintainable system later in the operational phase. The current survey approach does not account for these changes; therefore, the length of time a system has been in the operational state may influence the perceived effort to maintain the system.

Management of the deployments of a single version of a CBS to multiple locations will contribute to the overall effort to maintain the system. The research method identifies the activities associated with the deployment to multiple sites as a factor that contributes to perceived effort; however, many of the systems in the dataset did not feature multiple deployments. Future work should more thoroughly consider the effort associated with deploying to multiple locations.

The current model is focused only on the complexity associated with the COTS installation in the system. A CBS has the potential to have other dependencies including those on hardware components, custom code components and other external interfaces. Future work should expand to include other potential dependencies and the impact of those dependencies on the effort required to maintain the system.

The measurement of maintenance effort for CBS is an area that also warrants further study. For example, future research could consider direct tracking of labor hours associated with maintaining the COTS portion of a system. Identifying the actual COTS maintenance effort would eliminate the subjectivity introduced by surveying an expert on each individual system. Alternatively, if perceived effort is retained as a measure of CBS maintainability, the survey questionnaire could be expanded, the scoring approach to "N/A" responses could be refined, and the weighting factors used to establish the maintainability index could be evaluated.

Finally, the current sample set only included systems that were maintained by the same organization that developed the system. One system in the original request was maintained by an organization that did not develop the system, and because of this unique characteristic, it was excluded from the evaluated sample set. Many contracting offices are moving to a model where one company develops a system and hands the complete system to another organization to maintain and enhance. Therefore, future work should include investigations into the applicability of the model in this unique maintenance paradigm.

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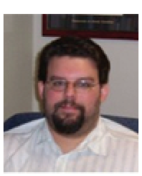

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CHAPTER 5

Ambassadors of the Sensible World

Aurélien Gamboni

We may ***work on things****, but the opposite is perhaps even more true:* ***things work on us****. Reflecting on several projects of art and research that I have been involved in over the past years, which address different aspects of the environmental mutations currently in process, this paper will aim to partly divert from a usual focus on the deliberate intentions and goals that we can set ourselves as authors, rather observing how various objects of concern can progressively grow in our conscience and in our practice, calling for new transdisciplinary and investigative tools. These projects include the observation of a negotiation summit re-enacted at SciencesPo Paris in 2012, during which the "specter" of climate change seemed to appear in the room as an almost physical presence; the long term artistic research project "A tale as a tool" developed with anthropologist and writer Sandrine Teixido, involving a text of fiction as an investigative object of mediation, allowing to collect testimonies by members of frontline communities from the South of Brazil to the North of Norway; and the research project "The Anthropocene Atlas of Geneva" at Geneva school of Art and Design, gathering self-reflexive interviews with numerous scientists, artists and other actors of the ecological transition.*

Keywords: anthropocene studies, artistic research, situated knowledge, transdisciplinarity, human-nonhuman assemblages, theories of attention.

5.1 Introduction

As artists or researchers we may work on things, but the opposite is also true: things work on us. Whatever object or phenomenon we aim to grasp, whatever matter to handle, they affect us in ways that cannot necessarily be measured nor described. They transform our conscience, or should we say, they precisely build it anew. Piece by piece. Contact after contact.

> *This movement seems motionless, yet it crushes the landscape of logic under glacial reveries. This slow flowage makes one conscious of the turbidity of thinking. Slump, debris slides, avalanches all take place within the cracking limits of the brain. The entire body is pulled into the cerebral sediment, where particles and fragments make themselves known as solid consciousness* [1]. **Robert Smithson**

As I started to write this paper, I wanted to reflect on several projects of art and research that I had been involved in over the past years, which addressed different aspects of the environmental mutations currently in process. In that regard, it seemed important to partly divert from a usual focus on the deliberate intentions and goals that we can set ourselves as “authors”, rather observing how various objects of concern can progressively grow in our practice, overflowing disciplinary boundaries, stepping in unexpected contexts and enlisting unexpected actors.

In my case, this approach has proved to be a necessity. Generations of artists have been able draw their engagement either from an intimate knowledge of wildlife, from a parallel study background (e.g. in natural sciences), or from an extensive comprehension of ecological thinking and activism, among other kinds of precious experiences in the matter. For my part I had none, and like many, I came to realize that I was totally unprepared. Unprepared to the vastness of the changes that were occurring around me, unprepared to the complexity of these transformations and their countless implications, and finally unprepared to the difficulty of even perceiving them. Of course, this could be considered a widely shared condition, and there are many ways to experience what Isabelle Stengers and Bruno Latour called the “intrusion of Gaia” in human affairs [i, 2], described as an “a ticklish assemblage of forces that are indifferent to our reasons and our projects” [3], thwarting our plans and challenging our capacity of attention.

The following narrations are only moments in longer term projects, all of which are collaborative ones. The collective Save as draft for the first scene, Sandrine Teixido for the second, and my current colleagues at Geneva School of Art and Design for the third, all would certainly narrate the same events in quite different ways. Yet across all these different engagements, I will describe some of the moments during which my mental dispositions have been either challenged or affected by the very **objects of my attention**. The kind of moments in an investigation process where perceptions shift, representations are transformed and new relations appear. Issues appear knotted with other issues, being with other beings, up to constituting an indivisible fabric, not unlike the “string figures” evoked by Donna Haraway [4].

5.2 The Unexpected Apparition of the (Climatic) Ghost in the Negotiation Room

The large building of rue Saint Guillaume in the 7th arrondissement, emptied of all its usual activities, is now the scene of a strange ballet. People gather and disperse in the rooms, alleys and stairs. They write, talk and re-write the writings. So far, everything is going as planned, it may all be finished before the night falls.

Drafting sessions, plenary sessions, and corridor diplomacy: if there is one specter to evoke at this point, it would be that of COP 15, the 2009 UN summit of negotiation on climate change which was held in Copenhagen a year and a half before, and was quite univocally considered a huge failure. Yet, this is not the Bella Center but the historical building of Sciences Po in Paris, and instead of the 10,500 delegates of the initial event, almost 200 students are gathered here to re-enact the summit in a simulation process and to bring it to a new conclusion, hopefully a more ambitious one. [ii]

With my fellow companions observing the process, we had never seen anything quite like that. At some point, the level of engagement in the game had become so high that the frontiers between fiction and reality started to blur. Even our own role in that process was questioned that very night, when the crisis occurred. At first, it was a rather comfortable role: as a small group of artists and researcher from the Speap program [iii] – gathered under the name ***Save as Draft*** [iv] – we had proposed an observation protocol that could allow us to witness the ***translation of scientific objects into political objects***, as we explicitly aimed for. We had selected two participants of the simulation – one from the delegation of India and one scientist from the IPCC group – that we equipped with a sound recording device, following them with a Go-Pro camera and taking detailed notes about their every movements, encounters and discussion. Rather than documenting the process at large, we intended to be at the best position to observe how specific objects of the negotiation would circulate within this context, how they would be described and transmitted from a person to another, from a room to another, from a medium to another, and how they would progressively evolve and aggregate in that process, shrinking their way into the final draft of the resolution.

Since we also needed a fictional role, we were registered as journalists, entitled to circulate within all parts of the 3 floors building with a press badge. Inside our "headquarters", a small room equipped with computers, some of us would be permanently processing the material gathered by the "field" observers, sometimes exchanging roles. To be perfectly honest, I wasn't always totally comfortable during the three days of the event. The technicality of the matters discussed, even simplified for the purpose of the exercise, was challenging. Over the previous year, we had something like an accelerated training on the matter of climate change, both from some of the Speap guest lecturers and from the testimonies we had been personally gathering among scientists, negotiators and activists that had been involved in the real COP15 summit. In fact, every participant to this event had been preparing for a while, but in the end there was no preparation for the way things unfolded.

"We are all going to die!" If I recall correctly, the participant who pronounced these words was from the European delegation. It is now later in the night, and the whole situation looks transformed. The negotiation is on the verge of collapsing, and it doesn't look like a game anymore. "This is real, now!", tells me one of the coordinators of the Secretariat, as she prevents me from entering the crisis room were selected members of the delegations are now meeting. "No press allowed!" At first I simply don't understand what is happening, ***we were supposed to be observing the event and allowed to access all sessions, she has no right to block me!*** It will take me some time to realize that it is not just me and some others who are locked outside of the crisis room, but all of us, the 200 "players", who are now locked in this fictional space.

The "crisis", as it was later called, came from the fact that some among the participants had been doing their maths. Fittingly, it was the Indian delegate followed by Joffrey who first started redoing some of the calculations that had served as the basis for the simulation, soon joined by the IPCC member and a Venezuela representative. Trying to solve the challenge of both recognizing the legitimate "development" of countries of the Group 2, some of which are expecting a fast expanding demography, while keeping up with the reduction of greenhouse gases emissions to achieve the mitigation goals, had proved irreconcilable in their calculations. These were first made on a piece of paper, then repeated several times on the computer,

Figure 5.1: The emptied plenary session during the crisis of negotiation (Photo credit: Filipe Païs).

gathering new people around it as the problem started to spread, calling for new meetings, shattering all basic forms of consensus that had been patiently built until then, interrupting the drafting sessions, and even emptying the recreational screening of Yann Arthus-Bertrand's movie "Home" from all its spectators (see Figure 5.1).

Still following the Indian delegate, Joffrey had been allowed inside the crisis room with a selected number of participants. With the others, I ended up witnessing the "press conference" that was held later on. Radical measures had been proposed in order to preserve the possibility for an agreement to take place, and guarantee the necessary funds to avoid the worse effects of climate change. The delegates from the World Bank and the World Trade Organization (also represented among the participants) were even the ones to promote a tax on financial transactions! Despite these efforts, it was acknowledged that the 2°C goal could probably not be achieved, which meant, among other dreadful consequences, that the Pacific islands could not be saved.

Of course, this was only a game [v]. Still, it was quite striking to consider that this event, based on the basic parameters of the COP15 that took place a year and a half before, would end up concluding that far more important means were necessary to achieve a significantly less ambitious result. As disturbing was the feeling that this all started to look somehow closer to reality than maybe the actual COP15 summit had been. There was now a sense that this massive and ungraspable object, or "hyperobject" as Timothy Morton would call it [5], was becoming palpable within the building of Saint-Guillaume street. A sense that climate change was appearing not as a mere object of negotiation, challenging the geo-political distribution of powers as it was being staged, but as a true actor, taking control of the event from now on. Like a specter, whose presence had been slowly growing between these walls as its name was being repeatedly evoked, but that nobody expected to show up.

The closing assembly of the simulation was finally approaching, and with my

Figure 5.2: On the waters of the maelstrm, May 2014 (Photo credit: Teixido/Gamboni).

fellow companions we were expected to present a kind of performative feedback in that context. It had been a long night for everybody. After finally achieving a new agreement on the basis of the terms previously described, the delegations were now writing their final speech, which, in the case of the Pacific islands delegation, meant enacting their planned disappearance despite all the ambitious efforts conceded. I remember Joffrey and Simon in our headquarters, selecting the film footage of the exact moment when the first calculations were made that had led to the complete overturn of the whole process. I also remember Sandrine writing the text of our intervention, addressing this feeling of a new entity that had made irruption during the simulation. A “shapeless monster” was one of the terms she used.

On the moment, I am not sure that I entirely grasped what was at stake. Maybe none of us entirely did, in fact. Since then, many of the participants of that event, either the delegates or my fellow companions, have continued working on some of the environmental challenges of our time, including that of climate change. I wouldn’t call this experience a revelation in a mystical sense, but it was certainly a transformative one, and we left with the strong feeling that something more than a mere exercise had taken place that week.

5.3 Seismic Disruptions in the Subarctic Marine Soundscape

We had passed several times close to Henningsvær, while driving on the E10 that crosses the Lofoten archipelago from West to East, but so far we hadn't taken the bridge to join the little island. Henningsvær is one of the many typical little towns of the Lofoten, with its setting of colourful fisherman's cabins. It also hosts a couple of restaurants, a caviar factory transformed into a museum, an "Arctic tattoo" shop and, right next to it, the sign "Ocean Sounds" hanging over an office door.

Heike Vester is a German biologist specialized in the communication of marine mammals. Sandrine and I are sitting in her office, explaining like we always do the somehow unusual reason of our presence in the region: ***We are doing an investigation based on Edgar Allan Poe's short story called "A descent into the maelström" – yes, that one about the three fishermen caught in the whirlpool. We came here to collect testimonies and narratives that can resonate with this story, regarding how we can perceive environmental threats, how we can build knowledge in situation of risks. We chose this region because it is the place where the real "malstrøm" is located, but we're also interested in the current local struggles against the development of the oil industry. More broadly, any forms of environmental knowledge related to this border region of the Arctic is of interest for us.*** [vi]

Like most of the people we encountered previously, whether natural scientists, eco-activists, historians, fishermen or state officers, Heike Vester is very well disposed to share about her experience. She first came in the region in the late 1990s and soon decided to stay, in order to study the pilot whales and killer whales, two extremely social and particularly vocal species. Since then, she has been tracing the presence of these whales as they come to the region, attracted by the vast numbers of cods coming to the fjord to spawn every year. Equipped with a hydrophone and a sound amplifier, she goes on boat in the fjord and records underwater soundscapes, to later analyze the high frequency conversations of these marine mammals [vii]. But of course, along with the whales come many other noises, and the soundscapes of what appears as an ideal research field also testifies to the growing impact of human activities.

> – ***When you are out there, you record everything, you study everything. You can't just study one thing. Nature is not like that.***

It is by mere chance that we came to meet her. A couple of days earlier, we had finally decided to join a touristic boat ride to the Moskenstraummen, the actual "malstrøm" that inspired Edgar A. Poe. Although our main focus was to collect testimonies, we certainly had to visit the phenomenon at the origin of our investigation. The trip had been both deceiving and fascinating. A deep fog had started to rise as soon as we passed the village of Å, at the far end of the E10 road, to navigate alongside the ever wilder and craggier shores, closer to to the cliffs of Hellsegga. Once on the very spot, almost nothing was to be seen. The fog was complete, but it was also strangely bright, as if we were floating in a thick cloud of light (see Figure 5.2). It is precisely there, in the midst of this big nothingness, that they appeared, first as some elusive black shadows on the white sea, then more distinctly as the killer whales – four of five of them – started to emerge. They turned around our boat and then accompanied us, even on our way back to the village of Reine. It was a lucky encounter: we knew that we probably wouldn't have come to the office of Ocean Sounds if we hadn't meet them on that day.

> ***–You saw killer whales there? When ?***
>
> ***–A few days ago, it should have been on Tuesday...***

Heike seems surprised, she wants us to explain exactly where we saw them, even asking to see our pictures. She is increasingly worried by the disturbances affecting the whales. In the conversation that follows, many of our understandings of the current situation in the Lofoten will be challenged. She starts playing a recording. Distinctly, we hear the marine soundscape being disturbed by a deep tremor, repeating every 8 or 9 seconds, relentlessly. [viii]

> ***–When you're above water it's beautiful, silent, and then you hang in the hydrophone, and you hear... Right now, we hear a lot of the seismic shootings. Last week, we had three boats at the same time. And one is 500 kilometers away, the other 200, 300 kilometers away, and we hear it. And then the whales are gone...***
>
> ***–You hear the boats...?***
>
> ***–Seismic, for the oil. When they're looking for the oil, they use seismic air-guns. Seismic investigation. It travels for two thousand kilometers. And there's no regulation in Norway.***
>
> ***–But... Two thousand kilometers?***
>
> ***–Yes, it's the sea!***

On the moment, this information seems difficult for us to process. The petroleum controversy in the region, focusing merely on the local implementation of offshore extraction platforms, and distributing the main positions between the defense of or resistance against these implementations, first seem to prevent us from conceptualizing this new dimension of the problem. The moratorium preventing oil explorations in the regions of Lofoten, Vesterålen and Senja is still valid when we meet Heike [ix], but this is not sufficient, as these seismic shootings performed hundreds (even thousands) of kilometers away for exploration purpose already have a huge impact here, as these sounds testify. Together, they even constitute "a sound wall all along the coast of Norway" as Heike calls it.

> ***– So imagine, you come, you swim like you have always done, then you come to this area and you hear that sound. You don't know what it is, it could be an earthquake, it's such a high frequency, so loud. It's not a boat, they know boat noise, it's disturbing but they know it. Where does it come from, what is it? And it does cover communication, the same frequency is masking the communication of some of the whales and I see that they just go. Pilot whales, for the first time this year, they came and then after two days, they just left.***

Like Poe's character in the tale, who cannot convince his fellow fishermen to believe his story after he survived the maelström, Heike has difficulties in having other people listen to these sounds. She tried to contact Greenpeace and the WWF, but at that time they're already mobilized to protect whales in other regions and the Lofoten islands are not a priority. She has proposed fishermen to join her on her boat and listen to these sounds, warning them that their fish "stocks" might also soon be affected, so far without success. The perception that the area is protected is still largely spread.

> ***It's not protected, what are you talking about? You can't protect something that is already impacted! They keep going, but it's underwater. No one sees it, no one hears it. If I wouldn't be there with my hydrophone, no one would know.***

As it often happens, widely covered controversies tend not only to polarize the opinions, but also to flatten the complexity of the problem and to render invisible some of the practices and experiences that don't fit in this picture. In that context, restituting some of this visibility becomes part of the investigative task. At that time, we are only on the verge of starting to hear about many of the specific changes occurring in the region, many of which constantly challenge the scale and the territorial constraints of our investigation.

Following the different leads encountered, our investigation map gets progressively populated by new beings and new problematics: from the warming of the sea, which implies that possibly the cod spawning might no longer happen in the Vesfjord in the future, displacing the whole fishing industry up-north, to the contaminants that follow the streams up to the vulnerable regions of the Arctic, connecting both areas as a jointly strategic marine ecosystem; from the fishing villages displaced during the modernization period in the 1950s to the suppressed memories of the coastal Samí populations in the area, both of which carried a precious environmental knowledge that few persons can revive. In the end it wasn't one issue against another, but an entanglement of inter-related issues that the investigation allowed to start discerning [x].

5.4 An Alliance with a Ttree: Towards a (Situated) Anthropocene Atlas

The weather is clement for the season, which is twice fortunate. First, because it will facilitate the little investigative tour that I have planned for our London guests [xi], and secondly because the tree might even come into leaf today, which would be a perfect coincidence. We all stand underneath its branches, observing the buds while waiting for our interviewee (see Figure 5.3).

Exactly how old is that Horse Chestnut tree, no one knows exactly. Its observation started in 1929, when he was elected to succeed to its predecessor, thus becoming Geneva's third "Marronnier officiel " since the beginning of this local tradition in 1818. An important role for an important tree, as the day when it first comes into leaf officially marks the beginning of Spring. During all the winter, it is the responsibility of the Sautier of the Republic of Geneva to observe its buds as they start getting shiny, one of the signs that they are about to open. And when the first bud finally comes into leaf, the Sautier makes an official announcement and inscribes the date on a handwritten record.

Figure 5.3: Observing leaf buds on the official Horse Chestnut tree.

> ***–During this period I come everyday, it's on my way. I like to see the marronnier all the time, and see how he's doing, because he's getting old. These days, I even come in the afternoon, because by experience – I've been doing this for 16 years now–, by experience I know that when the sun comes out in the afternoon and when it's warm like today, the bud might open.***

Maria Anna Hutter is the 70th Sautier of the Republic, and the second woman at this very special position since the 15th century. She enjoys evoking her relation with the aging marronnier, which is now leaning over the promenade's fence, over the road and the University park des Bastions, partly sustained by a large triangular metallic support. At our request, she accepts to show us the handwritten records of all previous dates of leafing, which is kept in a glass safe box in one of the assembly rooms of the Grand Council nearby. Inside the box, the old parchment, fixed on a large slice of wood, has been extended by a second piece of parchment on the verso. Looking at the dates on the first side – mostly covering the 19th century – and then looking at the more recent ones, certainly offers a striking contrast. On the recto, mid March to mid April is the dominant period during which the trees come into leaf, while on the verso, it rather spans from mid February to mid March, sometimes even in January. Once, the buds even opened twice, starting in December: that was in 2002, the year before the memorable summer heatwave that, according to the evaluations, caused the death of around 70,000 persons in Europe [xii].

The official horse chestnut tree, a witness of climate change? After all this is not surprising: why wouldn't the tree be affected by the evolution of its life conditions? Climatologist Martin Beniston, that we meet later that day, made a study in 2014 [6] where he compared the evolution of climate in various cities in Europe, witnessing not only the general warming trend that have been both modeled and observed, but also considering the displacement of the average climate characteristics (temperature, humidity, etc.) from a region to another. This "climate analogue" study showed a displacement of climate of 15 kilometer per year, highlighting that Geneva now has the climate of Toulouse in the 1950s, while Toulouse inherited that of Madrid in the 1950s. Certainly, it is no wonder that a tree planted in Geneva, growing in Toulouse and then heading towards Madrid would face some difficulties in adaptation. And if you add the other factors such as the impact of urbanization, or the spreading of diseases facilitated by global warming, it gives an idea of the stress imposed on ecosystems. We share the chestnut tree's record with the climatologist, who validates it as a potentially valuable climate indicator [xiii].

> –***This is the strongest warming yes, it was already in February, in fact even in January! Amazing... In fact we – I mean the climate community – we use different sorts of indicators when we want to reconstruct past climates, before the time when we had instruments to record directly. And these sort of indirect indicators of changing climate can be extremely valuable. Your tree is a valuable indicator.***

In the afternoon, our little group joins the lake. Close to the touristic site where the Geneva water jet is located, yet much more discreet, stand two erratic blocks emerged from the water called Pierres du Niton. It is said that they were involved in some local rituals in pre-modern times, as some inscription on the stones might attest, and later they were used as altimetric reference for Switzerland. More generally, these boulders were some of the first clues attesting that the climate could evolve over the ages, as remnants of a time when the region was buried under 700 meters of ice. When the Rhone glacier progressively retreated, some of the blocks carried by the ice stayed, puzzling the observers and giving birth to numerous local legends. ***What about our own "erratics"? What are they going to be in the future?***, asks London-based artist Neil Cummings who is part of the tour. This question perfectly sets the tone for the investigation that will later unfold, attempting to build an anthropocene atlas that would be specifically related to the region of Geneva [xiv].

Two days after our visit, the ***marronnier officiel*** came into leaf. One year later, he died. Apparently, it was a mushroom attack along with a butterfly parasite that killed it, both of which are now fast spreading with the warming climate, threatening all the horse chestnut trees in the region. A fourth official tree was elected. It is still a ***marronnier***, but the city's green service confirmed: one day they will not be adapted anymore, and a new tree species will have to be chosen.

5.5 Concluding Remarks

> ***We should bring back to earth and reclaim everything that our lives are suspended on, and that ceaselessly tends to escape us. What we prepare is not an assault but a movement of continuous substraction, the attentive, soft and systematic destruction of all politics detached from the sensible world*** [xv] [7] Julien Coupat & Eric Hazan.

While the scenes previously described each call for their own conclusions, some joint considerations can retrospectively be drawn. What becomes apparent is that specific conditions are necessary for an encounter to take place, although these encounters are of a different kind. The carefully built simulation event in Sciences Po, involving the strong engagement – also in terms of emotional engagement – of its participants, was necessary. So was the failure of the initial process, that forced them all to derail from the planned scenario, moving beyond the mere exercise and thus building a stronger relation to the current issues at stake. Similarly with Heike Vester and Maria Anna Hutter, their carefull observations of the whales and of the horse chestnut tree both require precise procedures that allow them to record that something else – something unexpected – is happening, and the high level of dedication necessary to sustain day to day relations with these beings certainly raise different affects in this prospect.

In terms of being affected, my own position is particular. It isn't equivalent to that of the students participating first-hand to the simulation, or to Heike Vester and Maria Anna Hutter doing daily observation on a tree or in a fjord. Still, what I experienced wasn't a mere transmission of information. I might say that for me these encounters happened also ***as a sensible experience*** of sharing knowledge in the context where it is produced, and ***in the company*** of those who allowed it to be experienced, leaving me reliant on their contribution. In fact, it is something that we have often been discussing with Sandrine in the course of our investigation ***A tale as a tool***: the manner in which every person that we meet can operate for us as a guide, like the fisherman leading the narrator on the mountain in Poe's tale, sharing not only their stories but also contributing to stage the necessary conditions for a certain transmission of knowledge to happen. And these situations, along with the affects that they mobilize, are about as important as the stories themselves.

This process obviously relies on the context of the investigation itself, which encourages these forms of encounters. The notion of serendipity, described by Sacha Kagan as a "walker's wisdom" [8], emphasizes the necessary movement that puts us ***in contact*** with unexpected issues and beings and allows them to change our perspective. It requires a certain of ***disposition to attentiveness*** – something that Ana Lowenhaupt Tsing termed the "arts of noticing" [9] – and doesn't proceed from a predatory logic of coining down these issues and beings and capturing testimonies, rather favoring the possibility for them to step on our way while acknowledging their ability to somehow enlist us.

This is what happened in the Lofoten archipelago: after all, it is the killer whales who first burst into our investigation. This presence in itself was not sufficient, for we lacked the ability to interpret its importance, which is what Heike Vester then provided. Sandrine and I were always struck by the way the biologist, while describing how the whales are affected, was in fact repeatedly putting us in their position: "So imagine, you come, you swim like you have always done, then you come to this area and you hear that sound..." Both in that process of imagining (and sharing) the perspective of the whales themselves, and in her attempt to advocate for them by enlisting the fishermen and other actors in their defense, she perfectly plays the role of ***spokesperson*** proposed by Bruno Latour and Michel Callon [10]. And although we meet her at a time when her calls are still mostly unanswered, which makes her testimony even more striking, that situation will progressively evolve.

More could be said here about how the "voices" of non-human beings can be heard, and the official chestnut tree is a good example. I mentioned its potential role as indicator, but surely it does more than that. The ***marronnier officieel*** does more than just attesting what phenology and other methods in paleoclimatology mentioned by climatologist Martin Beniston – such as the famous ice core samples extracted from the ice sheet – already provide in a more extensive manner. In fact, what stroke me with the ***marronnier*** is precisely the fact that its budding record wasn't meant to serve for a scientific purpose. The effects of socially-caused global environmental changes, appearing in the midst of a local tradition already weaving nature and culture in an interesting fashion, then gave it a quite different take. Although the ice samples require very careful and precise procedures, they are still for many of us distant features, we may care for what their analysis tell us but we don't ***care for them***, at least not in the way that we can care for a particular tree, and for a particular tradition. Maybe this is what making an alliance with this tree – as well as with the whales and many others – suggests: that building relations with other beings, developing narratives that bind us with them, gives us a sense of what it means when they are affected, for we know that we ultimately share a common fate.

I already mentioned the risk carried by highly covered controversies to flatten the complexity of the issues encountered in an investigation process. But that could also be said of many kinds of dominant representations and ideologies – progress and globalization being not the least – that operate in that con-text as powerful attractors [xvi]. They render invisible issues, practices, histories, they render invisible the countless beings and their world-making projects [9] that are stranger to their logic. We might call them ***attentional attractors***, selecting the things we look at, as well as the way we look at them. It is always crucial to find ways to drift from these magnetizing forces, here joining voice with Yves Citton while calling for an ***ecology of attention*** [12], in a necessary attempt to regain a certain power on our attentional environments. This has been an important concern driving the realization of The Anthropocene Atlas of Geneva [xvii] during the past two years, as the interviews were not only focusing on mere "testimonies", but rather on the very capacity of each actor to produce representations that may challenge the very perception of our own investigation field. That is: to produce other ***attentional gestures*** [13].

In the case of A tale as a tool, the investigation process as defined with Sandrine, is also meant to keep this necessary openness. Indeed, we don't come to a region claiming straight ahead to investigate (for instance) the oil controversy and climate change effects. Instead we come with a heterogeneous object, a text of fiction, that the persons we meet can interpret in their own fashion, while being invited to relate it to their own practices, knowledge, and matters of concern. In that process, Poe's fiction of the maelström operates as a mediator object in our investigation, that allows for a certain encounter to take place. We might say that it also works as an attractor, but as a soft one: one that can be handled and re-appropriated by the people we meet, one that allows for a certain symmetry in the transmission of knowledges – while sharing stories on both sides–, and finally one that shouldn't overshadow the set of entangled relations that it is meant to both discern and enhance. In a different understanding of the term coined by Fredric Jameson, we might call this a "vanishing mediator" [14], as it gathers people around this new object while shifting the usual perspectives, before eventually fading out and letting room to the matters of concerns expressed and the new assemblages produced.

Yves Citton once highlighted the polysemic richness of the expression in French ***faire attention*** (Citton 2017), which isn't exactly equivalent to "paying attention".

Faire attention à means "to be attentive to", which is understood here as an active process (literally "making attention"), but it means as well "being careful of" and "watching out". The ***arts of noticing*** are not only a practice of observing and acknowledging the existences of other entities and their ***world-making projects***, it is also a practice of care and a call for prudence. For we shouldn't ignore that the modernization front keeps on advancing, brought to an accelerated and hyperbolic dynamic by the predatory logic of advanced capitalism, and threatening the relations with everything that sustain our very existence. Resisting the "upcoming barbary", as Isabelle Stengers summons us [3], first of all means enforcing the nets of solidarity relations that sustain life in all its forms. In this regard, whether we focus on the agency of non-human beings, or on the practices that participate in translating it and making it visible, anyway we get back to the fact that deep environmental mutations are occurring, and that in the perspective of becoming sensible to these changes, all voices are necessary and all translations welcome.

Notes

i. Both of these authors obviously refer to the "Gaia theory" developed by chemist James Lovelock in the 1970s.

ii. Initiated by Sciences Po Paris and IDDRI (The Institute for Sustainable Development and International Relations), this event was entirely self-organized by the students of Sciences Po in June 2011, under the title "COP RW - et si ça s'était passé autrement?". We might call this a kind of role play, or a simulation, as it is being occasionally organized by associations related to the United Nations. For more information on the subject, see the article by David Goutx in the journal Négociations (2014): https://www.cairn.info/article.php?ID_ARTICLE=NEG_022_0017

iii. The program SPEAP – Master d'Experimentation en Arts Politiques, was launched at Sciences Po Paris in 2010 by philosopher and anthropologist Bruno Latour and co-directed by Valérie Pihet, gathering artists and researchers to experiment various forms of collaborative investigations. Link: blogs.sciences-po.fr/speap

iv. When it officially recognized itself as a collective, Save as Draft included Joffrey Becker, Axel Meunier, Sandrine Teixido, Simon Ripoll-Hurier and myself. At the time of the simulation, it also benefited from the contribution of Sylvain Gouraud, Filipe Païs and Eléonore Saintagnan. The contribution of Save as Draft to the simulation "COP RW" was part of the commissions proposed to the participants of the SPEAP program. It led to two performative interventions: the first one during the opening session of the simulation, based on interview material with scientists and negotiators who had taken part to the actual COP15, and the second one during the closing assembly, based on documents from the observation.

v. If we wanted to draw conclusions regarding the actual negotiation process, the outcomes of this exercise would prove quite limited since the goals, the complex calculation models, as well as the practical means at disposal were here highly simplified.

vi. A tale as a tool is a project of art and research developed since 2011 with anthropologist and author Sandrine Teixido. It led to numerous investigations, from the South of Brazil to the North of Norway, partnering with artistic and academic institutions and involving frequent collaborations: www.ataleasatool.com

vii. To know more about the research activities of biologist Heike Vester: https://ocean-sounds.org

viii. The sound can be heard on the website of ***A tale as a tool***: https://ataleasatool.com/document/sons-seismic

ix. This moratorium, acknowledging the resistance of the local populations and the vulnerability of the marine ecosystems, was first planned until 2017. Despite the frequent attempts by the ruling conservative party (***Høyre***) to cancel it and the ***Arbeiderparti***'s turnaround on the subject, the status quo is still valid today, although it remains fragile. In the meantime, oil exploration and extraction is being performed along all the other coasts of Norway.

x . Among other public events (exhibitions and conferences), this investigation maping process has been narrated in the series of performances ***MALSTRØM 68N: An inaccessible place*** at Théâtre de l'Usine, Geneva, in June 2015.

xi. This guided tour that I organized was part of a Seminar from the Pre-Doctorate /PhD series hosted by CCC Research-Based Master program at Geneva School of Art and design in March 2015. Involving a partnership with Chelsea College of Arts, University of the Arts London, this specific Seminar was also meant as one of the preliminary events to the research project The Anthropocene Atlas of Geneva (see note 14).

xii. For a more detailed report on the complex methods to evaluate the casualties provoked by this extreme event, see the report directed by INSERM for the World Health Organization "Improving Public Health Responses to Extreme Weather/ Heat-Waves – EuroHEAT": www.euro.who.int/_data /assets/pdf_file/0018/.../E91350.pdf

xiii In addition to global warming, other factors like the city's "heat island effect" might be taken into account to explain the evolution of the buddings, although in Geneva's context it is not expected to be a decisive factor.

xiv. The research project The Anthropocene Atlas of Geneva, supported by the Swiss National Fund for scientific research, was conducted at Geneva School of Art and Design from December 2016 to November 2018. The project director was Prof. Gene Ray, and the field researchers were Janis Schroeder, Kathleen McHugh Stevenson and myself. Its findings can be consulted here: https://head.hesge.ch/taag

xv. The translation is mine.

xvi. Central to the studies of dynamic systems and chaos theory, the notion of "attractor" has been recently borrowed by Bruno Latour in his book Où atterrir? [11], where he proposes to map the re-distribution of the main political positions, in regard to the crisis of the modernization discourse.

xvii. See note 14.

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About the Author

Geneva-based artist **Aurélien Gamboni** develops a practice of investigation, often involving field research and collaborations, and leading to multiple forms of installations, texts and lecture-performances. After having developed a long-term inquiry on The Conjurer by Hieronymus Bosch and the “ecology of attention", he is currently leading with Sandrine Teixido an investigation on Edgar Allan Poe's “maelström" and the cosmopolitics of nature, a multi-site inquiry taking place between Europe, Brazil and the United States. **Aurélien Gamboni** is a former curator of Forde independent art space (2006-2008), he took part in the artists and researchers collective Save as draft (2010-2012), and contributed as scientific collaborator to the SNF research project The Anthropocene Atlas of Geneva (2016-2018) at Geneva School of Art and Design (HEAD), where he currently teaches.

He took part in numerous exhibitions worldwide, including:If It's A Bird, Shoot It!, Sculpture Center, Long Island city, NY, 2008; The Big Picture, Tanya Leighton Gallery, Berlin, 2009; Weather Permitting, 9th Mercosul Biennial, Porto Alegre, 2013; Voglio Vedere le Mie Montagne, Museo MAGA, Gallarate, 2015; Guanabara Bay: Hidden Waters and Life, Museu de Arte Contemporânea, Niterói, 2016; A tale as a tool, Centre de la Photographie Genève, 2017; Eblouissements, 5th Biennial of Lubumbashi (DRC), 2017. He was awarded a Swiss Art Award in both 2011 and 2016.

CHAPTER 6

Relationship of Airports, Population, Competitiveness Indexes and Human Development with Confirmed and Deceased Cases by COVID-19: Need for Transdisciplinary Systemic Decisions

C. Hernández-Aguilar and A. Domínguez Pacheco

In the face of the global crisis as a result of the COVID-19, with more than a million cases confirmed today, it is necessary to make the best decisions by world organizations, governments and authorities in nations, localities, families and individual level, etc. for survival and reduction of pain and uncertainty. In this way, the relationship of some variables with confirmed cases and deaths could be useful for decision makers. In this study, it is proposed to relate variables such as human development index, population quantity, area, competitiveness index and number of airports (including airfields and flight paths) of 14 countries in the region of Asia and 24 in the Americas.

The statistical method used for analysis was Principal Component Analysis, PCA. According to the evaluated variables, it was found that for the countries of Asia and the Americas; the variables with the highest correlation ($R > 0.96$) with the number of confirmed cases and deaths are the variables of population and number of airports (including airfields and flight paths). For both Asia and the Americas, there was a positive correlation between the number of confirmed cases and deaths and the competitiveness and human development index. The correlation of these variables is lower for countries in the Asia region with respect to the Americas. On the other hand, it was found second fortnight of March had drastic changes in the rise in the number of confirmed cases and deaths, as well as in the spread of contagion in more countries. It is interesting to become aware of the impact of individual or local decisions on what can happen in a devastating way in the world. In this way more than ever systemic decisions are necessary for the future and survival of humans.

Keywords: Systematic decisions, number of airports, confirmed cases with COVID-

19, principal component analysis, variable correlation.

6.1 Introduction

Faced with the current problem of COVID-19 disease, where man is in terrible vulnerability, impotence and lack of knowledge; as well as human pain and poly-crisis, among other the economic and social. More than ever, learning to decide systemically is required, and awareness of how individual or group decisions can lead to a global crisis. An event that occurred in a market of the Hubei-Province, specifically in Wuhan city, at last December, caused the appearance of pneumonia cases starting with seller's pneumonia on December 8, 2019 (Cossarizza et al., 2020; Who-Report 1, 2020) [1-2]. As of December 31, it was reported to the World Health Organization (WHO), and in this way an outbreak began, which was declared by this organization as pandemic on March 11, previous declaration of January 30 as an epidemic and a public health emergency of international concern (WHO-Report 59, 2020) [3].

Perhaps within all this tragedy unprecedented in the history of humanity, one could reflect on an urgent need for man to modify his way of deciding. It is necessary to walk towards what would be systemic-transdisciplinary decision processes, to propose the various alternatives towards the best ways of solving real-world problems [4-7]. This 2020 pandemic started with individual, group, and local decisions, and had repercussions at the planetary level. Three months after the outbreak began, it spread to almost 181 countries worldwide with 1,013,157 confirmed cases (UJH, 2020-April 2) - [8]. It is when one observes the complexity of the systems, and their perfect interconnection of everyone with everyone and the repercussion of individual or group decisions with a whole, regardless of the kilometers of distance to which the decision maker is.

It is necessary to rethink, how are decisions made? Under what holistic awareness of the impact is decided on a day-to-day basis or about the consequence of the decision in the future? What would be the impact on the different systems? Right now; what you are deciding to do, deciding to think, deciding to buy, deciding to sell, deciding to say, deciding to feel, deciding to invent, deciding to have, proposing, etc. Do you think about your consequences?

Focused on who we decide, in ourselves or in others, in economic interests or in man. On what or who do we base our decision? And, as the individual decisions, it can affect the other (close), the other (distant) and the other (environment). In this study, some characteristic variables of 14 countries in Asia and 24 in the Americas are related to the number of confirmed and deceased cases as of March 29. Discussing some aspects related to the importance of systemic decisions, in case of decisions of the COVID-19 pandemic problem that is experienced globally.

A global problem, such as the one experienced, has multiple impacts, but especially life and death, due to the disease itself or the problems associated with the pandemic. In general, it could have repercussions and impacts on the near or distant future in different dimensions of life; to country level or the industry, economically level, educationally, nationally, to emotionally level, mental health, etc.

This event has shaken the world, where decisions are relevant within each country, within each state, each community and each individual. In this way, adopting systemic transdisciplinary approaches is the way to make the best decisions. It is useful to use methods that help visualize multivariable problems to assess the relationships of variables and support decision-making.

Etymologically, deciding comes from the Latin decidere, cut, 'decide, resolve'. So today decision makers have to "solve" a problem. For which to have more analysis of variables, in this case correlations of variables related to the confirmed cases with COVID-19 and number of deceased could support to continue adding elements that allow better decision and to move towards transdisciplinary systemic decisions (TDSD) where the one that makes the decision, the executor of it, i.e. the decision maker is of vital importance: his values and conscience, his self-investigation and his self-transformation towards a systemic thought is essential. In a systemic crisis, systemic decisions are required and for systemic decisions, a TDS focus on the decision maker or group of decision makers helps.

6.2 Materials and Methods

In this study, 24 countries in the region of the Americas (USA, Canada, Brazil, Chile, Ecuador, Peru, Mexico, Colombia, Panama, Argentina, Costa Rica, Uruguay, Dominican Republic, Venezuela, Honduras, Bolivia, Jamaica, Paraguay, Guatemala, Trinidad and Tobago, Barbados, Haiti, El Salvador and Nicaragua) and 14 of region of Asia (China, Republic of Korea, Australia, Malaysia, Japan, Philippines, Singapore, New Zealand, Viet Nam, Brunei Darussalam, Cambodia, Mongolia, Lao People's Democratic Republic, Fiji and Papua New Guinea) were characterized by confirmed cases with COVID-19 (CC), total deaths (D) (as of March 29), human development index (HDI), population, area, competitiveness index (CI) and number of airports (included airfields and runways) (NA) according to data from the World Health Organization, the United Nations, World Economic Forum, and the US Central Intelligence Agency (WHO-Report 69, 2020; UN, 2020; FEM, 2019; ACI, 2013) [9-13].

6.2.1 Statistical Analysis

The principal component analysis method was applied, where the percentage variability explained by each component were determined (Tadesse and Bekele, 2001) [14]. Variable correlation circle and factor map where clusters are formed using software R, R commander and FactoMiner (R Commander version 2.6-2) and Fitopac (version 2.1).

6.3 Results and Discussion

The countries formed various clusters based on their behavioral similarities in the evaluated variables: confirmed cases, death quantity, human development index, population, area, competitiveness index and # of airports (included airfields and runways). In the case of 14 Asian countries, three clusters were formed (Figure 6.1a): 1 (Philippines, Viet nam, Cambodia, Mongolia, Lao People's, Democratic Republic, Papua New Guinea), 2 (Republic of Korea, Australia, Malaysia, Japan, Singapoure, New Zealand, Brunei Darussalam) and 3 (China). Cluster 3 is characterized by the highest values in relation to confirmed cases, deaths, population and airports (Included airfields and runways), which is distant from the other countries represented by the distance of its representation in main component with respect to

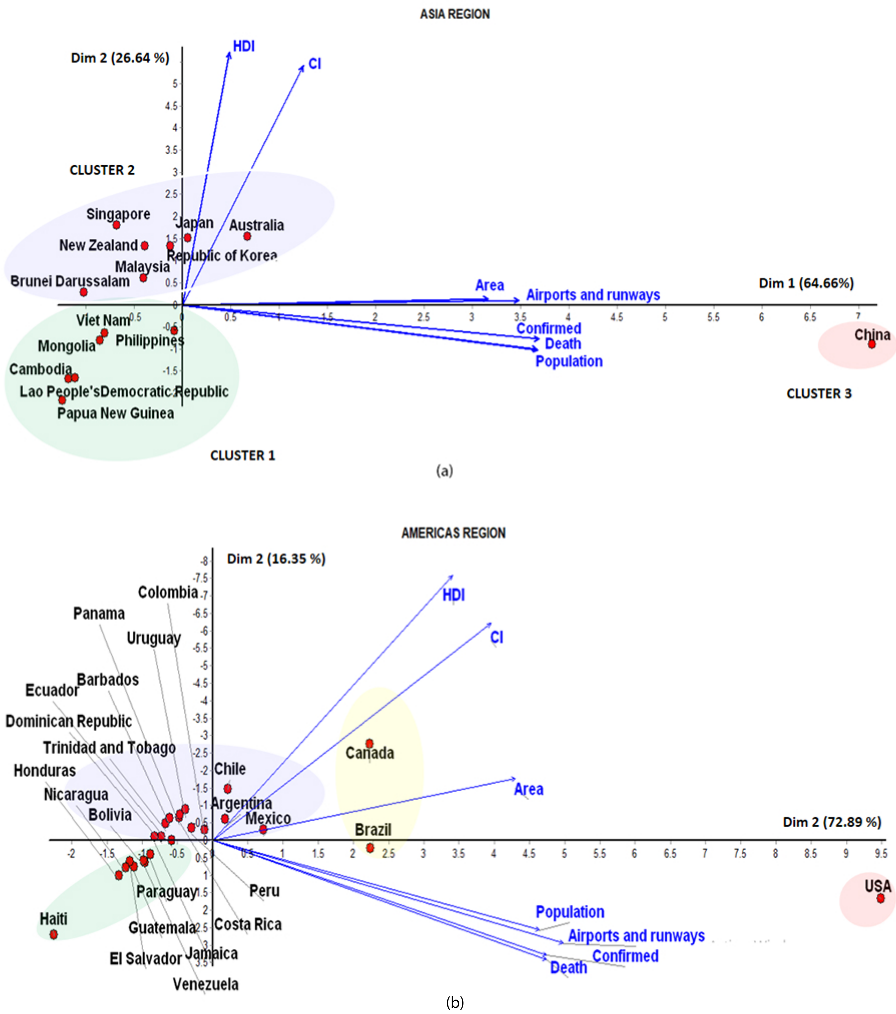

Figure 6.1: Superposition of variables and clusters formed according to behavioral similarities of variables: confirmed cases, deaths, human development index, population, area, competitiveness index and # of airports (Included airfields and runways), a) Asia region and b) Americas region.

the other points of the other countries having the lowest values: the countries that make up cluster (1). Cluster 2 is characterized by the highest rates of human development index and competitiveness. Cluster 1 is characterized by the lowest rates of human development index and competitiveness.

In the Americas region, the 25 countries formed four clusters (Figure 6.1b): 1 (Venezuela, Honduras, Bolivia, Paraguay, Guatemala, Haiti, El Salvador, and Nicaragua) 2 (Chile, Ecuador, Peru, Mexico, Colombia, Panama, Argentina, Costa

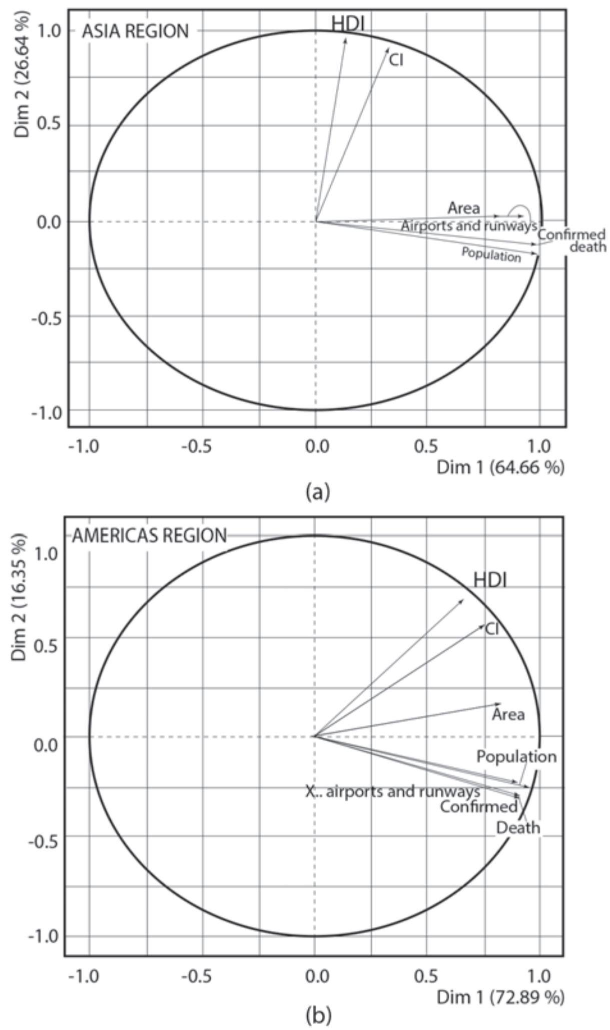

Figure 6.2: Variable correlation circles (a) Asia Region, (b) Americas Region

Rica, Uruguay, Dominican Republic, Jamaica, Trinidad and Tobago and Barbados), 3 (Canada and Brazil) and 4 (United States of America). Cluster 4 has the highest values of the variables CC, D, NA. The countries with the lowest values in these variables were those that make up cluster 1.

Figure 6.2 presents the circle of correlations of the variables evaluated in this study, where it is possible to observe that for the Asia region (Figure 6.2a), there is an absolute positive correlation (Angle formed between them is less than 15°, so the $\cos\Phi > 0.96$-1, where Φ is the angle formed between the two vectors of the correlated variables) between the variables confirmed cases and number of deaths; with the variables of population, number of airports and area of the country.

A moderate positive correlation ($R = \cos\Phi > 0.50$) was found between confirmed and deceased cases with the human development index and the competitiveness index. In this region all these variables are correlated. It is necessary to point out a strong correlation between confirmed cases of COVID-19 and the number of airports.

In the Americas region, the number of airports and the number of population are the most highly correlated with the number of deaths and confirmed cases (Figure 6.2b), it can be seen the vectors that represent the variables CC, D and HDI and CI forming an angle less than the formed with the other variables (NA). It is possible to mention that in the Americas region the correlation between CC and D is higher than in the ASIA region, where it is an absolute correlation.

It could be visualized to support decision-making, which is the variable most correlated with the problem in cases of cases confirmed with COVID-19, which for both cases is the number of airports. This type of mobility that allows people to be transported from one place to another could contain populations infected with the SARS-CoV-2 virus or sick with COVID-19. This has worsened since an outbreak in one locality turned into a pandemic. Decision makers take on relevance in this spread of the disease since perhaps it could have been stopped by having a systematic vision.

The SARS-CoV-2 virus is infecting more and more populations, and currently there are no treatments or vaccines. Although infection does not lead to serious illness for many people, around 10-20% of infected people need hospital care (Robert Koch Institute), it is collapsing the hospital system in different cities around the world (Muller *et al.*, 2020) [15]. So the best decisions must be made for the benefit of the populations in the world. In addition, today more than 30,000 deaths and thousands of people with pain and panic in different countries, etc. Systemic decisions to avoid impacting so many human lives, it is necessary, a change of focus towards transdisciplinary systemic decisions would be indispensable.

Since the international emergency was announced on 30, January to decision makers, they would have been supported by a systematic TDS approach. Because there is no vaccine for this new virus that causes harm and death, it is important to take appropriate action at points of mobility. This study demonstrates the absolute correlation between the number of confirmed COVID-19 cases and the number of airports. In fact, one of China's radical measures was lockdown of Wuhan on Jan 23, 2020, and suspended all outgoing tour groups beginning Jan 27, 2020 (Pung *et al.*, 2020) [16]. Despite these measures, many travelers had already left and the great spread that is today occurred.

Right now, we should learn about the main strategies that have been successful for the countries that are having greater control over this problem, such as Korea, Japan, a single population in Italy, etc. This means that the decision maker with a transdisciplinary systemic approach would also have to see how the problem is addressed in the real world by other decision makers. Changes regarding the number of countries infected were growing rapidly, as well as the number of confirmed people and deaths. The global interconnection allowed rapid expansion due to being a type of virus that is so easily spread from human to human (Bernheim *et al.*, 2020) [17]. Systemic decisions that also involve anticipating what may happen are required. In the case of Lombardia, Italy decision makers implemented measures to limit viral transmission – including restricting movement, despite imposing strong decisions on March 8^{th} (Remuzzi and Remuzzi, 2020) [18], perhaps those should have been made earlier.

A rethinking of decision making and its modification is necessary. Future generations would be wise to train in a type of systematic transdisciplinary decisions, for the survival of the human species. A challenge for the following years in the training of children and young people, future decision makers. Who will pass after pain some of them in an evolution of thought.

Callaway (2020) [19], published in Nature and warned that the disease was becoming unstoppable, when it spread at 100 countries, and more than 100,000 infected people. A systemic approach could help, as it will stop if interconnectivity does not stop in the world. So decisions that involve stopping interconnectivity also have consequences, but evaluating the best alternatives is necessary and still remains necessary to stop this pandemic but make them under the TDS approach.

Figure 6.3a shows the six clusters formed by behavioral coincidences of the analyzed variables: number of confirmed cases, number of countries where the virus spread and number of deaths. The first Cluster is formed by the behavior of the variables in December (15-31) and January (1-15): the changes were abrupt every 15 days, having the most drastic as time progressed in the three variables analyzed by period of time. The highest changes being in March according to the period of time analyzed in this study. Figure 6.3b shows the absolute correlation between the number of confirmed cases with disease and the number of deaths.

The numbers of confirmed cases varied, as of the first half of January, there were 46 cases, but it took another 15 days to increase the number of confirmed cases. On January 23rd, the United States reported the first case of covid-19 disease and it spreads to Europe on January 25th, with the first cases being reported in France (WHO-Report 5, 2020) [20]. Subsequently European countries that confirmed cases with covid-19 were Germany, Finland and Italy (WHO-Report 8, 2020) [21]. At the end of January, 11 days after starting the World Health organization the case reports, the spread of the virus went to 19 countries, outside China, with a confirmed number of cases of 9 826 (WHO-Report 11, 2020) [22], of which 2.16% (213) died.

In the month of February, the number of confirmed cases increased more than eight times, from those that existed in January; amounting to 85 403 with 3.42% of deceased (2 924). However, the worldwide status of confirmed cases with COVID-19 changed surprisingly in March. At the first half of March, there were 153 517 confirmed cases and at the end of the month it reached more than half a million confirmed cases with COVID-19, with a total of infected countries of 183. The intuitive vision of the systemic decision-maker is essential. As well as, attend to what is reported regarding future problems. In the case of the present pandemic, it had been mentioned before that the environmental changes and constant contact of humans with zoonic organisms could result in transmission between species and human diseases (Becker *et al.*, 2008) [23]. Even, some authors considered was the

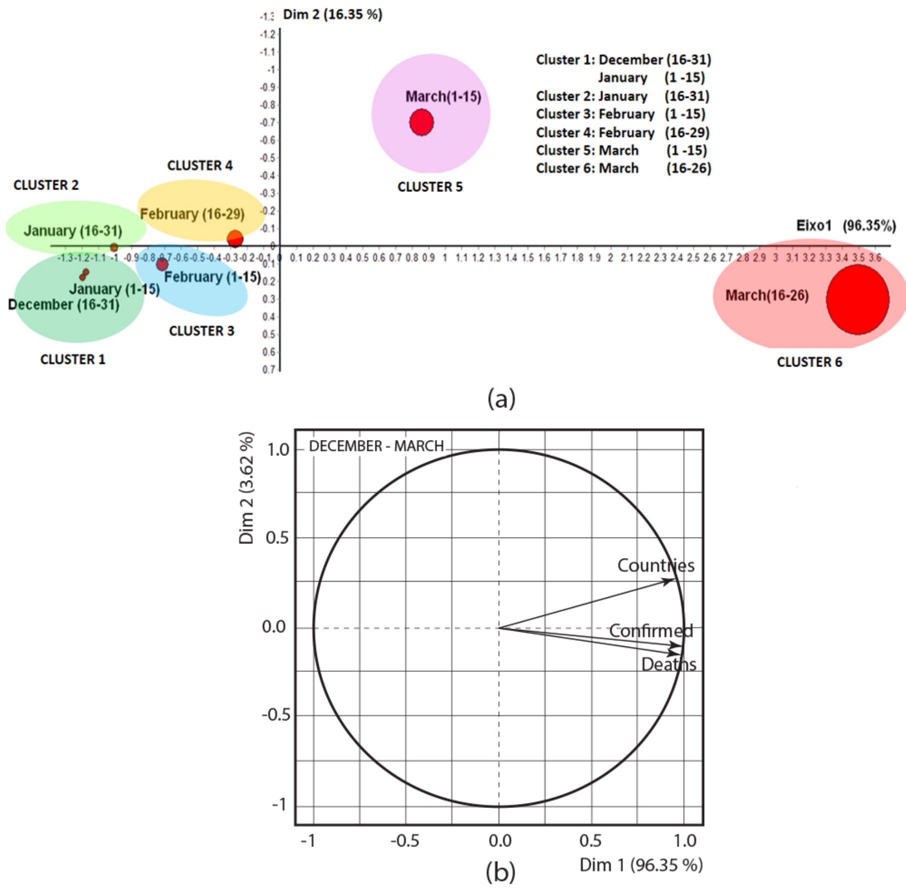

Figure 6.3: Superposition of variables and clusters formed according to behavioral similarities of variables: confirmed cases, deaths, human development index, population, area, competitiveness index and # of airports (Included airfields and runways), a) Asia region and b) Americas region.

emergence of SARS-CoV heralded a new era in the transmission of severe respiratory illness, which could be of rapid spread around the world due to the globalization with great massive economic impact (Peiris *et al.*, 2004; Menachery *et al.*, 2015) [24-25]. Of course, the impact is being today in different dimensions, not only the economic one.

Figure 6.3. Relation of confirmed cases of covid-19, number of countries where it has spread and number of deaths per day (March 26, data obtained from the WHO-Reports 1-69, 2020) a) Clusters for time periods (December-March), b) circle of correlation of variables.

On the other hand, Pung *et al.* (2020) [12] indicated that SARS-CoV-2 is transmissible in community settings, and local clusters of COVID-19 are expected in countries with high travel volume from China before the lockdown of Wuhan. The respective mobility points, such as airports, must have adequate control and measures.

Decision makers have an essential role in proposing the necessary strategies in the entry and exit points, as can border, maritime and land points, in a need to keep posing to control an outbreak. Each country must have a preparedness, alert and response plan (WHO, 2000) [26]. Preparedness is a combination of activities started before a crisis occurs and its objective is to create infrastructure and empower public health workers (Moradi *et al.*, 2020) [27]. It is really far-sighted what Korea did, four days after the notification of new cases in china, decision-makers in Korea started screening and quarantine plan at the airports. Future vision is one of the characteristics of the systemic decision maker. Among many other established strategies, that despite being one of the first infected countries, to date they reach a total of 10,284 confirmed cases and 184 deaths. In comparison, for example with countries such as the United States, in the Americas region, where it was also one of the first infected, but today the number of infected are 367 507 with number of deaths of 10 980 according to the University of Johns Hopkins (April 6, 2020) [28].

In this way, knowing the history of the problem and its evolution, as other countries that have already experienced similar problems are solving. It is part of the transdisciplinary systemic vision that could help decision makers of the governments of various nations. Some patients started in December in Wuhan, later it is observed (Figure 6.3), that behavioral changes reflected by the different clusters formed started in just 15 days of difference. Clusters were formed due to the similarities between variables of confirmed cases, deaths and number of countries infected.

According to reports from the world health organization; after Wuhan the Chinese provinces affected by the virus were Guangdong, Beijing Municipality and Shanghai Municipality. Later it happened in other countries such as Thailand, Republic of Korea and Japan, which are countries located a few km from the epicenter of the epidemiological outbreak. Regarding the number of confirmed cases, the WHO started the reports on January 20th, 2020, where a total of 258 cases were located in the Chinese provinces and a single case in the neighboring countries (WHO-Report 1, 2020) [2], not yet there were reports of deaths at that time. But at 31 January, there were already 10,000 cases, which 106 Outside of China in 19 countries. It began to spread uncontrollably (WHO-Report 11, 2020) [22]. The United States began implementing public health entry screening at 5 major airports as of January 23rd (Din *et al.*, 2020) [29]. In February, 59 airline companies suspended or limited flights to Mainland China and several countries including USA, Russia, Australia, and Italy have also imposed travel restrictions (Chinazzi *et al.*, 2020) [30. However, to date it has not been enough, to stop the pandemic.

Although on a small scale, there have been decisions by authorities that have managed to contain the disease. In Vo'Euganeo, 50 km west of Venice, the authorities made the strategic decision to close the town of 3,000 people in mid-February. They applied RNA tests to the entire population, those who tested positive were quarantined, the number of people suffering from covid-19 decreased from 88 to seven in less than 10 days. Sergio Romagnani, a professor at the University of Florence, said that, in this population, most people infected with covid-19–50-75% - were asymptomatic, but represented “a formidable source" of contagion (Day, 2020) [31]. The decisions of the decision makers were immediate and radical.

Therefore, there are populations where tests are not applied to most of the pop-

(a) (b)

Figure 6.4: (a) Global cases in the world according University Johns Hopkins (March 28) and (b) Commercial flight map in the world (Internet, 2020).

ulation, in this way, all would have to behave as if they had COVID-19 and to be in quarantine, not to infect. Because if the tests are not done, it is not known if you have it or not, since there are asymptomatic cases. Decision makers play a relevant role in what happens in their towns that are their responsibility. Choosing what is convenient and at the same time the population becoming aware of the importance of obeying are signs of humility in the face of the crisis, and hence the success of the place. Decision makers with humility, learning from others is also necessary to stop the pandemic that started as an epidemic.

It is highlighted that the COVID-19 epidemic was declared this way by the WHO on January 30^{th}, 2020, and after of 30 days, on March 11 it was formally declared a pandemic when 114 countries were infected, confirmed cases 118 000 and 4 291 people who had lost their lives. The aspects that unleash the pandemic could be diverse. Knowing of the evolution of the problem can serve, any minimum detail that could foresee greater impacts of the problem, and when it comes to life and deaths it's essential; it is systemic, radical and fast decisions that must be made by decision makers. The decisions of the group of decision-makers have a great impact.

Figure 6.4a and 6.4b present the cases confirmed worldwide with COVID-19 as of March 28 issued by Johns Hopkins University, and a commercial flight map found on the internet (Internet, 2020) [32]. These maps observe similarities between the regions with the highest confirmed cases in the world and the concentration of commercial flights. It is possible to observe, the regions of East Asia, Europe and America where most of the confirmed cases with COVID-19 are centered is where there is the most concentration of international flights. It could be seen that the pandemic, among other aspects, is due to the mobility of air passengers, but it could be extrapolated to air, sea and land mobility. The first strategies by some countries were directed in that direction (mobility of passengers), control of those entry and exit points, despite them, it has not been enough to contain the pandemic. Systemic Decisions in the face of a systemic problem, where individual systemic decisions will have relevance for the near future will continue to apply, which involve transformation of thought and consciousness to work all the humanity.

Represent the study system systemically (Figure 6.5), analyze it systemically, visualize behavioral variables associated with the system and the problem, define the different holistic levels, as well as contextualize them in the present, past and future, form Transdisciplinary groups to decide, etc., could support decision-making.

The future, decision-makers must train transdisciplinarily, where they invite them to be self-investigating in order to self-transform and, thus, reach the decisions that opt for survival and minimal disaster. The decision makers of the world, at different scales, must become aware of their decision and become co-responsible with what their world is going through, that is, all of humanity, because global problems require global decisions and we should all participate in stopping what is happening. The transformation of the world's decisions demands this moment that is currently lived.

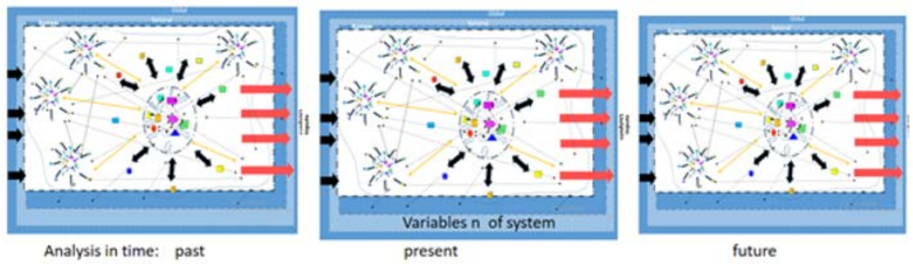

Figure 6.5: Systemic representation of the problem to be decided (present, past and future).

Einstein said: "You cannot solve a problem at the same level of thought in which it was created", therefore the importance of evolving our thinking in order to propose solutions in a holistic way. In this way, living a process to decide would be relevant. Live a process to decide systematic even more, in these times of crisis. From the culture that one has, from the beliefs that are lived and coexisted, it is time to become aware of the importance of a spirituality. In this case too, the transdisciplinary perspective could serve to return to oneself and, auto-take self and transform self, to achieve those necessary transdisciplinary systemic decisions in these times, which would simply be human decisions.

6.4 Conclusions

An absolute positive correlation was found between the analyzed variables with the highest correlation between the cases confirmed with COVID-19 and the number of airports; the correlation for the Americas region being more notable. It is necessary to adopt transdisciplinary systemic approaches for solving global problems, training new students in systemic decisions will be necessary in future generations.

Acknowledgments

We would like to thank our institution, all our teachers, our students, our families. These are times of crisis, and thank you all for your strength in the face of pain. Thank you for your teachings, in this step through life. Today are times of so much learning, that they could be so good in the sense of the transformation of humanity. I thank everyone with intense pain. We thank everyone who is having the courage, the patience and the humility, without losing hope, envisioning a better world.

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CHAPTER 7

New Performance Measures for Dallas–Fort Worth, Texas System-of-Systems (SoS)

Jon K. Ilseng

The purpose of this paper is to propose new performance measures for the local Dallas-Fort Worth, Texas System-of-Systems (SoS). Current traditional performance measures do not integrate the needs of the local Dallas-Fort Worth, Texas SoS and the needs of for-profit organizations, government agencies and educational institutions. As sustainability concerns and issues become pervasive, relationship between productivity/efficiency and effectiveness in the local Dallas-Fort Worth, Texas SoS becomes very important. Based on the results of an on-line survey and using the Balanced Scorecard Template, three new performance measures are proposed: 1) Cost/Logistics Index, 2) Performance/Logistics Index and 3) Availability/Logistics Index. A comparison of these new performance measures versus current performance measures is discussed.

Keywords: Performance measures, system-of-systems, sustainability, productivity, society.

7.1 Introduction

Performance measure is a numeric description used in for-profit organizations, government agencies and education institutions to determine the efficiency and effectiveness of such organizations. Effective performance measures, quantitatively, describe important and key information about services and how they are produced. Good performance measures are typically based on data and can help whether an organization is achieving its objectives and the improvement being made to meeting organizational goals. Performance measures usually let organizations know the following: 1) are they currently performing with regards to their respective competitors, 2) are they meeting their current goals, 3) are processes controlled, 4) are improvements necessary, and 5) is there information to make intelligent decisions [1].

A performance measure is a quantifiable expression composed of some number or amount and a unit of measure. The number or amount is a magnitude (how much) and the unit of measure is a meaning (what). In general, performance measures can be categorized into one of the following six general areas:

1. Efficiency – Shows the degree to which a process produces the expected output at a minimum resource cost. It asks the question "Are we doing things right" (Fried, et al., 1993 [2]).
2. Quality – It shows the degree to which a product or service meets customer requirements and expectations (Crosby, et al., 1992 [3]).
3. Timeliness – Whether a unit of work was done properly and on time.
4. Productivity – is the value added by the process divided by the value of the labor and capital consumed (Tangen, 2002 [4]).
5. Safety – Defines the overall health of the organization and the working environment of the employees (Maudgalya, et al., 2008 [5]).
6. Effectiveness – Compares the profit from new products to the investment in new product development (McGrath and Romeri, 1994 [6]).

Current performance measures have been discussed by many researchers. As sustainability concerns and issues become pervasive, relationship between productivity/efficiency and effectiveness in the local Metroplex SoS becomes extremely important. Kajikawa (2010) [7] studied the interdisciplinary characteristics of sustainability science and discussed the main issues to integrated disciplines. He analyzed the structure of sustainability science and considered the necessity of transdisciplinary expertise and how such initiatives were conducted in Japan.

Valerdi, Ross & Rhodes (2007) [8] studied the differences between Traditional Systems Engineering and Systems of Systems Engineering (SoSE). They indicated the main differences as:

1. Traditional Systems Engineering develops a single system to meet stakeholders' performance requirements. SoSE's purpose evolves new SoS capability to leverage legacy systems's synergies and emerging capabilities.
2. Traditional Systems Engineering's Systems Architecture is established early in the life cycle and the expectation set remains relatively stable. SoSE's Systems Architecture is dynamic adaption as emergent needs change.
3. Traditional Systems Engineering's cost is a single stakeholder group with a stable funding profile. SoSE's cost is multiple stakeholder groups with an unstable funding profile.

Baruch and Ramahlo (2006) [9] explain how academic scholarly works measure organizational outcomes which are reported as either organizational effectiveness or organizational performance (OEP). They analyzed 149 scholarly articles published in the past decade which centered on business organizations, nonprofit organizations and a combination of both. Searcy (2009) [10] explained how the System of Systems (SoS) Engineering perspective is used to corporate sustainability performance measurement. He indicated that measuring corporate sustainability is a difficult problem characterized by uncertainty and ambiguity.

Doolen, Traxler and McBride (2006) [11] suggested a supplier score card to help improve supplier performance. They proposed the following five-steps for a supplier scorecard:

1. Identify the strategic/operational objectives related to supplier performance,
2. Develop equitable performance measures for suppliers,

3. Engage suppliers to ensure performance measures are credible,
4. Create a design which evaluates supplier performance and
5. Educate suppliers on performance measures.

Youngblood and Collins (2003) [12] proposed a technique used to evaluate trade-off issues between performance measures concerning which performance measures are better than others. They suggested the use of the multi-attribute utility theory when developing a balanced scorecard. Brooks and Coleman (2003) [13] discussed a process that could be used to evaluate an organization's performance measurement system. "Specifically, they proposed a process consisting of three steps,"plan-do-act".

Keating, et al. (2008) [14] studied how to derive and decompose system-level requirements from a SoSE viewpoint. They describe the main differences that exist between Systems Engineering (SE) and SoSE requirement domains, how SE and SoSE requirements are derived and decomposed, what are the current problems with SoSE requirements. Keating, et al. (2003) [15] proposed concepts and implications for SoSE. They believe that SoSE needs disciplined approaches, must involve a different level of thinking than is currently used for traditiona SE, and best practices must be captured during the SoSE life cycle.

DiMario, et al. (2008) [16] proposed a framework that addresses SoS complexities and its challenges. They use the Zachman Framework to address SoS architecture issues. Elrod, et al. (2013) [17] discussed what performance measures Supply Chain Managers can use for their particular business and services. Supply Chain Managers play key roles in many for-profit companies and they discussed those performance measures that improve the overall supply chain process.

Laihnonen, et al. (2014) [18] studied a conceptual framework for capturing performance of a service system by applying it to two distinct service systems. Mehrabad, et al. (2012) [19] discussed the development of predictive tools in performance measurement and how to model it to help managers target performance measures based on achieving minimum cost and strategic priorities.

Halachmi (2005) [20] proposed that performance management can take many forms when dealing with internal issues from an organization and that performance measures are a possible sub-system of performance management. Psomas and Kafetzopoulos (2014) [21] compare ISO 9001 certified and non-certified manufacturing companies with regards to performance measures, both financial and non-financial. Rossiter and Pantano (2006) [22] evaluated the Balanced Scorecard by listing claims made by its authors and to justify further research in dynamic performance measurement systems for global organizations." Gosselin (2005) [23] discussed that manufacturing firms continue to use financial performance measures, despite recommendations from experts and academics.

This paper reviews the traditional performance measures used by for-profit organizations, government agencies and educational institutions. The relation of firms, government agencies and educational institutions is phrased in a Systems of System (SoS) perspective, with a discussion of the forces for parasitic behavior and symbiotic behavior.

7.2 Traditional Performance Measures

For the purposes of this paper, the focus of the local SoS is the "Metroplex" metropolitan area of Dallas-Fort Worth, Texas. The Dallas-Fort Worth Metroplex is home to a high number of technology companies (Raytheon, Lockheed Martin, Cisco, Oracle, Texas Instruments, etc.) and research universities including the University of Texas-Dallas (UTD), University of Texas-Arlington (UTA), Southern Methodist University (SMU), University of North Texas-Denton (UNT) and Texas Christian University (TCU) and community and technical colleges like Collin County Community College (CCCC) and Tarrant County Community College (TCCC). For the Dallas-Fort Worth Metroplex local SoS, interactions are very important. These interactions can be either parasitic, where the success of one requires the sacrifice of another. Or they can be symbiotic, where success for one fuels success in the others. As sustainability concerns become more prevalent, the relationship of efficiency and effectiveness in this local SoS is crucial to ensure it is symbiotic. Sustainability is continuing global issue and industry, educational institutions and government agencies must continue to address it.

The current performance measures in industry, government and educational institutions include Data Envelopment Analysis (DEA) and Evidential Reasoning (ER). Chen, et al. (2010, p. 2) [24] state "DEA is a mathematical programming method for evaluating firms' productive efficiency that has been used considerably in the operations research and management literature." Borhan and Jemain, (2012) [25] summarize that ER focuses on the "evidential reasoning algorithm and is different from many conventional Multi Criteria Decision Making modeling methods in that it uses an evidence-based reasoning process to reach a conclusion". They believed that ER has many advantages, as it can handle: 1) a mixture of quantitative and qualitative information, 2) a mixture of deterministic and random information, 3) incomplete information and 4) a large number of attributes and alternatives.

The research design and methods for identifying the relation of these systems from a SoS perspective and discussing how parasitic and symbiotic behaviors affect it is prescribed in the U.S. DoD Systems Engineering Guide for Systems-of-Systems Engineering Version 1, (2008). The U.S. DoD SoS Engineering defines four types of SoS as follows:

1. Directed SoS are those in which the integrated SoS is built and managed to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.
2. Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the system are based on collaboration between the SoS and the system.
3. Collaborative SoS have the component systems interact more or less voluntarily to fulfill agreed upon central purposes. The Internet is a collaborative system. The Internet Engineering Task Force works out standards but has no power to enforce them. The central players collectively decide how to provide or deny service, thereby providing some means of enforcing and maintaining standards.
4. Virtual SoS lack a central management authority and a centrally agreed upon purpose for the SoS. Large-scale behavior emerges and it may be desirable. Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering (2008).

For identifying and proposing performance measures that integrate the needs of these various SoS with regards to sustainability, Neely, et al. (2000) [26] recommend a process-based approach that has desirable characteristics of a performance measurement system design process. Particularly, they believed these performance measures must: 1) be understandable, 2) ensure calculation method(s) is very clear, 3) ensure data collection is understandable, 4) enable/facilitate benchmarking, 5) prefer ratio-based performance measures to absolute numbers, 6) be easy to understand, 7) provide fast feedback and 8) stimulate continuous improvement.

Neely, et al. (1997) [27] recommended a structured approach which specifies what a performance measure constitutes: 1) performance measures should be derived from strategy, 2) performance measures should be relevant, 3) performance measures should relate to specific goals or targets, 4) performance measures should be consistent in that they maintain their significance as time passes, 5) performance measures should be reported in a simple consistent format, 6) performance measures should provide relevant information, 7) performance measures should be precise and 8) performance measures should be objective.

7.3 On-line Survey

An on-line survey was sent to Dallas-Fort Worth SoS City Managers, County Commissioners, Universities, Community Colleges, not-for-profit and for-profit companies. 90 respondents out of 100 completed it. The on-line survey developed by the author for this paper was used to understand what performance measures are currently collected and what performance measurement models or tools are currently being implemented. Question 1 asked the definition of your current organization (i.e. Educational Institution (Community College or University), For-Profit or Non-Profit Company, Government Organization (City, County, State or Federal). Question 2 asked the number of employees in their respective current organization. Question 3 was "What kind(s) of performance measurement is (are) implemented in your organization" offered interesting responses. Question 4 was "Which performance measurement model or tools are used in your organization." Question 5 asked "What are the initial reasons for your organization to implement its performance measurement system?" Question 6 asked to "List the top five most important performance measures in your organization and to define them". Question 7 asked "For any of the top five most important performance measures listed in Question 6, are publicly accessible?"

Reviewing the results to Question 3, the top performance measures implemented in order of importance are: 1) Financial Performance Measurement, 2) Sustainability Measurement, 3) Process Management Measurement, 4) Customer Satisfaction Measurement, 5) Human Resource Performance Measurement and 6) Strategy Performance Measurement. Logistics performance was also listed under the Other category. As shown in Figure 7.1, it is not surprising that Financial Performance was the top performance measure since all these SoSs realize that having satisfactory financial performance ensures they stay in business. The results for Questions 4 and 5 are given in Figures 7.2 and 7.3.

For Question 6, all on-line survey respondents listed the following:

a. Cost/Financial Measure

b. Customer Satisfaction

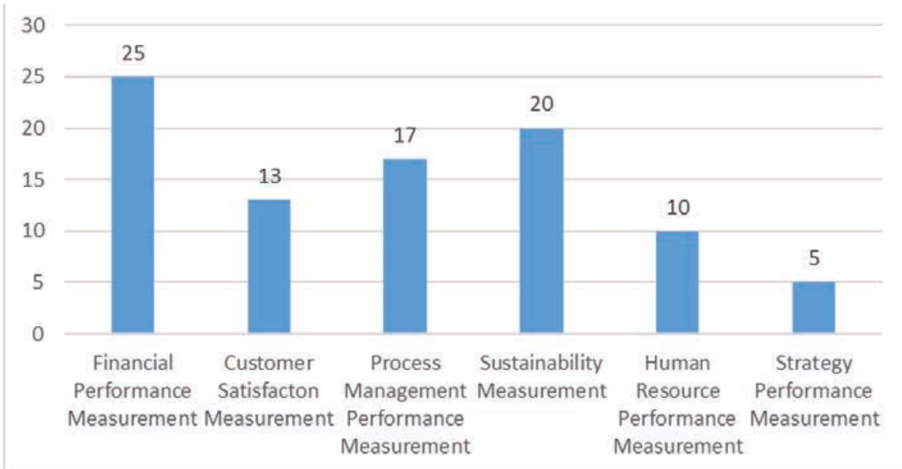

Figure 7.1: Results of responses to question 3.

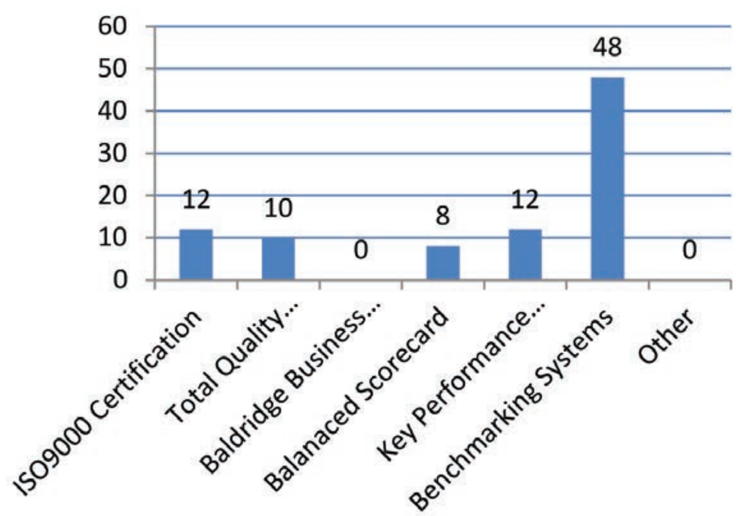

Figure 7.2: Results of responses to question 4.

c. Logistics

d. Sustainability

e. Return on Invested Capital

f. Measures relating to Environmental Issues (energy usage, water usage, etc.)

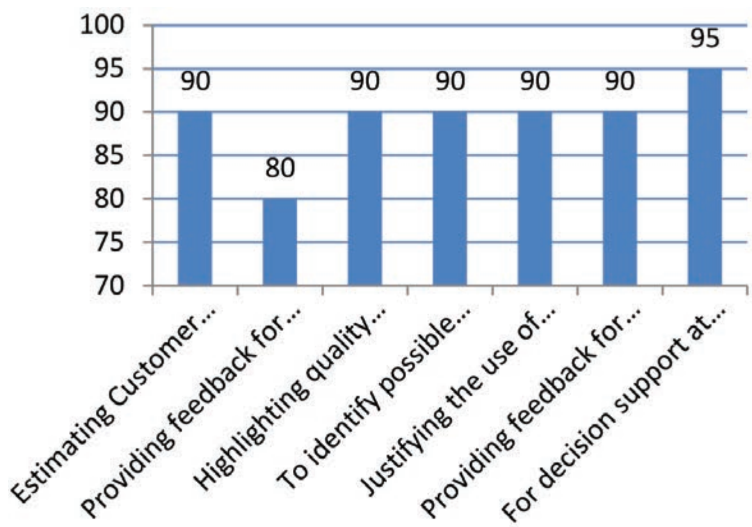

Figure 7.3: Results of responses to question 5.

7.4 Discussions

An important finding was the literature review indicated a lack of research in productivity for a SoS. Also, the literature review indicated that there has not been a systematic study of performance measures in a SoS that encompasses for-profit organizations, governmental agencies and educational institutions. This gap identifies an important sector for further research.

The Cost/Logistics Index measures the actual cost of the SoS versus the logistics information. It is calculated as follows: (Actual cost/Budgeted cost)/(Logistics Performance Index). For each system in the Dallas-Fort Worth SoS, you take the monthly actual costs expended and divide it by the budgeted costs. Then you divide this value by the Logistics Performance Index. There were 90 respondents in the online survey. Assigning Cost Performance Index (cumulative-to-date) CPI/CTD data from the DoD selected acquisition reports (SARs) and the logistics performance index (LPI) scores from the World Bank to match each system in the Dallas-Fort Worth SoS as close as possible, the Cost/Logistics Index measures for each of the 90 respondents is shown in Figure 7.4 and Figure 7.5. Figure 7.4 shows the Cost/Logistics Index for fifty-four systems in the Dallas-Fort Worth, TX SoS and Figure 7.5 shows the Cost/Logistics Index for thirty-six systems in the Dallas-Fort Worth, TX SoS.

This data shows that the higher the Cost Index (i.e. greater than 1.0) and the higher the LPI (i.e. scores greater than 3.5 or higher) the lower the Cost/Logistic Index measure, which is desirable . The lower Cost Logistics Index Measures are good scores while the higher scores are not. The scores range from 0.245 to 0.644. If we sum all the ninety Cost Logistics Index Measures and divide by ninety, we will have an average Cost Logistic Index Measure = 0.3478 for the Dallas-Fort Worth, TX SoS. This means that this measure is a good indicator for measuring the Dallas-Fort Worth, TX SoS from a Cost/Logistics viewpoint. The lower the value implies

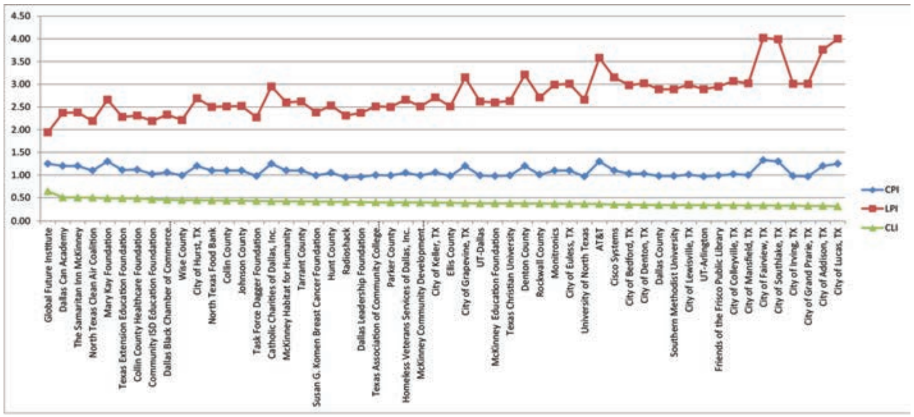

Figure 7.4: Cost/Logistic Index Measures for fifty-four systems in Dallas-Fort Worth, TX SoS.

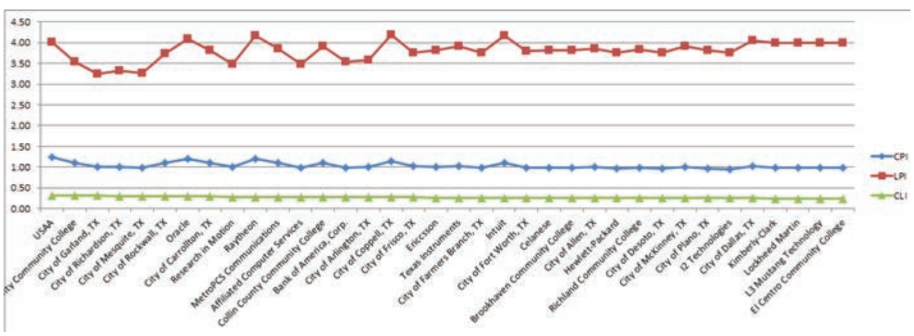

Figure 7.5: Cost/Logistic Index Measures for thirty-six systems in Dallas-Fort Worth, TX SoS.

the SoS is performing within its cost budget while also managing the logistics that come with it.

The Performance/Logistics Index measures the performance of the Dallas-Fort Worth, TX SoS versus the logistics information. For each system in the Dallas-Fort Worth, TX SoS, performance is defined as the (system operational time/system non-operational time)/(Logistics Performance Index). For each system in the Dallas-Fort Worth SoS, we take the system operational and divide it by the system non-operational time. Then this value is divided by the Logistics Performance Index. There were 90 respondents in the on-line survey. If we assign values from 0 to 1.0 for each system performance in the Dallas-Fort Worth, TX SoS and the LPI scores from the World Bank to match each system in the Dallas-Fort Worth SoS as close as possible, the Performance/Logistics Index measures for each of the 90 respondents is shown in Figure 7.6 and Figure 7.7. Figure 7.6 shows the Performance/Logistics Index for fifty-four systems in the Dallas-Fort Worth, TX SoS and Figure 7.7 shows the Performance/Logistics Index for thirty-six systems in the Dallas-Fort Worth, TX

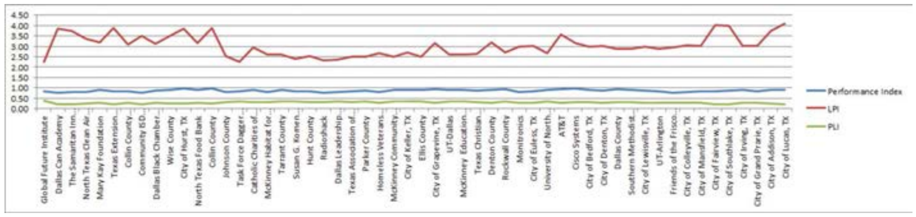

Figure 7.6: Performance/Logistic Index Measures for fifty-four systems in Dallas-Fort Worth, TX SoS.

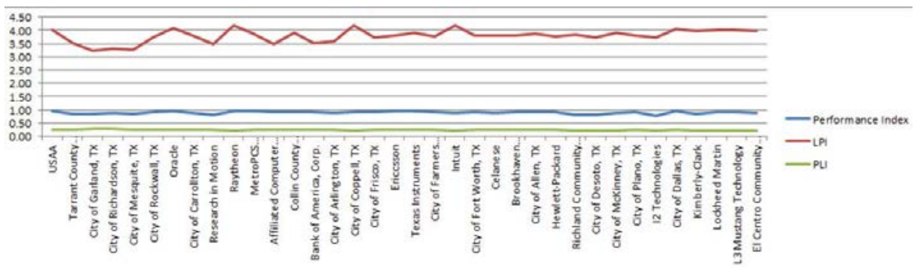

Figure 7.7: Performance/Logistic Index Measures for thirty-six systems in Dallas-Fort Worth, TX SoS.

SoS.

This data shows that the higher the Performance Index (i.e. values approaching 1.0) and the higher the LPI (i.e. scores greater than 3.5 or higher) the lower the Performance/Logistic Index measure, which is desirable . The lower Performance Logistics Index Measures are good scores while the higher scores are not. The scores range from 0.195 to 0.379. If we sum all the ninety Performance/Logistics Index Measures and divide by ninety, we have an average Logistic Index Measure = 0.270 for the Dallas-Fort Worth, TX SoS. What this measure tells us is that it is a good indicator for measuring the Dallas-Fort Worth, TX SoS from a Performance/Logistics viewpoint. The lower the value implies the SoS is performing as required while also managing the logistics that come with it.

The Availability/Logistics Index measures the availability of the Dallas-Fort Worth, TX SoS versus the logistics information. For each system in the Dallas-Fort Worth, TX SoS, Availability is defined as the (system uptime/system downtime)/(Logistics Performance Index). For each system in the Dallas-Fort Worth SoS, we take the system uptime and divide it by the system downtime. This value is divided by the Logistics Performance Index. If we assign values from 0 to 1.0 for each system availability in the Dallas-Fort Worth, TX SoS and the LPI scores from the World Bank to match each system in the Dallas-Fort Worth SoS as close as possible, the Availability /Logistics Index measures for each of the 90 respondents is shown in Figure 7.8 and Figure 7.9. Figure 7.8 shows the Availability/Logistics Index for fifty-four systems in the Dallas-Fort Worth, TX SoS and Figure 7.9 shows the Availability/Logistics Index for thirty-six systems in the Dallas-Fort Worth, TX SoS.

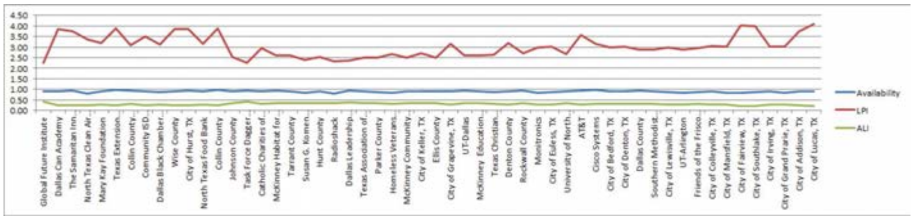

Figure 7.8: Availability/Logistic Index Measures for fifty-four systems in Dallas-Fort Worth, TX SoS.

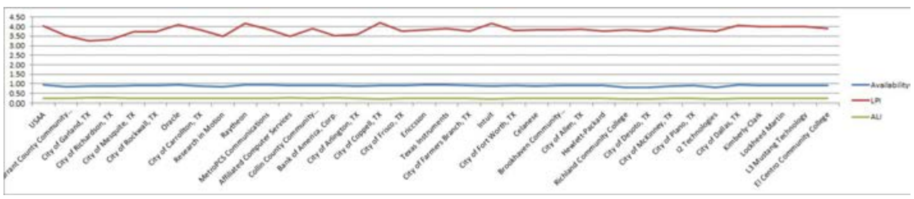

Figure 7.9: Availability/Logistic Index Measures for thirty-six systems in Dallas-Fort Worth, TX SoS.

This data shows that the higher the Availability Index (i.e. values approaching 1.0) and the higher the LPI (i.e. scores greater than 3.5 or higher) the lower the Availability/Logistic Index measure, which is desirable . The lower Performance Logistics Index Measures are good scores while the higher scores are not. The scores range from 0.212 to 0.418. If we sum all the ninety Availability/Logistics Index Measures and divide by ninety, you have an average Availability/Logistic Index Measure = 0.278 for the Dallas-Fort Worth, TX SoS. This measure tells us that it is a good indicator for measuring the Dallas-Fort Worth, TX SoS from a Performance/Logistics view point. The lower the value implies the SoS is performing as required while also managing the logistics that come with it.

7.5 Conclusions

Based on the data and survey results collected and using the BSC Template, the following performance measures are proposed for the Dallas-Fort Worth, Texas SoS.

1. Cost/Logistics Index – Cost/Logistics Index measures the actual cost of the SoS versus the logistics information. The Cost/Logistics Index measures the actual cost of the SoS versus the logistics information. It is calculated as follows: (Actual cost/Budgeted cost)/(Logistics Performance Index).
2. Performance/Logistics Index – Performance/Logistics Index measures the performance of the SoS versus the logistics information. The Performance/Logistics Index measures the performance of the Dallas-Fort Worth, TX SoS versus the logistics information. For each system in the Dallas-Fort Worth, TX SoS, performance is defined as the (system operational time/system non-operational time)/(Logistics Performance Index).

3. Availability/Logistics Index – Availability/Logistics Index measures the availability of the SoS versus the logistics information. The Availability/Logistics Index measures the availability of the Dallas-Fort Worth, TX SoS versus the logistics information. For each system in the Dallas-Fort Worth, TX SoS, availability is defined as the (system uptime/system downtime)/(Logistics Performance Index).

These three performance measures can measure cost, performance and availability for each system in a SoS with regards to sustainability, whereas current measures do not. On a scale from 0 to 0.99, the lower the scores for each measure, the better each system in a SoS can perform (cost, performance and availability) with regards to sustainability. For example, in the Dallas-Fort Worth, TX SoS, El Centro Community College has the #1 CLI = 0.24, #12 PLI = 0.22 and #14 ALI = 0.23. Since El Centro Community College is an educational institution, we can research why an educational institution in the Dallas-Fort Worth, TX SoS is ranked very high in these three performance measures. For the non-profit system, Global Future Institute has the #90 CLI = 0.64, #90 PLI = 0.37 and #89 ALI = 0.41. The question to ask is, "Why is this non-profit system ranked low in these three performance measure?" For a profit system, L3 Mustang Technology has the #2 CLI = 0.24, #18 PLI = 0.22 and #10 ALI = 0.22. For a governmental institution, City of Dallas, TX has the #5 CLI = 0.25, #23 PLI = 0.23, #18 ALI = 0.23. Each performance measures indicates how that particular system in a SoS is performing in terms of cost, performance and availability with regards to sustainability.

The three proposed measures can measure any geographic SoS while traditional measures do not. For example, these three performance measures could be used to perform a SoS study comparing the geographic SoS of a community that attracts an existing company at the expense of a community that loses that company. Another example could be, if Texas Instruments, which has its corporate headquarters in the Dallas-Fort Worth, TX SoS, decides to relocate to the Houston, TX SoS, these three performance measures could be used to explain or predict these types of move.

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CHAPTER 8

Complexity of Global Refugee Crisis: Needs for Global Transdisciplinary Collaboration

Moran, D., Gulbulak, U. Ertas E., Students from 2020 Capstone Design, ME-Section-5 Class

*People are on the move for many reasons such as war and civil war, human rights, violation, economic, social, climate, environmental, political, and individual reasons that create these changing aspects. In such complex situations, the need to flee (**forcibly displaced**) versus the choice to leave (**migration**) can be difficult to determine. The issue of refugee resettlement is complex and includes many factors to consider. Factors being considered for their impact on resettlement include budget and cost issues, federal law and policies, administration challenges, security screening process, education and training, health and housing, crime rate, socioeconomic issues and many others. The objective of this chapter is to discuss how the aforementioned factors relates and interact with one another using Interpretive Structural Modeling (ISM).*

ISM methodology implementation against this problem was consisted of a group of 25 undergraduate students in senior design class, all pursuing Mechanical Engineering degree at Texas Tech University, two Ph.D. students, one faculty member in design, four research engineers from different companies. This group recognized significant difficulties and challenges in carrying out successful refugee resettlement and sought to identify the main factors affecting the problem and how they were interrelated, with the goal of improving the rate of success for these displaced individuals.

Keywords: Refugee resettlement, interpretive structural modeling, forcibly displaced, migration.

8.1 Introduction

People are on the move for many reasons such as war and civil war, human rights, violation, economic, social, climate, environmental, political, and individual reasons that create these changing aspects. In such complex situations, the need to flee (*forcibly displaced*) versus the choice to leave (*migration*) can be difficult to determine.

The worldwide population of *forcibly displaced* rose by 2.3 million people in 2018

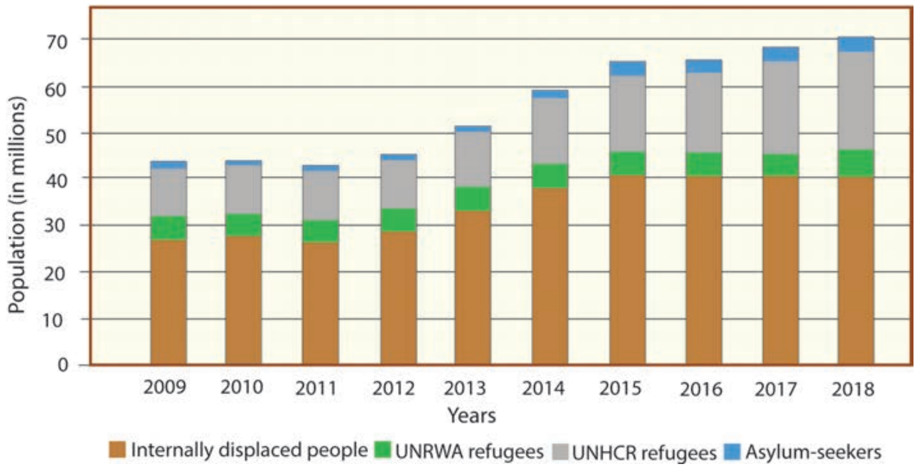

Figure 8.1: Global forced displacement during 2009-2018 (recreated from [1]).

reaching to 70.8 million – 20 people are displaced every minute in a day. The worldwide population of forcibly dislocated people grew considerably from 43.3 million in 2009 to 70.8 million in 2018, reaching a record high as shown in Figure 8.1 [1]. This increase took place between 2014 and 2015, cause to move mainly by the Syrian conflict along with other conflicts in the region such as in Iraq, Yemen, and Sudan as well as other poor countries. The complexity of the issue makes it difficult to understand global refugee problems.

8.1.1 Challenges of Managing Refugee Resettlement

Successful resettlement of refugees is the overall goal of any government that is offering asylum to any displaced people. To define resettlement as the integration of refugees into the host society with government assistance but transitions to self-sufficiency and the end of government aid being the completion marker. The administrative and programmatic factors that have been perceived as most important to successful refugee economic self-sufficiency. It is known that refugees have been successful in obtaining employment but key challenges for economic self-sufficiency remain. Some of these challenges are like those faced by low-income people in mainstream programs. The most common challenges that are included: resource issues, transportation, language barriers, and hard-to-serve clients [2].

The issue of refugee resettlement is complex and includes many other factors to consider. Factors being considered for their impact on resettlement include: budget and cost issues, federal law and policies, administration challenges, security screening process, education and training, health and housing, crime rate, socioeconomic issues and many others.

8.2 Method

The focus of this section is to discuss how the aforementioned factors relates and interact with one another using Interpretive Structural Modeling (ISM). Interpretive Structural Modeling (ISM), a well-established methodology for handling and decomposing complex problems was proposed by Warfield in 1973 [3]. ISM identifies and summarizes relationships among specific parameters and provides fundamental understanding of how those parameters relevant to the complex problem. Thus, helps researchers to structure complex problems in a meaningful way to overcome challenging unstructured problems [4].

8.2.1 Context

Transdisciplinary Collective Intelligence: ISM methodology implementation against this problem consisted of a group of 25 undergraduate students in senior design class, all pursuing Mechanical Engineering degree at Texas Tech University, two Ph.D. students, one faculty member in design, four research engineers from different companies. This group recognized significant difficulties and challenges in carrying out successful refugee resettlement and sought to identify the main factors affecting the problem and how they were interrelated, with the goal of improving the rate of success for these displaced individuals.

8.2.2 Process

Effectiveness in accepting and integrating immigrants into a new home country requires transdisciplinary collaboration among, and within, institutional sectors in the receiving countries. Partnering and joining must occur between organizations such as: social services; education; government; community-based organizations, and others.

The working group developed transdisciplinary collective intelligence using Interactive Collective Intelligent Management (ICIM) Workshop to investigate the issue. (1) The Nominal Group Technique (NGT) was used to develop and clarify a list of factors affecting the complex issue [5], (2) Interpretive Structural Modeling (ISM) process was used to develop:

(a) Structural self-interaction matrix
(b) Final reachability matrix
(c) Digraph
(d) MICMAC Analysis

The working group identified nine factors for how to handle complex issues of refugee settlement. The factors were grouped into six levels. Through MICMAC analysis, it was shown how these factors are interrelated to support the successful refugee settlement (see Figure 8.2 for Sequence of activities to develop an ISM model).

8.2.3 Content

The working group developed a set of factors affecting complex issue of refugee settlement showing how a select factors of the problem they identified were related to each other. One of the Ph.D. students, Utku Gulbulak, who is familiar with the ICIM facilitated the workshop.

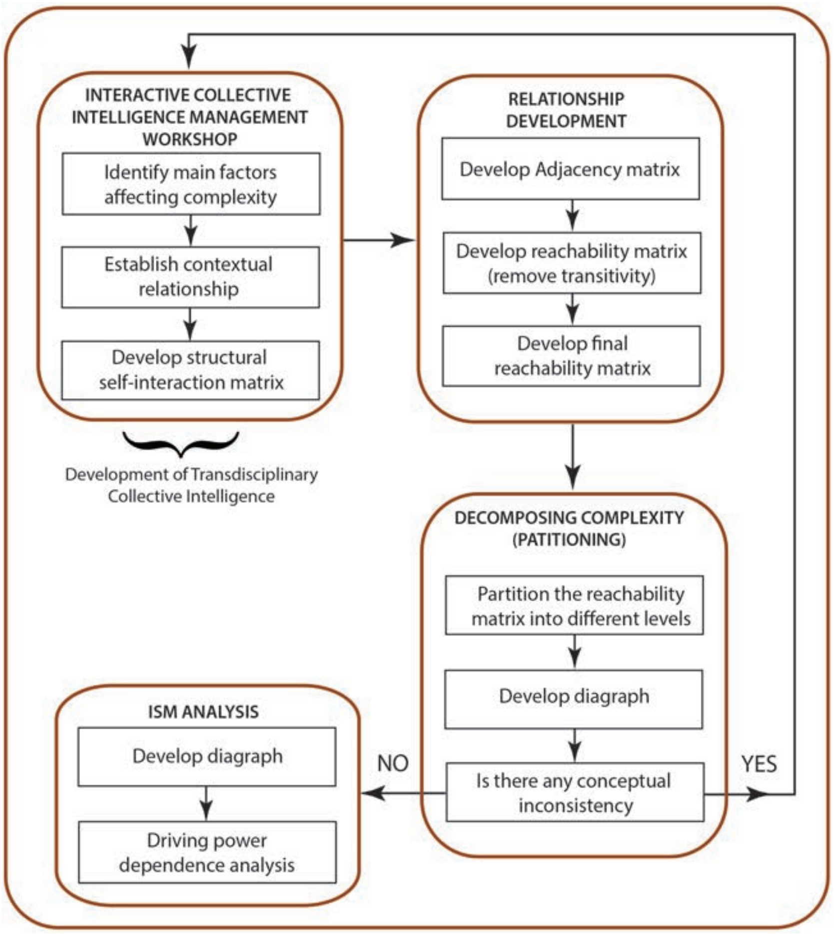

Figure 8.2: Sequence of activities to develop an ISM model.

8.3 Identifying Factors

During the first stage of the workshop, potential factors which affects the successful refugee settlement were identified. One of the methodologies that has been found useful was NGT structured method for group brainstorming that encourages contributions from group members and enables quick agreement on the relative importance of issues, problems, or solutions. NGT was used to obtain and specify potential factors. The working group developed twenty factors affecting issue in hand.

8.3.1 Structuring the Factors

Following the development of factors, a part of NGT process was used to determine which of the factors were most important. From the set of twenty factors, the following subset of nine were structured using methodology of ISM. Those were the ones receiving the highest scores in the voting on most important main factors.

Budget (Cost)

There are various costs that the Office of Refugee Resettlement (ORR) takes into account in the budget for funding refugee resettlement. The first and most obvious being the monetary costs: funding for transitional and medical services, social services, preventive health, shelter, utilities, supplies, training and education etc. Of course, the higher quality of the product or service provided to refugees translate to the higher cost. However, the minimum standards needed to make sure planned settlements support refugee communities to live with security and in a healthy environment which provide them quality of life. To determine the most feasible investment, depending on factors such as federal law and policies, the budget request is formulated based on the number of people in need.

Policies and Rules

Federal (Nation-State) laws and policies are significant when dealing with a wave of refugees trying to enter a new country. They dictate how effective a refugee crisis can be handled by a host country. Furthermore, the laws and policies set up how the country is going to respond to the situation. According to the Lumina Foundation, the federal policy "must support widespread change that puts the needs of individuals and society first" [6]. Whether it could be a temporary or permanent solution, the host country is responsible for accommodating the refugees and creating the laws that will govern them. The host country creates these laws and policies in order to offer protection, shelter, and life to the refugees – facilitating the process of resettlement. Nation- State policies and rules can also, on the contrary, limit the number of refugees entering the country and hinder the resettlement processes.

Screening Process

Refugees seeking resettlement must pass through a series of steps planed at ensuring they will not pose a security risk to the hosting country – security is among the top priorities of a nation.

In the last couple of years, nations have come a long way in finding ways to intercept threats and stopping them before they can happen. This is in part because of new technologies that can pick up encrypted communication and certain pattern of messages being transmitted around the globe paired with the work of the various intelligence communities for host countries.

In the United States, the 9/11 tragedy of 2001 [7] drove surveillance changes within the intelligence community which provide greater sets of data for evaluating incoming asylum seekers from "high risk" countries. Following 9/11, strengthened border and airport security provided additional measures for efficient and more effective measures for evaluating persons entering the country. This increased security posture within the U.S. since 9/11 has seen positive results accompanied by the downsides of strained relationships between the U.S. and countries that have had to ban due to security reasons and the general view of the population these countries and the rest of the world [8].

U.S. is one of the most diverse and forward-thinking countries in the world however, U.S. still must stand firm when it comes to putting the interest of the country and people first. This conflict of self-interest versus world relations goes on to affect processes like receiving refugees from war torn countries and disaster-stricken countries. Having to screen refugees for reception and placement together with making sure that U.S. is not putting the interest and safety of the people of the nation at risk continues to be a challenge for the nation and the world.

In the U.S., the Resettlement Support Center (RSC), contracted by the U.S. Department of State (DOS), handles an interview and collects the refugee's personal data and background information for the screening process. The United States determines the number for refugee admissions through the president and congress on a yearly basis. Applicants for the refugee program must pass a security screening to confirm that they do fall under the description of a refugee in addition to health and criminal history. Those who pass a security check and are within the number of admissions are then handed over to private voluntary agencies that handle refugees' basic needs as well as employment counseling. The United states policy also states that one year after admission, they can apply for permanent status. Followed by naturalization, which occurs after five years from admission [9].

Security screening process varies from country to country. It also takes into consideration where the refugees are coming from. When Canada took in 25,000 Syrian refugees security was one of the top priorities. They focused mainly on people who are considered low security risk but are vulnerable to danger. These people include women, complete families, and members of the LGBTI community. When they came into Canada, they went through a vigorous screening process. The process was made up of pre-identification of refugees, immigration and security interviews, identity and document verification, and re-checks of identification upon arrival [10]. In the European Union (EU) it is much harder to control. Countries are subjects to refugees seeking shelter from countries are able come directly to their borders. This makes it much harder to implement policies because they face chaotic situations every day. In the EU they use private agencies such as Frontex and EASO to support these screenings [11]. They mainly focus on running background checks to screen for criminal records and terrorist involvement. While the EU is trying to improve their screening processes, it has been difficult to do so. Since many countries are so behind in the security process it would take many years to get to the standard set by the U.S.

Administration Challenges

Administration challenges regarding the logistics and bureaucracy in the execution of decisions for resettling refugees will delay resettlement. "Turkey continues to host the largest number of refugees worldwide, with close to 4.1 million refugees, including 3.7 million Syrians and nearly 400,000 asylum-seekers and refugees of other nationalities [12]." The ability to provide for such a large influx of refugees while simultaneously documenting every individual and the services provided to them is essential for successful resettlement.

Obtaining information about the refugees and how they are faring is the only way to know if current administration policies are achieving their desired goals. One key metric for successful resettlement is measuring the time between the influx of refugees and successful resettlement. The greater this time of resettlement, the greater the cost to the host country which is accompanied by frustration of both parties and a prolonged the suffering of the refugees. "The main challenges remain the pressure on national resources and the availability of services for refugees and host communities. While state institutions are addressing these challenges, the protracted nature of the refugee situation has drawn public attention to the social impact of the refugees' presence [12]." Resettlement occurring in a timely manner increases the likelihood that it will be successful. "History shows a well-established pattern: as the number of refugees and the length of time they remain in a host country grows, the citizens of that country become less willing to provide for them [13]." Therefore, increasing administration efficiency will reduce the hindrance to resettlement.

Administratively collected data in Turkey revealed that "In 2016, the Turkish government announced a work permit system to tackle the Syrian employment problem, but the program is not popular...only about 32,000 Syrians have received work permits to date. Syrians face a number of obstacles and disincentives when applying for work permits. First, to acquire a work permit, they must work in the province in which they are registered as under temporary protection. Since registration is required within 10 days of arrival in Turkey, however, this province is usually the one where the refugee entered Turkey. Therefore, refugees are disproportionately registered in the provinces bordering Syria, while the jobs tend to be elsewhere – in big cities in western Turkey, such as Istanbul, Izmir, and Bursa. These destinations are naturally where many of the refugees go and work, regardless of registration, but they do so as part of the underground economy [14]." This administratively collected data is now useful in addressing this particular issue with resettlement and decrease the time to self-sufficiency with the individuals involved. This is just a single example of the importance of administrative procedure as a factor to successful resettlement.

Health and Shelter

During the resettlement phase, health care needs to be provided to the refugees. In doing so, this factor will affect the cost and the crime rate of the shelter. Although health care is a large expense, it will ensure a high survival rate. The more services physicians provide, the higher the cost will be to maintain that standard of care. As a result of having healthier patients both physically and mentally, the crime rate decreases. The opposite will occur if no health care is provided.

The health care set by the host government is completely structured by the federal policies of said government. The benefits that refugees receive are based on federal administrative regulations. Adversely, health care is dependent on federal policy, and not the other way around. In terms of economics, a government-subsidized health care program can create an entirely new market of jobs, specifically ones set up to support the refugees as they are taken in. Economics slowly transforms from micro to macro level depending on the length of government-funded care, and the number of refugees supported.

Education and Training Programs

Education and training programs are crucial for refugees to adapt and make a life for themselves in a society. Without these programs, refugees are left to fend for themselves and survive in a culture they are most likely very unfamiliar with. A major challenge for refugees, namely children, is that most education systems do not always accommodate foreigners the same way that they accommodate children that native citizens in that country. Even within the same host country individuals from different regions may have diverse educational needs [15]. This leads to further challenges as these children grow up and attempt to start a career because they are immediately at a disadvantage due to the lack of education forced upon them [15].

With proper education and training programs, however, refugees can start their new lives with newfound skills and knowledge, further improving their chance at thriving in a new country and increasing the rate of achieving self-sufficiency. Another added benefit to these programs is that with the added prestige of education and training, they will be better equipped to combat any possible discrimination they might endure as they will be equally educated as the native population.

One third of the 50,000 refugees that the United States has excepted per year for the last decade are children [16]. For these children the challenge of finding education may be difficult [17]. Fortunately, the National Education Association (NEA) provides a list of resources for those in search of education and support. The list provides several links for refugees to reference, in which provide information on where they may find education [18]. The most recent data shows that there are more than 840,000 immigrant students in the United States [10]. Existing programs such as the English Language Acquisition Program and the Migrant Immigration Programs offer federal and state funding to these children in need of assistance [19]. The UN Refugee Agency provides 18.5 million people assistance in 134 countries around the world, providing many of those such immigrants the opportunity for education [19]. Education can provide refugees the knowledge and skills to rebuild their lives and develop a path to a more peaceful and flourishing future for themselves and their families.

Self Sufficiency

In order to help refugees become self-sufficient, there must be help from the country where they are settling in. In the United States, the Refugee Career Pathways program helps refugees to achieve self-sufficiency by providing different types of training. The training consist of, assistance in creating personalized career development plans, classroom and work-based learning opportunities, career coaching and mentoring, connections with educational opportunities, apprenticeships, on-the-job training, recredentialing and credential recognition, and vocational English language training [20]. In Germany, it is mandatory for refugees who lack German language competence to participate in integration courses. Refugees who sign up for vocational programs are more likely to be recruited by the German government to work [21]. In 2016, the German government and the German Confederation of Skilled Crafts planned to create a nationwide program in order to prepare refugees into their apprenticeship. With this program refugees will be trained in different trades such as metal and electrical work. They would also be able to take language and integration classes [22].

Safety and Security

"Protecting the physical security of refugees entails securing their areas of residence, or taking steps to prevent their safety from being jeopardized. It also requires that the living environment of refugees should be peaceful, humanitarian and civilian, free of violence and criminal activity, and conducive to the realization of human dignity... [23]". Crime rate is something we want to take precaution when it comes to refugees. There are plenty of federal policies that prevent crimes within refugee establishments. Upon researching crime rate in refugee camps with large number of refugees became noticeably more safe, both in terms of their levels of violent and property crime [24]. However, we should not rule out this possibility because there are petty crimes that do occur within the establishment. No doubt that some countries have federal policies to prevent crimes, but some countries don't have policies to enforce upon refugees.

Social Issues and Economic Impact

Economic issues that affect the countries where refugees reside are mainly in the cost of their well-being. The governments of those countries are responsible for food, housing, and education to name a few. Large scale refugee populations can have serious impact on the social, economic and political life of host countries (in particular developing countries) and creates strain on the local administration. Refugees will compete with the host country citizens for resources of host countries. Gradually, their presence will cause to considerable demands on natural resources, education and health facilities, energy, transportation, social services and finally employment [25].

The economic impact of refugees on host countries can also be positive–an economic stimulus may be generated by the refugees and can help to further development of the host regions. Communication issues will negatively impact the ability of the refugees to find employment, which will alienate them from being accepted and integrated into the host society. "In Turkey, where a huge population of refugees have unprecedented access to quality government services but only in a foreign language, language has become a pivotal issue. This goes both ways: Syrian refugees need to learn Turkish especially to access education and jobs and to participate in community life, and government officials need Arabic-Turkish interpreters in order to provide individual services including registration, legal aid, health services and MHPSS (Mental Health and Psycho-Social Services) [26]." The ability to create social relationships is compromised by the language barrier and further inhibits integration into the host society. "Only one in every four refugee women says they have Turkish friends. A total of 79.7 percent of women say it is because they 'don't speak Turkish' that they could not make friends, while 10.4 percent say their immediate circle of acquaintances are entirely Syrian and they can only communicate with people of their own ethnicity. Some 10.4 percent say Turkish and Syrian culture are not different." [27] The impact of the language barrier is especially hard on refugee children. "Language barriers can make refugees feel isolated, hopeless, and anti-social, which often leads to depression. Struggling with speaking and comprehension makes it difficult for refugees to make friends with...peers and can unfortunately make them a target for bullying. It also leads to a lack of confidence, inhibiting many from speaking up and participating in class, and ultimately missed job and educational opportunities [28].

The social issues that affect the refugee population can range from poverty, racism, social disorganization, public health, social inequality, and many more. Many social issues last for the rest of the refugee's lives. Economic and social issues are real part of the refugee crisis that should be addressed. The international community should help compensate for the costs required in providing reasonable lifestyle for the refugees [25].

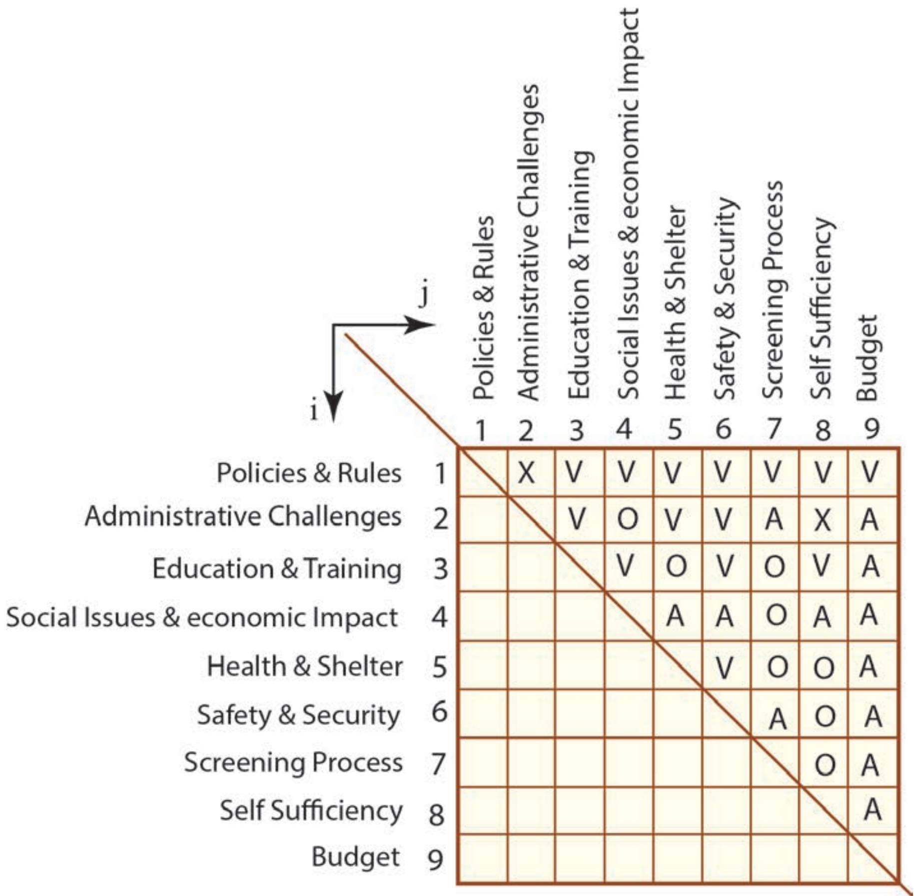

Figure 8.3: Structural Self-Interaction Matrix (SSIM).

8.3.2 Interpretive Structural Modelling (ISM)

Structural Self-Interaction Matrix (SSIM)

The above factors are assumed to be interrelated, rather than independent, where it is noted that some factors may increase the effects of other factors. The next step was to determine contextual relationship to develop structural self-interaction matrix shown in Figure 8.3. Using expert opinions along with working members the SSIM was developed. As shown in Figure 8.2, combination of these three steps is called *Transdisciplinary Collective Intelligence Development* [29].

Contextual relationship for each factor, the subsistence of a relation between any two factors (i and j) and the associated direction of the relation are questioned. The following four symbols are used to denote the direction of relationship between the factors (i and j):

- V: Variable i affects variable j

$$
R_a = \begin{array}{r c}
 & \begin{array}{ccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \end{array} \\
\begin{array}{r}
\text{Policies \& Rules } 1 \\
\text{Administrative Challenges } 2 \\
\text{Education \& Training } 3 \\
\text{Social Issues \& economic Impact } 4 \\
\text{Health \& Shelter } 5 \\
\text{Safety \& Security } 6 \\
\text{Screening Process } 7 \\
\text{Self Sufficiency } 8 \\
\text{Budget } 9
\end{array} &
\left[\begin{array}{ccccccccc}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\
0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
\end{array}\right]
\end{array}
$$

Figure 8.4: Adjacency matrix.

- A: Variable j affects variable i
- X: Both variables, i and j, affect each other
- O: No relationship between variables i and j

Considering on the contextual relationships, the structural self-interaction matrix (SSIM) shown in Figure 8.3 was developed for the nine main factors.

Adjacency matrix

Then the adjacency matrix, R_a, shown in Figure 8.4 is developed via transforming SSIM into a binary matrix, by substituting V, A, X, and O by 1 and 0 per the schema described below:

- Enter ‘V’ when the relation is from i to j (in the reachability matrix substitute in the (i,j) entry as 1 and (j,i) entry as 0).
- Enter ‘A’ when the relation is from j to i (in the reachability matrix substitute in the (i,j) entry as 0 and (j,i) entry as 1).
- Enter ‘X’ when the relation is from I to j and j to I, both direction (in the reachability matrix substitute in the (i,j) entry as 1 and (j,i) entry as 1).
- Enter ‘O’ when there is no relationship between the row (i) element and the column (j) element (in the reachability matrix substitute in the (i,j) entry as 0 and (j,i) entry as 0).

Reachability Matrix with Transitivity

Using the transitivity rule, a reachability matrix, R_t, shown in Figure 8.5 was obtained. Transitivity rule states that, if a factor ‘A’ is related to factor ‘B’ and if factor ‘B’ is related to factor ‘C’, then factor ‘A’ is related to factor ‘C’. This matrix was updated until transitivity is established.

$R_t =$

		1	2	3	4	5	6	7	8	9
Policies & Rules	1	1	1	1	1	1	1	1	1	1
Administrative Challenges	2	1	1	1	1	1	1	1	1	1
Education & Training	3	0	1	1	1	0	1	0	1	0
Social Issues & economic Impact	4	0	0	0	1	0	0	0	0	0
Health & Shelter	5	0	0	0	1	1	1	0	0	0
Safety & Security	6	0	0	0	1	0	1	0	0	0
Screening Process	7	1	1	1	1	1	1	1	1	0
Self Sufficiency	8	1	1	1	1	1	1	0	1	0
Budget	9	1	1	1	1	1	1	1	1	1

Figure 8.5: Reachability matrix for directed relationships between the elements with transitivity.

$R_f =$

		1	2	3	4	5	6	7	8	9	Driving power
Policies & Rules	1	1	1	1	1	1	1	1	1	1	9
Administrative Challenges	2	1	1	1	1	1	1	1	1	1	9
Education & Training	3	0	1	1	1	0	1	0	1	0	5
Social Issues & economic Impact	4	0	0	0	1	0	0	0	0	0	1
Health & Shelter	5	0	0	0	1	1	1	0	0	0	3
Safety & Security	6	0	0	0	1	0	1	0	0	0	2
Screening Process	7	1	1	1	1	1	1	1	1	0	8
Self Sufficiency	8	1	1	1	1	1	1	0	1	0	7
Budget	9	1	1	1	1	1	1	1	1	1	9
Dependence		5	6	6	9	6	8	4	6	3	$\Sigma = 53$

Summation of ones (9)

Summation of ones (5)

Figure 8.6: Final reachability matrix.

Final Reachability Matrix

The final reachability matrix as shown in Figure 8.6 was established by including driving power and dependence of factors. Summation of ones in the corresponding rows give the driving power and the summation of ones in the corresponding columns gives the dependence.

Table 1: Reachability set, antecedent set, iteration levels.

Factor Numbers	Reachability Set	Antecedent Set	IntersectionSet	Factor Levels
1	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8	
2	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 4, 6, 8	1, 2, 3, 4, 5, 6, 7, 8, 9	2, 3, 8	
4	4	1, 2, 3, 4, 5, 6, 7, 8, 9	4	I
5	4, 5, 6	1, 2, 5, 7, 8, 9	5	
6	4, 6	1, 2, 3, 5, 6, 7, 8, 9	6	
7	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 4, 5, 6, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 4, 5, 6, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	
2	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 6, 8	1, 2, 3, 7, 8, 9	2, 3, 8	
5	5, 6	1, 2, 5, 7, 8, 9	5	
6	6	1, 2, 3, 5, 6, 7, 8, 9	6	II
7	1, 2, 3, 5, 6, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 5, 6, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 5, 6, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 3, 5, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	
2	1, 2, 3, 5, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 2, 3, 7, 8, 9	
3	2, 3, 8	1, 2, 3, 5, 7, 8, 9	2, 3, 8	III
5	5	1, 2, 5, 7, 8, 9	5	III
7	1, 2, 3, 5, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 3, 5, 8	1, 2, 3, 7, 8, 9	1, 2, 3, 8	
9	1, 2, 3, 5, 7, 8, 9	1, 2, 9	1, 2, 9	
1	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	IV
2	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	IV
7	1, 2, 7, 8	1, 2, 7, 9	1, 2, 7	
8	1, 2, 8	1, 2, 7, 8, 9	1, 2, 8	IV
9	1, 2, 7, 8, 9	1, 2, 9	1, 2, 9	
7	7	7, 9	7	V
9	7, 9	9	9	
9	9	9	9	VI

Level Partition

As shown in Table 1, The reachability and antecedent set for each variable are obtained from final reachability matrix [3]. Earlier obtained driving force and dependence from Figure 8.6 helps to classify the factors into groups. Positions of these group are determined by the separation of antecedent and reachability sets. From these two sets an intersection set is established. Next the factors which are common in the reachability set and antecedent set are included in the intersection set. These three sets help to identify the level of the factors. When all the factors of the intersection and reachability sets of any certain factor are the same, then that factor is identified as the top level of the ISM hierarchy. When the top level factors are known, it is discarded from the list of remaining factors to identify the next level. This iteration process is repeated until all the levels are identified. For example, the first iteration is given by Table 2. Since factor 4 has the same reachability set as the intersection set, factor 4 will be the top level of the ISM hierarchy.

Formation of Digraph

The digraph is an illustration that shows the existence of the direct and indirect relationships between the factors. As shown in Figure 8.7, the relationship of sets and binary associations through matrices can now be translated into graphical form by using theory of digraphs (directed graphs) [30]. If there is a relationship between factors and j has impact on i, the connection between factors will go from j to i.

MICMAC Analysis – Classification of Performance Measures

The MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée á un Classement) (cross-impact matrix multiplication applied to classification) analysis is used to identify and to analyze the driving power and the dependence of the selected issues was developed by Duperrin and Godet in 1973 [31]. Through MICMAC analysis factors are arranged with respect to their driving power and dependence in four clusters [32]: (1) autonomous, (2) dependent, (3) linkage, and (4) independent factors. The driving power and dependence of each of factors are imported from Figure 8.6. Figure 8.8 shows the driving power-dependence map for refugee resettlement success factors.

8.4 Discussions

The factors affecting successful refugee settlement in a multi-project environment presented in Figure 8.7 show complex interactions among them. This complexity can be described using cyclomatic complexity through digraph as [33]:

$$M = E - N + 2P \tag{8.1}$$

where
E = the number of edges of the graph
N = the number of nodes of the graph
P = the number of connected components

The number of edges (depicted as arrows) shown in Figure 8.7 is 16, the number of nodes (depicted as rectangles) is 9 and the number of connected components, P is equal to 1. Then, the cyclomatic complexity M of the digraph given in Figure is

$$M = 16 - 9 + 2 \times 1 = 9$$

A higher number of cyclomatic complexity means that the complexity of an issue will be complicated to understand. The acceptable upper bound that has been used for cyclomatic complexity is 10 [33]. Since digraph gives close to a complexity of 10, the issue of refugee settlement is too complex to understand. As seen from Figure 8.7, issue of refugee settlement consist of multiple levels of combinations and

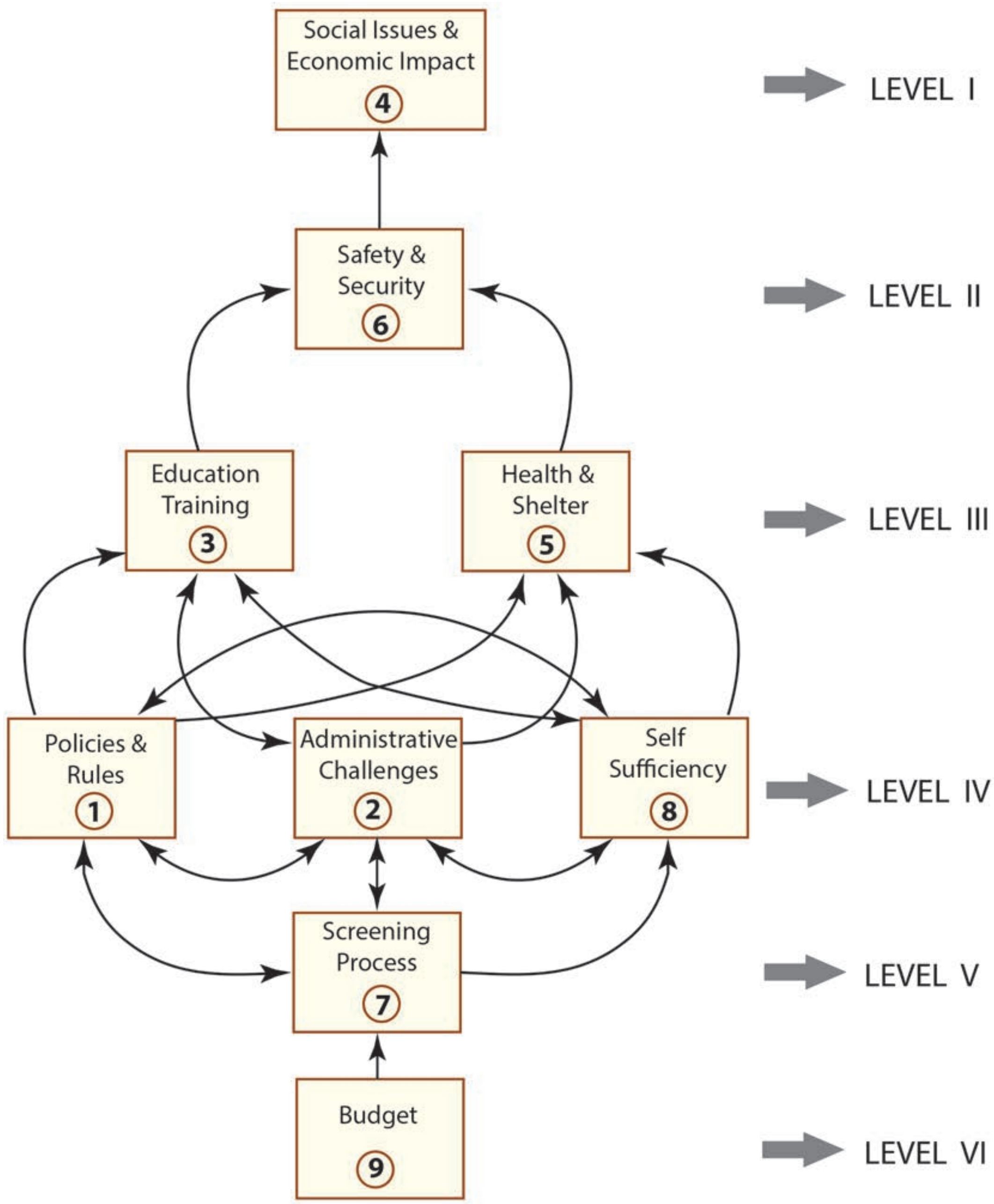

Figure 8.7: Digraph.

functional behaviors can arise at many of the levels. It is usually difficult in dealing

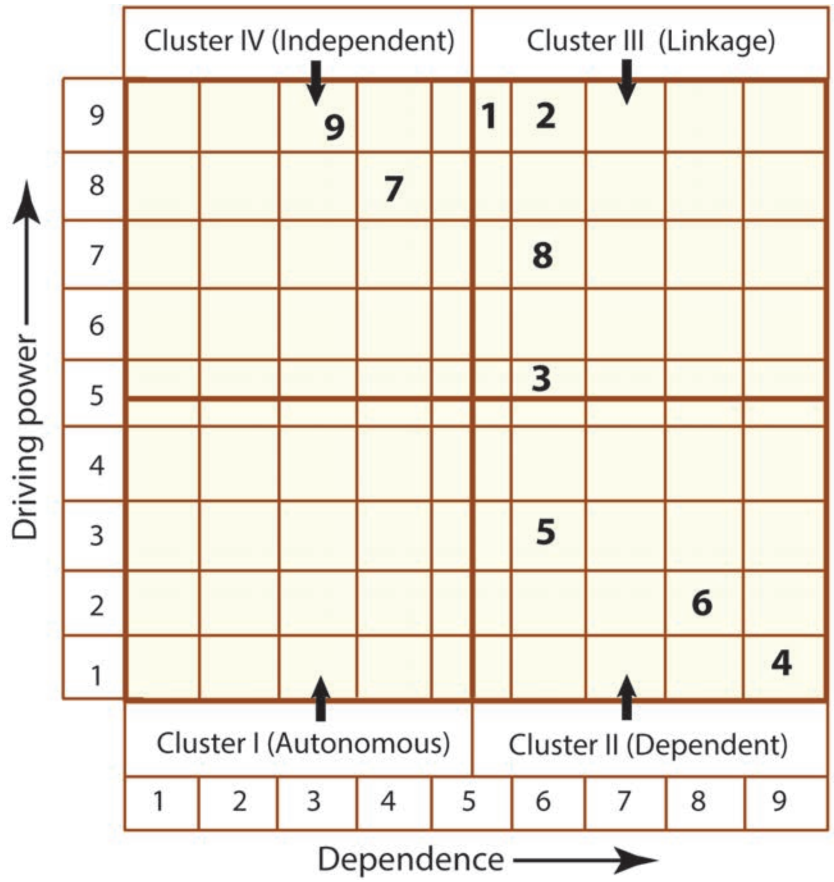

Figure 8.8: MICMAC Analysis.

with complex issues such as this one. The complexity of the refugee issue is due to the presence of many factors and interactions among these factors. The existence of directly or indirectly related factors complicates the solution of the issue which may or may not be articulated in a clear fashion.

The issue of refugee is complex and includes many factors. As shown in Figure 8.7, Level IV is the most complex one because of many interactions with the other levels. Administration plays important role for the success of the refugee settlement to implement policies and rules in order to help refugees become self-sufficient. Level IV effort should support education and training programs as well as health care needs which are crucial for refugees to adapt and make a life for themselves in a society. A source factor of establishing a realistic budget should be allocated to separated families, detained children, threatened immigrants and also all the required activities of secure and successful resettlement of refugees. However, this effort should not be at the cost of crucial education, housing, and nutritional assistance programs that promote public safety and improve poverty at hosting countries.

Figure 8 shows that there are no autonomous factors. The absence of these factors shows that all the considered factors influence the successful refugee resettlement. Hence, the management should pay attention to all the factors for a successful adoption of resettlement success measures. Health & shelter, safety and security, and social issues and economic impact are in the category of dependent quadrant. This means that this issue has little driving power but strong dependence (called driven factors).

The linkage cluster consists of four factors, including that the policies and rules (factor 1), administrative challenges (factor 2), Self-sufficiency (factor 8), and education and training (factor 3).These factors have strong driving power, as well as strong dependence power, therefore, they are considered as key factors for the success of the refugee settlement. These factors are critical, meaning that any action on these factors may influence the other factors and an effect on themselves by the other factors.

The fourth quadrant includes independent barriers that have a low dependence but strong driving power. In this research, budget & cost (factor 9) and screening process (factor 7) are in this quadrant. It can be assumed that these factors may be considered as the important key parameters, as well as the root cause of problematic issues. Management should give the greatest attention to these factors in order to meet the terms of the success of the goal of the refugee settlement.

As shown in Figure 8.7, factors safety and security (factor 6), social issues and economic impact (factor 4) are positioned at the top of the hierarchy. They are also very significant measures for the successful development of a refugee settlement as they are being affected by the other factors: living environment of refugees should be peaceful, humanitarian and civilian, free of violence and criminal activity, and conducive to the realization of human dignity.

8.5 Concluding Remarks

It has been shown that the issue of refugee settlement consist of multiple levels of combinations and functional behaviors can arise at many of the levels – the problem of refugee settlement is too complex to understand. In this research, budget & cost (factor 9) and screening process (factor 7) are considered as the important key parameters, as well as the root cause of problematic issues. Management should give the greatest attention to these factors in order to meet the terms of the success of the goal of the refugee settlement.

It is important to note that ISM is a tool to identify the order and directions of the complexity of relationships among the factors affecting certain issues. It does not provide any relative weight associated with the factors. Complex systems such as this one, require communications and exchange of information among responsible organizations. Information flow between organizations can be created using a Design Structure Matrix (DSM) in order to better map organizational responsibilities and their interactions to address the problems associated with the refugee resettlement. Clustering (integration) of organizations can provide new understandings into organizational decomposition and integration.

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CHAPTER 9

Is Transdisciplinary Education Engaging the 21st Century Engineering Student?

Bob Stroud

Objective evidence shows whether contemporary engineering students are engaged by transdisciplinary education. This is done by first using a diffusion of innovations approach that isolates "transdisciplinary engineering" occurrences on the Internet from occurrences of disciplinary engineering, and then showing trends, forming conclusions, and making recommendations.

Keywords: Transdisciplinary engineering, transdisciplinary education.

9.1 Introduction

Basarab Nicholescu, in his paper *Methodology of Transdisciplinarity – Levels of Reality, Logic of the Included Middle and Complexity* [1], states:

"Transdisciplinarity is a relatively young approach; Swiss philosopher and psychologist Jean Piaget (1896-1980) developed the concept seven centuries after disciplinarity evolved. The word itself first appeared in France, in 1970, in the talks of Jean Piaget, Erich Jantsch, and Andr Lichnerowicz at the international workshop 'Interdisciplinarity – Teaching and Research Problems in Universities,' organized by the Organization for Economic Cooperation and Development (OECD) in collaboration with the French Ministry of National Education and University of Nice." [2]

By definition, transdisciplinarity relates across multiple domains concurrently as in Figure 9.1 from Ertas [3, 4]. This chapter shows whether contemporary engineering students, generally in disciplinary engineering domains, are being engaged by transdisciplinary education. The approach taken by the paper uses the degree to which occurrences on the Internet can be used as measure of diffusion and adoption [5, 6] of transdisciplinarity into engineering education. Since occurrences are discoverable by extant search engines (e.g., Google Scholar), a measure of transdisciplinary engagement is the frequency that "transdisciplinary engineering" occurs on the Internet over time. This is similar to the approach used by Roberts [5], Wognum et al. [7], Lee and Burr [8], Stroud [9], and Vanasupa and Thurman [10]. Because

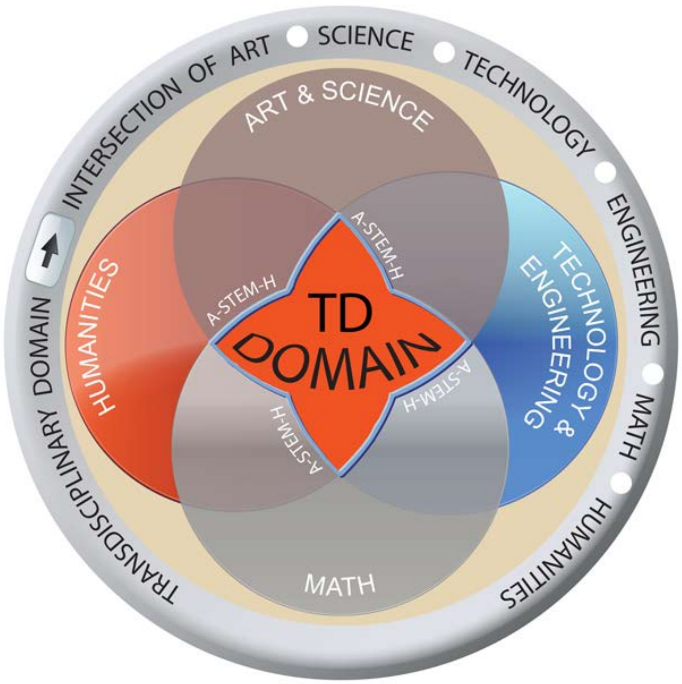

Figure 9.1: Ertas shows the transdisciplinary relationships among Arts, Science, Technology, Engineering, Math, and Humanities (A-STEM-H).

"transdisciplinary" integrates multiple domains, the search is carefully performed to isolate "transdisciplinary engineering" occurrences from *disciplinary* engineering occurrences.

9.2 Research Methodology

This chapter reports the results of time bounded occurrences of terms found on the Internet using Google Scholar. This is a numerical and not an inferential work like that of Adams [11]. It is merely indicative of the degree that transdisciplinary engineering is engaging contemporary engineering students via publications.

Recall that "transdisciplinarity" first appeared in 1970. The Internet occurrences (including patents and citations) returned by Google Scholar for "Transdisciplinary" and "Transdisciplinary Engineering" over five-year intervals beginning in 1970 are shown in Figure 9.2. Note the log scale in the ordinate.

These data show that cited occurrences increased for both "transdisciplinary" and "transdisciplinary engineering" with a dramatic increase in citations for "transdisciplinary engineering" in the last five-year interval.

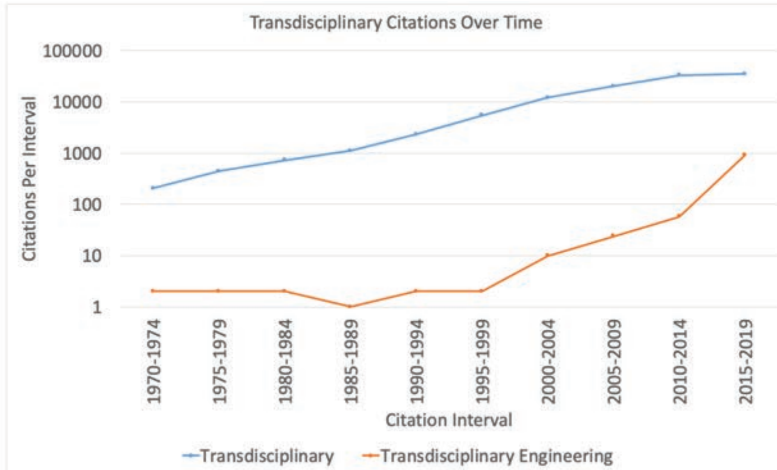

Figure 9.2: Internet occurrences for "Transdisciplinary" and "Transdisciplinary Engineering" over time since 1970 show increases over the period and that "Transdisciplinary Engineering" increased dramatically in the last five years.

Similarly, Figure 9.3 shows the occurrences for selected "disciplinary" engineering domains Electrical Engineering, Mechanical Engineering, Civil Engineering, Industrial Engineering, Petroleum Engineering, Nuclear Engineering, and Computer Engineering in the same intervals over the same period.

In the mainstream disciplines considered over the study period, all but "nuclear engineering" experienced a decline in the number of occurrences at or near the end of the study period, i.e., nearest the present time. This invites the question of whether this is somehow correlated with the "STEM" (Science, Technology, Engineering, Mathematics) concern that has the attention of the media, federal and state agencies, and legislative bodies in the United States [12-14] and elsewhere [15-17]. Or is it something else, such as an increase in emphasis on transdisciplinary engineering? Recall that "transdisciplinary" and "transdisciplinary engineering" occurrences, although far smaller in absolute terms, are not experiencing the same decline, though the increase in "transdisciplinary engineering" publications does not account for the apparent decrease in disciplinary publications.

The data show that the occurrences of "transdisciplinary" on the web over time since 1970 have increased slightly more than a factor of almost 200. Occurrences of "transdisciplinary engineering" on the web over time since 1970 have increased by a factor of almost 500. While occurrences of "transdisciplinary" were about 100 times more than occurrence of "transdisciplinary engineering" at the beginning of the study period (recall that "transdisciplinarity" was first used in 1970), by the end of the study period, the ratio was less than 40. One interpretation is that "transdisciplinary engineering" is further engaging those that publish their work, including students, in ways that are indexed and discoverable on the Internet. Further, disciplinary engineering occurrences increased over the survey period but almost all began to decrease from their peak near the present time. "Transdisciplinary" and

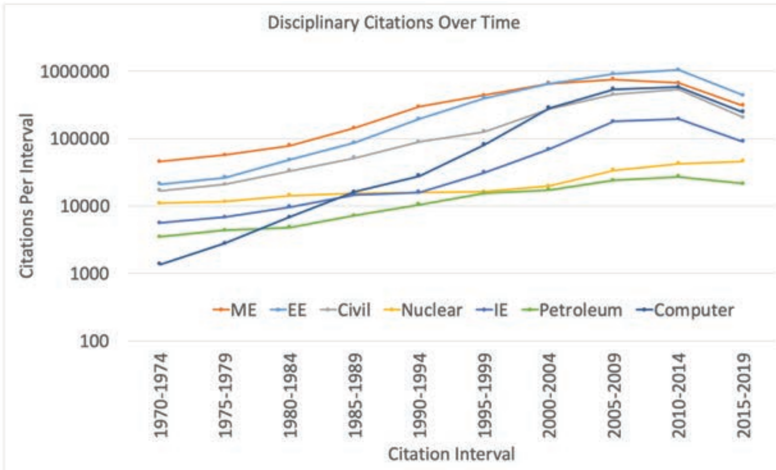

Figure 9.3: Internet occurrences for disciplinary engineering publications over time since 1970 show an increase over the period but a decrease in almost all of the last five years.

"Transdisciplinary Engineering" occurrences increased over the survey period, and continue to increase.

9.3 Discussion

The trend suggested by the change in occurrences of "transdisciplinary" and "transdisciplinary engineering" over time is positive – "transdisciplinary engineering" occurrences are increasing faster than "transdisciplinary" occurrences and both are continuing to increase compared to most disciplinary occurrences on the Internet over the same time period.

The ATLAS web site home page at "Transdisciplinary Activities" shows a large list of "Transdisciplinary Research Programs" and journals (not all of these are specific to "Transdisciplinary Engineering").[1] One indication is that "Transdisciplinary Engineering" is becoming more "observable" (leveraging this term from control theory [18]) at least from a web index perspective. A simple way to foster this is to include terms such as "transdisciplinary engineering" in key words and abstracts of papers indexed by journals and discoverable by search engines. This is the "pull" side of publish/subscribe [19].

On the "push" side of publish/subscribe, disciplinary engineering students need to see concrete instances of how Transdisciplinary Engineering can inform and strengthen their practice. How does it directly lead to more responsibility, authority, compensation, employment [20], or something else about which they care? If not directly, then how does it help engineers solve contemporary problems such as better understanding and therefore management of complex systems? For example, in *The Value*

[1] At http://theatlas.org/index.php/td-research-programs, accessed 31 July 2020.

of Transdisciplinary Collaboration in Robotics Education and Research [21], Santamaría shows how transdisciplinary engineering contributes to solving a contemporary problem in robotics through engineering and social science. *In Systems Engineering in the Fourth Industrial Revolution* [22], contributors Wognum, Mo, and Stjepandić offer applications of transdisciplinary engineering to an online hearing aid service system and a 3D printing licensing system. *In Transdisciplinarity for Sustainability: A Unifying Framework for Navigating Transformational Learning Systems* [10], Vanasupa and Thurman use a water capture and storage system as a model for an application of transdisciplinary engineering. *In Information and the Future of Transdisciplinarity* [23], Brenner notes that application of transdisciplinary principles to the engineering improves the common good by constructive contribution to the sustainable development of society through design and construction of devices that better reflect society's cognitive, social, emotional and informational needs.

A 2016 National Academies Workshop [24] noted "It may be that the traditional boundaries of disciplinary focus – reflected in the undergraduate 'major' and the graduate area of concentration – are becoming increasingly blurred, resulting in a need for greater emphasis on interdisciplinary and transdisciplinary approaches to classroom instruction and labs. Institutions of higher education increasingly recognize the need to ensure that students have experiences in multiple disciplines and have the opportunity to work with faculty and other students across many different areas of focus and concentration. Because the workplace of the future may be characterized by an even greater 'convergence' of disciplines (and by the need for more STEM-capable workers even among those not in traditional STEM careers), the undergraduate and graduate level experiences for all students increasingly need to reflect this reality as well."

A 2017 National Academies report [25] denoted engineering research as "Multidisciplinary research primarily focused on technological innovation" and transdisciplinary engineering research as "... research focused on high-impact societal challenges, exploiting technological convergence and especially bringing in the social sciences as appropriate."

In his 2018 book *Transdisciplinary Systems Engineering*, Madni [26] states "Engineering education, which is at the heart of the engineering enterprise, has not kept pace with the needs of the twenty-first-century workforce" and "Unfortunately, engineering education today continues to focus on individual disciplines and narrow technical domains, ignoring the immense potential of cross-disciplinary education enabled by disciplinary convergence. This mindset will clearly need to change if progress is to be made in transforming engineering education."

In *Philosophical Underpinnings of the Transdisciplinary Research Methodology* [27] in 2018, McGregor states transdisciplinary researchers (to include transdisciplinary engineering researchers) "would identify any relevant theories (if they exist) to underpin the research, or develop new ones if required, decide on which literature and best practice to review pursuant to the complex problem, and develop a method for sampling, collecting and analyzing data and *reporting* the integrated, synthesized results". Emphasis added by the author. *Reporting* is understood to mean publishing.

A 2019 National Academies Workshop [28] reports "Peer-reviewed journal publication remains a primary currency of success. For convergent efforts that involve interdependent teams, a number of participants identified the need to understand and capture researcher contributions to overall success as part of full authorship lists, rather than simply as first or last author. As with funding proposals, journals may increasingly need to develop a peer review process and review criteria that can accommodate efforts combining multiple fields as part of cutting-edge research, including multiple areas of science, engineering, medicine, and social and behavioral sciences."

The same workshop further reported: "The same issues of allocating credit on collaborative publications and recognizing the impact of integrative publications outside the primary disciplinary journals used by a researcher apply to the evaluation process for promotion and tenure. Many participants suggested that researchers whose projects cross disciplines deserve a process for obtaining credit when doing so. One participant described the tenure process as a choke point in the academic environment. In general, numerous participants stated a need to be more explicit about what is involved in convergence and which criteria can be used to measure success. How scientists judge other scientists is critical to the culture of the community, and many participants voiced support for reshaping processes for intellectual credit, peer review, and advancement to support convergence. One question for debate is whether to create new kinds of tracks – for instance, team science, transdisciplinary, or convergence-focused tracks – or to change promotion and tenure criteria to encompass a greater variety of career trajectories. If pursued, significant further stakeholder engagement would be necessary to design a convergence tenure track."

In their 2019 paper *To be or Not to be Transdisciplinary, That is the New Question. So, How to be Transdisciplinary?* [29], Pasquier and Nicolescu observe that pedagogy needs to be "integrative" and "implicative": "Integrative means that every form of transmission is useful depending on the moments and the contexts. Implicative signals that pupils are offered situations to become fully actors of the process of their learning." Here, the contexts and the situation include publication of research results so that all can benefit from research.

In a 2020 National Academies Workshop [30], Shrivastava stated that academics have fragmented conversations in higher education into more than 8,000 different disciplines in the United States alone and more than 15,000 in the world, since scholarly disciplines are defined differently around the world. He suggested not trying to integrate across 8,000 disciplines, which is impossible, but to look at problems on the ground. "What is it that needs to be solved? [Then] bring in the relevant conversations in resolving those issues. That's what transdisciplinary science tends to do."

Thus, there is wide agreement that transdisciplinary education is an important augmentation of undergraduate and graduate education in general and engineering education in particular.

9.4 Progress

To measure adoption of transdisciplinary engineering education practices, the degrees offered and curricula at three major universities were examined for transdisciplinary engineering content and compared over time to assess the extent of transdisciplinary engineering education.

In 2013, a representative for Texas A&M University (TAMU) in College Station, Texas stated[2] "I am happy to indicate that we working on developing an undergradu-

[2] The author earned a BSEE degree from Texas A&M.

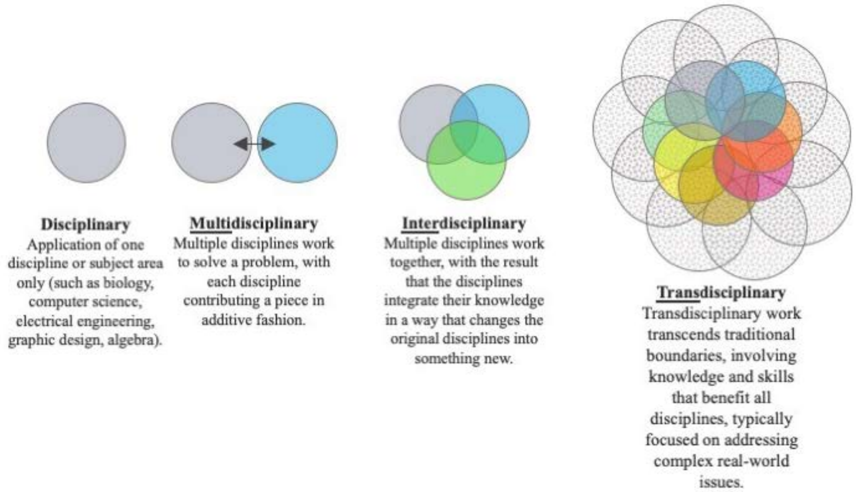

Figure 9.4: Distinctions between disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary applications ([31] as referenced in [25]; graphic adapted from Kelly and Burr [8]).

ate multidisciplinary engineering degree for the very near future. The goal is to allow students the flexibility of having breadth in multiple engineering disciplines to have concentrations in areas that require the breadth. We already have in place the graduate multidisciplinary engineering [Ph.D.] degree program, which is administered at the college level."

Elements of TAMU's engineering program are explicitly multidisciplinary or interdisciplinary but are not transdisciplinary in the sense shown in Figure 9.4 [8, 25, 31].

In 2013, "transdisciplinary" did appear in the course descriptions in the catalog, but in conjunction with departments or course offerings in English; Recreation, Park and Tourism Sciences; and Urban Planning, but not engineering. Third, except for two courses on generic directed studies and research, all the courses in the interdisciplinary engineering degree are drawn from traditional disciplinary programs.

In 2020, a similar examination of the course offerings at TAMU revealed just three courses whose descriptions includes the word "transdisciplinary". Two of these are graduate courses and one is an undergraduate course. None of these is an engineering course.

TAMU has made progress in integrating transdisciplinary education into its engineering program. For example, university engineering faculty and their students have been more active in conducting transdisciplinary engineering research: in 2019, the National Science Foundation (NSF) made an award for its "Transdisciplinary Research in Principles of Data Science" (TRIPODS) initiative to TAMU. Thus far, no technical reports derived from this funding have been published that include the word "transdisciplinary," suggesting their publication regime could be more transdisciplinary forward in ways suggested in this chapter.

In 2014, a representative from Southern Methodist University (SMU) in Dallas, Texas[3] had this comment regarding transdisciplinary engineering: "We don't have such a program. We do have a graduate design track in the ME department but not a Transdisciplinary design."

SMU offered a Ph.D. degree program in Systems Engineering that aimed to achieve the following educational goals:

- "Provide a solid foundation and depth in systems engineering theory and practice.
- Provide breadth across" transdisciplinary" engineering fields.
- Provide specialized contributions to the Systems Engineering Body of Knowledge through the Doctor of Philosophy dissertation."

Emphasis added by the author. An examination of the 2013 curricula at this university found the word "transdisciplinary" did "not" appear, and the course offerings do not appear to be transdisciplinary in the sense shown in Figure 9.4. For example:

"SYSTEMS INTEGRATION AND TEST. The process of successively synthesizing and validating larger and larger segments of a partitioned system within a controlled and instrumented framework is examined. System integration and test is the structured process of building a complete system from its individual elements and is the final step in the development of a fully functional system."

This was a reductionist approach [32] and not a transdisciplinary approach.

Five years later, the link to the Ph.D. program in Systems Engineering at SMU that could include transdisciplinary content is absent and the degree offerings no longer include the Systems Engineering Ph.D. program that had transdisciplinary content. This is representative of the continuing challenge facing diffusion of transdisciplinary engineering into engineering education.

Texas Tech University in Lubbock, Texas[4] in 2016 offered a transdisciplinary track in mechanical engineering that leads to a Ph.D. degree. The 2016 group was the fourth for this notionally four-year Ph.D. degree program that started over a decade earlier. The degree program for this track includes these three courses:

- Transdisciplinary Discovery and Innovation for Engineers
- Transdisciplinary Design Process & Systems Complexity
- Transdisciplinary System Development Lifecycle and Management

This program clearly applies transdisciplinary engineering education.

In the United States in 2020, neither the Congressional Research Service (CRS) nor the Government Accountability Office (GAO) had relevant publications on transdisciplinary engineering. CRS had no reports that contain the word "transdisciplinary" while GAO had just 8 reports, none on transdisciplinary engineering. This is another avenue for diffusion of transdisciplinary engineering in the United States: further involve government.

Finally, this chapter is an extension of work reported in 2016, and considers five additional years of corpora. Over the time elapsed since the prior work, there has been a dramatic increase in the peer reviewed published literature on "transdisciplinary engineering," indicative of further integration of transdisciplinary engineering into the undergraduate and graduate engineering program of study. But this increase

[3] The author earned a MSEE degree at SMU
[4] The author earned a Ph.D. ME degree from Texas Tech

in publication is not uniform across the university engineering education community, leaving further opportunities for advances.

9.5 Conclusions

In 1999, in his round table discussion paper *The Transdisciplinary Evolution of Learning*, Nicolescu said [33] "While not a new discipline or a new super-discipline, transdisciplinarity is nourished by disciplinary research; in turn, disciplinary research is clarified by transdisciplinary knowledge in a new, fertile way. In this sense, disciplinary and transdisciplinary research are not antagonistic but complementary" and "The learning places should encourage and stimulate publications which record and analyze the major examples of innovative experience."

This chapter accords with these premises. It shows the diffusion of transdisciplinary engineering into disciplinary engineering education can be measured by the number of publications that include key phrases such as "transdisciplinary engineering."

Transdisciplinary Engineering is still a small subset of the transdisciplinary publication domain but the rate of increase of "transdisciplinary engineering" occurrences on the Internet is faster than that of "transdisciplinary" occurrences on the Internet.

This trend indicates improving establishment of "transdisciplinary engineering" in general and of transdisciplinary engineering education in particular.

Disciplinary engineering occurrences seem to be decreasing at the present, and this may be an indicator of an underlying "STEM" problem that is not in the scope of this chapter.

The endorsement of transdisciplinary engineering in secondary education may be improved by changing way promotion and tenure criteria emphasize transdisciplinary engineering.

Engineering educators should encourage the use of transdisciplinary engineering words in the publications of their research and the research of their students.

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About the Author

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CHAPTER 10

Being in the Hidden Third: Insights into Transdisciplinary Ontology

Sue L. T. McGregor and Paul Gibbs

This paper reflects two transdisciplinary (TD) scholars' attempts to glean deeper insights into Nicolescu's transdisciplinary ontology (i.e., multiple Levels of Reality and the Hidden Third). Respecting that Nicolescu's Hidden Third represents the convergence of quantum physics, philosophy, and inner experiences, one TD scholar explored 'What is it like to be in the Hidden Third?' by expanding on Nicolescu's constructs of cyber-space-time and transhumanism, which are grounded in quantum physics. The other TD scholar tendered philosophical insights by offering the idea of ontological emergence and the act of becoming as informed by the transcendentals. The intent was to understand 'the being of being' or perhaps 'the being of becoming.' The richness of Nicolescu's ontological thinking offers a range of interpretation, and we are grateful for the opportunity to feed off his methodological genius to respectively flourish through questions, clarification and truth seeking.

Keywords: Transdisciplinary ontology, cyber-space-time, transhumanism, ontological emergence, the transcendentals.

10.1 Introduction

In his formulation of a transdisciplinary methodology (i.e., a new way to create knowledge), Nicolescu (1985, 2002, 2016) [1, 2, 3] conceptualized the Hidden Third as the anchor of his formulation of ontology (i.e., reality, being, becoming, existence, existing). He considered the Hidden Third to be the spirit-opening, lubricating and unifying force that brings together divergent minds to address complex issues. During an email exchange (May 28, 2020) about a paper Paul Gibbs was writing about transcendentals and the unity of being, Paul serendipitously used the phrase*being in the Hidden Third*. Sue L. T. McGregor took this to mean 'What is it like to be in the Hidden Third?' Paul had actually meant, philosophically,"the being of being.' This paper emerged from our subsequent transdisciplinary (TD) conversations and collaboration.

It shares our respective musings about the Hidden Third, "which is at the same time scientific and philosophical" (Tavares, 2016, p. 9 [4]). The Hidden Third is "a point of convergence between quantum physics, Philosophy of Nature and inner experience" (Tavares, 2016, p. 9 [4]). We agree with Tavares' (2016) [4] premise

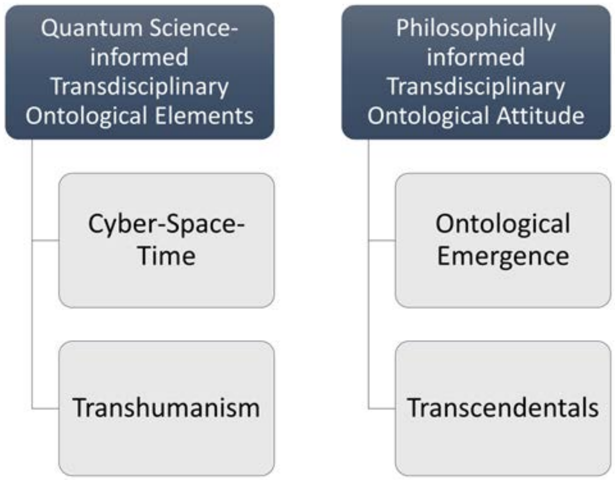

Figure 10.1: Quantum science and philosophically informed augmentations of Nicolescuian transdisciplinary ontology.

that encountering the phrase being in the Hidden Third was "the inception of a process where the greatest quantity of a substance is concentrated, something the development of that process is only going to dilute" (p. 10). We accept Tavares' (2016) caution that our attempts to explore what this phrase meant to each of us might dilute the power of the original phrase, which inspired us in the first place. But we offer this paper in anticipation that it will help others engage with Nicolescu's ontology, which is the most misunderstood aspect of his methodology. Resistance to his formulation of ontology has created "an unconscious barrier to a true dialogue" about transdisciplinary methodology (Nicolescu, 2010b, p. 23) [5].

The paper begins with a succinct orientation to Nicolescu's formulation of transdisciplinarity, which is augmented with a detailed discussion of his ontology. This is followed with Sue's thoughts on 'What is it like to be in the Hidden Third?' Her contributions herein reflect quantum physics per Tavares' (2016) [4] suggestion that the Hidden Third is partly understood through science. Having teased out other aspects of Nicolescuian ontology in another paper (McGregor, 2011) [6], she focused on cyber-space-time and transhumanism herein thereby extending two additional ontological elements. By sharing his thoughts on 'the being of being,' Paul tendered philosophical insights into the Hidden Third (per Tavares, 2016) [4]. He offered the idea of ontological emergence and the act of becoming as informed by the transcendentals – an ontological attitude (see Figure 10.1).

10.2 Overview of Nicolescuian Transdisciplinarity

When formulating transdisciplinarity, Nicolescu (2002) [2] used three philosophical axioms: (a) reality comprising the TD-Object, TD-Subject, and the Hidden Third

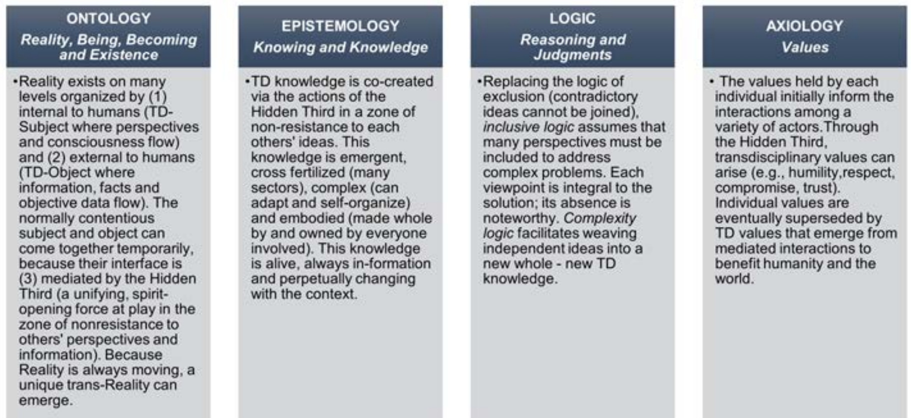

Figure 10.2: Nicolescuian transdisciplinary axioms.

(ontology); (b) knowledge as complex, emergent, cross fertilized and embodied (epistemology); and (c) logic (inclusive and complexity). Succinctly, he theorized that today's complex problems cannot be adequately addressed using fragmented mono, multi or interdisciplinarity, because these are constricted to the academy (respectively, one academic discipline, more than one, or between two or more). Complex issues like climate change and unsustainability can only be responsibly addressed by drawing on knowledge generated at the interface of university academic disciplines *and* the rest of the world (e.g., civil society, governments and businesses).

This approach respects the need to realign the sciences with humanity (Nicolescu, 2014) [7]. But the diverse nature of these sectors opens the door to extreme challenges in bringing such disparate mindsets together to address a problem. To accommodate the complexity of this knowledge creation process, Nicolescu tendered revolutionary formulations of what counts as reality, knowledge, and logic (reasoning, judgements and insights) (see Figure 10.2 and McGregor, 2018, [8] for a detailed overview). This paper concerns ontology (reality) and was prompted by Paul's turn of phrase *being in the Hidden Third.*

10.2.1 Transdisciplinary Ontology

Succinctly, Nicolescu (2002) [2] postulated that instead of one reality waiting to be discovered using the scientific method, there are multiple levels of Reality (he capitalizes Reality) organized along two levels (see Figure 3). One level concerns subjective Reality (TD-Subject), so called because it deals with the internal flow of perspectives and consciousness. Included are individual psychology and philosophy, family, community, society, history, and political ideologies. The other level concerns objective Reality (TD-Object), so called because it deals with the external flow of information, facts, statistics and empirical evidence. Examples include economics (business and law), technology, science and medicine, ecology and environment, planetary (worldwide and global), and cosmic and universe (Nicolescu, 2002, [2] 2014) [7].

Each level of Reality is different, but "every level is what it is because all of

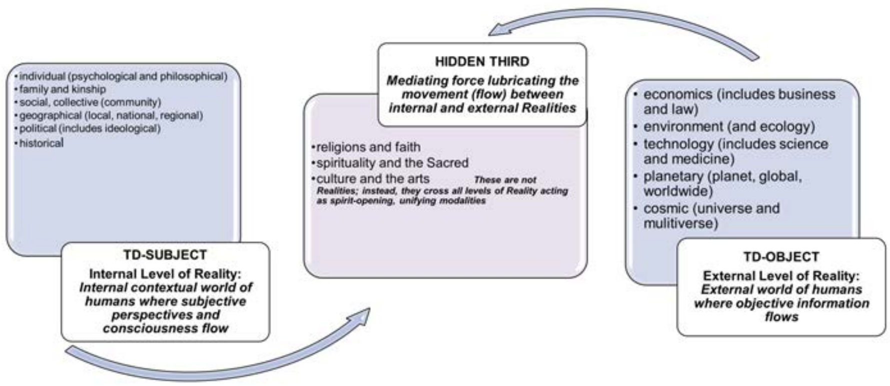

Figure 10.3: Nicolescuian transdisciplinary ontology.

the levels exist at the same time" (Nicolescu, 2014, p. 207) [7]. For example, every economic system is different, but a particular economy *is what it is* because of the political, geographical and technological realms within which it is embedded. Also, "studies of the universe [TD-Object] and the human being [TD-Subject] sustain one another" (Nicolescu, 2014, p. 208) [7]. Respectively, knowledge is at the same time exterior and interior; it is not one or the other nor is one more privileged *than* the other (Nicolescu, 2014) [7]. An inclusive, integrated knowledge is needed to address complex problems, and the creation of that knowledge requires both subjective and objective Realities.

To deal with complex problems, people must come together and interact. Such a problem might be building a new dam that will flood certain communities but provide power to the entire nation. Nicolescu (2002) [2] recognized the real possibility of tension, antagonism and contradiction among people during these interactions. To accommodate this aspect of creating transdisciplinary knowledge, he formulated the new notion of entering a zone of nonresistance to each other's ideas (the so-called neutral, included middle ground). He suggested that tensions created by movement between and along the many levels of conflicting subjective and objective Realities (see Figure 3) can be mediated by the Hidden Third (Nicolescu, 2002) [2]. This was his name for the unifying modalities that open people's minds to others' ideas (Eric Reynolds, personal communication, August 15, 2018).

The Hidden Third (like a middleman in a contentious negotiation) comprises art, culture, religion, faith, spirituality, and the Sacred (i.e., a sense of everything being connected) (Nicolescu, 2002) [2] (see Figure 3). It is well established that these creative and mind-opening outlets can successfully be used to build a shared identity and common purpose that transcends differences and conflicts (Bergh & Sloboda, 2010) [9].

In a recent paper, Nicolescu expanded on his explanation of TD ontology by referring to the TD-Object as "natural information" and the TD-Subject as "spiritual information" (Versluis & Nicolescu, 2018, p. 17) [10]. Natural information (external to humans) can be *measured* using instruments or experiments, but people *experience* spiritual information in their interiority (i.e., their inner thoughts, feelings, reactions). The TD-Subject is internal to humans, and its existence is totally dependent on the mind (McGregor, 2018) [8]. Both natural and spiritual information share the zone of nonresistance. Because of the unifying effect of the Hidden Third, the mediated flow of both natural and spiritual information across different levels of Reality can lead, respectively, to “the fusion of knowledge and being” (Versluis & Nicolescu, 2018, p. 19) [10].

In order to navigate the diversity of positions and values brought to the table in the zone of nonresistance, Nicolescu (2002) [2] recommended using inclusive logic. This replaces exclusive logic, which assumes that antagonistic and contradictory ideas cannot be connected – an idea expressed through *either/or* thinking (Brenner, 2008) [11]. Inclusive logic assumes instead that “that which appears to be disunited is united, and that which appears to be contradictory is perceived as noncontradictory” (Nicolescu, 2008b, p. 7 [12]). This represents *and/or* thinking. Nothing is excluded up front, because it may be necessary for the solution or the process of getting to the solution. Employing inclusive logic when contradictory ideas interact can better ensure a temporary resolution of antagonism, so that something new can emerge.

10.3 What is it Like to Be in the Hidden Third?

Via the Hidden Third, barriers come down between people and minds are opened, so something new can emerge. In an earlier, far-reaching exploration of TD ontology, Sue (McGregor, 2011) [6] had discovered Nicolescu’s formulation of multiple levels of Reality, which he theorized are plastic, malleable and always moving (Nicolescu, 2008a) [13]. “Reality cannot be reduced to substance; instead, reality is the complexus (an aggregate) of substance-energy-space-time-information” (McGregor, 2011, p. 7 [6]). Movement among these five elements is constant, meaning it is impossible to arrive at an exact and complete portrait of Reality (Nicolescu, 2008a) [13].

However, through people’s interactions in the zone of nonresistance mediated by the Hidden Third, a new Reality (called trans-Reality) is created for each complex problem being addressed. To explain, if TD-Subject is one circle and TD-Object is another circle, trans-Reality is the point (x marks the spot) where their edges touch. Trans-Reality is beyond all Realities, yet it exists at the same time (Nicolescu, 2002 [2], 2014 [7]). In this paper with Paul, Sue has augmented her understandings of what it is like to be in this space by exploring two additional elements used by Nicolescu (1999 [14], 2002 [2], 2014 [7]): cyber-space-time and transhumanism. What follows is her personal understanding of these two concepts informed by iterative readings of and musings over Nicolescu’s scholarship. Any erroneous interpretations (i.e., Nicolescu unintended) are her own.

10.3.1 Cyber-Space-Time

Nicolescu’s (2002, 2014) [2, 7] notion of *cyber-space-time* (CST) is of relevance to a discussion of ‘What is it like to be in the Hidden Third?,’ because he identified CST as a key aspect of the logic of the included middle, which people use in the Hidden Third. By way of background for CST, classical physics (general relativity) respects the four-dimensional space-time continuum. It “fuses the three dimensions of space and the one dimension of time into a single four-dimensional manifold” (“Spacetime,” 2020, para. 1 [15]). This “mathematical model joins space and time [past, present and future] into a single idea called a continuum” (“Spacetime,” 2020, para. 1

[15]), which is Latin *continuus*, 'uninterrupted' (Harper, 2020) [16]. The space-time continuum concerns the continuity of time (i.e., an unbroken, consistent existence), which is considered linear and moves in a straight line. There is a beginning, the passage of time and an end. Humans mark linear time by using clocks, calendars and day planners (Gibbs, Ylijoki, Guzmán-Valenzuela, & Barnett, 2014 [17]; Nicolescu, 2014 [7]).

The space-time continuum holds that time and space are closely linked and are even used to define each other. To illustrate, space is Latin *spatium*, 'a period or stretch of time' (Harper, 2020) [16]. H. G. Wells (1895) [18] said, "Time is only a kind of Space" (p. 10). Time and space are also thought to be smooth and continuous – no disruptions (Nicolescu, 2014) [7]. Pragmatically, "one cannot pass from one point of space and of time without passing through all intermediate points" (McGregor, 2011, p. 2 [6]) (i.e., no reversals, exceptions or skipped stages). Imagine time as marked by a clock; one cannot go back or skip any hours or minutes. To address a complexly wicked problem using this conceptualization of space-time, people would follow a series of steps or formulae, likely ineffectively.

Conversely, quantum physics (i.e., the theory of quantum mechanics) assumes that space-time is *not* always continuous (Nicolescu, 2014) [7]. In contrast, *discontinuous* (i.e., intervals, gaps, interruptions) means that, between two points, there is a gap of potentialities (McGregor, 2011) [6]; in other words, there is a quantum vacuum, which is at its lowest level of energy, but it is *not* empty [7]. Things can arise in this gap (Paul philosophically discusses *things*).

In more detail, when addressing a complex problem, people would remain open to possibilities and emergence while respecting the power of interruptions and bifurcations (i.e., branching off in different directions). They would eschew the principle of continuity (linearity) and remain open to nonlinearity (i.e., not sequential, not straight forward, not smooth progress forward). When nonlinearity is present in complex thinking scenarios, the dynamic can become quite chaotic (unpredictable) with the assumption that order is emerging just not predictably (Liang, 2017) [19]. For Nicolescu, discontinuity (i.e., the gap) "reflects the dark light of the unknown that paradoxically cooperates with the known by injecting information [i.e., new light] into the Kosmos" (personal communication, January 10, 2011).

Respecting discontinuity (i.e., the presence of gaps and interruptions) instead of continuous space-time, transdisciplinarity engages with *discontinuous cyber*-space-time (CST) (Nicolescu, 2002, 2014) [2, 7]. *Cyber* is a word-forming element from cybernetics, which is the theory and study of communication and control (Harper, 2020) [16]. Cyberspace is the notional (in the mind only) environment in which communication over computer networks occurs (Anderson, 2014 [20]; Mihalache, 2002 [21]). A contemporary example is the Internet, which is also called cyberspace (Gálik & Tolnaiová, 2019) [22]. Indeed, the networked computer (cyberspace) represents a ubiquitous logic that has transformed and connected virtually all aspects of the global economy, culture and society (Gibbs et al., 2014) [17]. But the term cyberspace is being used in other areas beyond the Internet as in this instance by Nicolescu.

First coined in the early eighties, adding the word *cyber to space-time* was a way to capture the phenomenon of a previously nonexisting space that emerges in the process of communication and development (Gálik & Tolnaiová, 2019 [22]; Mihalache, 2002 [21]). From a transdisciplinary perspective, put simply, as people engage in the zone of nonresistance mediated by the Hidden Third, a new space is born, which Nicolescu (2002) [2] called cyber-space-time. He proposed that inclusive logic is at work in this space, which is "the transcultural, transnational and transpolitical ... space of human choice" (Nicolescu, 2002, p. 82 [2]); that is, people choose to work with disparate minds (e.g., cultures, nations, politics) and strive to move beyond all of them to a new space within which to address a complex problem.

Nicolescu (2002) [2] further argued that, beyond assuming that cyber only means technology, bringing the *human* into cyber-space-time "alerts us to a new level of perception..., which reveals a world that breaks radically with the macrophysical world in which we pass our life. This 'new world' is not ruled by classical logic" (p. 79) (see also Gibbs et al., 2014 [17], who said cyberspace has its own logic). Instead, Nicolescu (2002) [2] formulated that moving around CST requires people to use inclusive logic to navigate interactions between subjective and objective worlds much like they would use nonlinear logic to navigate the Internet (e.g., Boolean searches using *and/or*).

Nicolescu (2002) [2] considered cyber-space-time a connecting principle that bridges mind (TD-Subject) (perceptions and consciousness) and matter (TD-Object) (facts, evidence, statistics) to make levels of perception more evident as people cross realities and communicate. In the Hidden Third, "time and space [are] linked by a relationship of contradiction" (Nicolescu, 2014, p. 132 [7]). Brenner (2003) [23] described CST as a "currently emergent level of reality" (p. 173). Nicolescu (2008a) [13] similarly described Reality as always moving, always fluctuating – hence emerging and becoming.

In this emergent reality, space is no longer viewed as smooth as in the classical space-time continuum. Instead, space in CST is depicted as *spacetime foam* (Wheeler, 1955) [24] or "*quantum foam* to describe the turbulence [and tension]" (Nicolescu, 2014, p. 67 [7]) among people as they strive to assimilate divergent views on a pressing matter. Instead of linearly moving through the "*distance between points*" (continuity) (Nicolescu, 2014, p. 68 [7]), people would move through a complex and turbulent space comprising a mass of small, transient (quantum) bubbles. Thus, CST comprises many small, ever-changing regions. Therein, space and time are not definite but fluctuate in a foam-like manner (Wilczek, 2010) [25]. When addressing complex problems, these small bubbles could represent emergent and evolutionary pockets of conversations, coming and going as the problem, people and knowledge evolve.

Another notable characteristic of CST is that it is simultaneously artificial *and* real just with different degrees of materiality (Nicolescu, 2002) [2] – in other words, it is more than dualistic '*either* artificial *or* real.' Also, within this space, there is a close relationship between the material (matter, artifacts) and the cognitive (mind, intelligence) (Lemos & Kern, 2009). [26] This premise aligns, respectively, with Nicolescu's (2002) [2] TD-Object and TD-Subject.

CST is also viewed as a network of collective intelligence characterized by hyperconnectivity (Lemos & Kern, 2009) [26]. If something is hyper, it is unusually energetic and maybe excessive (Anderson, 2014) [20]. Hyperconnectivity within cyber-space-time assumes that people who need to communicate *will* and *do* communicate (Ranadivé, 2003 [27]; Wellman, 2003 [28]). Cyber-space-time is thus an immersive environment of social communication (Lemos & Kern, 2009) [26] that depends on networks (Ranadivé, 2003) [27].

Madni (2019) [29] further linked hyperconnectivity with both growing complexity and an increasing convergence among academic disciplines. The same holds for Nicolescu (2002) [2] who focused on complexity and envisioned the convergence of disciplines with the life world. The verb *converge* means coming together from different directions to eventually meet (Anderson, 2014) [20]. This is exactly what happens in the zone of nonresistance, where people open themselves to others' perspectives and information, a process that is mediated by spirit- and mind-opening aspects of the Hidden Third (e.g., art, theatre, music, drama, faith, culture).

In summary, "cyber' space is a ritually created space of liminality with transformative properties" (Barbatsis, Fegan, & Hansen, 1999, last paragraph [30]). To break this down, rituals (i.e., habitually followed series of actions) can be used to create relations among people, and subsequent relations help to constitute the whole. A ritually created space emerges from rituals (Iteanu, 1990) [31]. A liminal space is barely perceptible – neither here nor there. When people enter it, they stand on a threshold, where something can cease to exist or can come into existence; it transforms (Turner, 1974) [32].

Respectively, in summation, when addressing complex problems, diverse people can operate within a ritually created space (CST) as they temporarily set aside their way of viewing things, cross the threshold and step into the liminal space (i.e., the zone of nonresistance mediated by the Hidden Third) where perspectives, consciousness and information can transform and be integrated into new knowledge using inclusive and complexity logics (Nicolescu, 2002, 2014) [2, 7].

Sue proposes that cyber-space-time and what it constitutes is part of what it is like to be in the Hidden Third. Another element related to being in the Hidden Third is transhumanism. Tirosh-Samuelson (2007) [33] asserted that "transdisciplinarity... captures the new state of affairs in human knowledge as much as transhumanism captures the new human condition" (p. 3).

10.3.2 Transhumanism

Nicolescu (1999) claimed that cyberspace allows the advent of a new humanism. In the spirit of *transdisciplinarity*, he called this *transhumanism*. By way of background, *humanism* (sans trans) is a thought system that attaches importance to humans instead of the divine or supernatural (Anderson, 2014; Rohmann, 1999) [20, 34]. This 17th century philosophical movement held that people should rely on their own observations and judgments instead of deferring to religious authorities to interpret life for them (Bostrom, 2005) [35].

Transhumanism is conventionally thought to be a subsequent 20th century philosophical movement focused on transforming the human condition by using technology and science to enhance both human intellect and physical attributes. People would use science and technology to evolve beyond their current physical and mental limitations (Bostrom, 2005 [35]; Tirosh-Samuelson, 2007 [33]). The crux of this conceptualization of transhumanism is the role technology plays in humanity's evolution (Tirosh-Samuelson, 2007) [33]. As a caveat, Nicolescu (2014) [7] would caution that humans should harness technology and science rather than be enslaved by them. Without due care, their use can negatively impact humanity and snare and enframe nature in the service of humans thus distorting Reality.

Indeed, when Nicolescu (1999) [14] linked cyber-space-time with transhumanism, he expanded its meaning beyond human physical and intellectual transformation via technology and science. He comprehensively viewed transhumanism as offering "each human being the maximum capacity for cultural and spiritual development" (Brenner, 2003, p. 177 [23]) (Paul addresses human potential and development as well). Eminent psychologist Abraham Maslow (1969) [36] positioned transhumanism at the top of his hierarchy of human needs by placing it above self-actualization. Cerma (2008, p. 167 [37]) explained that Maslow viewed transhuman as "centered in the cosmos" instead of in human needs. Maslow assumed that humans can place universal values like justice and rights above meeting their own needs (Koltko-Rivera, 1998) [38]. These values liken to Nicolescu's (2010a) [39] position on transdisciplinary values (to be discussed), which are much more than and far beyond each person's self-interest – they are *trans*personal as required for *transdisciplinary* engagement.

Indeed, for Maslow, transhumanism was "a transpersonal approach that focuses on amplified and transcendent states of consciousness" (Cerma, 2008, p. 167 [37]). Nicolescu's (2002) [2] formulation of the TD-Subject is intentionally grounded in consciousness (and perspectives), and the Hidden Third deals with spirituality and the Sacred (see Figure 3). Regarding the former, consciousness is an umbrella term for "a wide variety of mental phenomena" (Van Gulick, 2014, p. 4 [40]). It can mean sentience, wakefulness, self-awareness and being aware, or being conscious of something. Consciousness can be a state, a stream or an availability to interact (Van Gulick, 2014) [40]. Nicolescu (2005) [41] believed that the brain and mind encompass different levels of Reality and perception, which is why he placed consciousness in the TD-Subject.

Also, for Nicolescu, spirituality (in the Hidden Third) reflects introspection and interiority; that is, the *inner* field for transcendence (Versluis & Nicolescu, 2018) [10]. They explained that people can analyze an object or event to create external knowledge (e.g., chemically analyze an old painting and prepare a scientific report), but through their *consciousness* (TD-Subject), their *interior* experience of this object or event is entirely different from the written report.

Nicolescu (2014) [7] held that people cannot fully understand a complex problem (e.g., the painting metaphor) unless there is a connection between inner consciousness and external information; that is, TD-Subject and TD-Object. Respectively, this refers to both viewing and experiencing the painting, reading the scientific report about the painting and then coming to some judgement or assessment. A richer understanding will emerge from their conjoining. And like spirituality, the Sacred (i.e., a deep connection between people, their common life and the Earth) lubricate movement among the different levels of Reality (i.e., consciousness and information) (Nicolescu, 2014) [7]. That connection is more likely, if people can appreciate the power of and be motivated by Nicolescu's (1999) [14] formulation of transhumanism.

Indeed, transhumanistic refers to "a motivational state in which the person seeks something beyond personal benefit" (Koltko-Rivera, 2006, p. 305 [42]); that is,*trans*personal. Transhumanism concerns situations where a person is "motivated by values which transcend his [sic] *self*" (Maslow, 1969, p. 4 [36]). Maslow (1969) [36] called these "transcendent values, [because they are outside (beyond) a person and are focused instead on] ultimate verities [such as] truth, goodness... justice or order" (p. 3). Put simply, people would temporarily set aside their own needs and self-interest for some higher cause (Koltko-Rivera, 2006) [42].

Similarly, Nicolescu (2010a) [39] maintained that transdisciplinary values arise from work undertaken through the Hidden Third to address complex, wicked problems; in effect, a higher cause than self-interest. Nicolescu does not have a fourth axiology axiom, although Figure 10.2 does include it, so readers can appreciate his understanding. He asserted instead that emergent transdisciplinary values are what matter not the values people hold initially when they enter the zone of nonresistance to address the complex problem.

Rather, being in this space means respecting the emergence of specific values that are integral to generating new knowledge for a particular complex problem. Integral means they are necessary for completeness. Their absence would be notable. The new knowledge that *does* emerge is dependent on *particular* TD values engendered via the Hidden Third (McGregor, 2018) [8]. Examples of TD values that motivate people to work toward a cause higher than themself include humility, compromise, trust, tolerance and respect. Jointly agreeing that these values are important helps the work get done, so that new knowledge can arise.

In summary, unpacking cyber-space-time and transhumanism offers a clearer picture of how Nicolescu understood ontology. Cyber-space-time offers interconnectivity, the necessity and power of networking, and the principle that those who need to communicate with each other *will* do so. It frames transdisciplinary work as comprising many small, ever-changing regions whose navigation must be facilitated. The resultant work arising within these networks (small bubbles) is described as collective intelligence.

Cyber-space-time also serves as a bridge (i.e., interconnection) between mind (TD-Subject) and matter (TD-Object). It moves people through relationships that are rife with contradictions *and* possibilities by helping them better appreciate divergent perspectives on the problem. People are seen as stepping onto and across a threshold, where transformation leads to the emergence of new knowledge to address the complex problem.

Transhumanism enables those interested in TD ontology to assume that people can temporarily set aside their personal needs for a larger, higher cause. They can become open to suspending their self-interest and personal gain, so the divergent group of agents can focus on universal truths such as peace, order, rights, justice and sustainability. Transhumanism also offers the idea of amplified states of consciousness, which strengthen the work of the Hidden Third.

Harken to the example of building a new dam that will flood certain communities but provide power to the entire nation. Transhumanism assumes people can move beyond themselves for the greater good – the higher cause. Conversations among those affected by the dam issue will have to address what that higher cause might be and work to *that* valued end – from a *trans*personal space. The higher cause might be the nation, or it might be the impacted communities. Regardless, it is greater than (transcends) one person's self-interest.

10.4 The Being of Being

The Hidden Third transforms TD-Object and TD-Subject into a respective "fusion of knowledge and being" (Nicolescu, 2014, p. 212 [7]). Paul is philosophically interested in the being part of this fused state. In his own words: my philosophical approach to 'the being of being' hinges on Nicolescu's (2008a) [13] formulation of TD ontology (reality and being) with Reality constantly in flux, plastic and malleable. But not only is Reality always changing – so are the people engaged in TD work to co-create a new trans-Reality replete with co-created TD knowledge (McGregor, 2004) [43].

Paul believes that the pervasive transdisciplinary principle of *emergence* (Nicolescu, 2002) [2] encompasses the notion that we are always in the process of development. Such *becoming* cannot be adequately described only in deterministic ways as is assumed in mechanistic and scientific analogies of being. This process is primordially transdisciplinary, for it is best explored in its own terms not that of disciplines. I call this *ontological emergence*. Let me elaborate for your consideration.

10.4.1 Actualizing Potential through Ontological Emergence

In his metaphysics of transdisciplinarity, Nicolescu's (2010b) [5] focus on levels of Reality provides a wholeness in a cosmological process in which *being* is constantly changing within the Realities that it creates. In accepting his fundamental premise of the ontology of transdisciplinarity, I want to briefly explore an issue that is central to my reading of his ontology: the notion of change that is initiated by *causal power,* which refers to the likelihood that a cause actually caused the change or the effect (Luhmann & Ann, 2005) [44].

Instead of how causal power causes change, I am interested in how change in causal powers (passive, active and actualized) is the energizing force that enables our potentiality to flow (evolve and emerge) into the actual. Key to this emergence is potential, which has the Latin root *potentialis*, 'power' (Harper, 2020) [16]. This causal power is akin to the latent power in the quantum vacuum, which is simmering with unactualized potential. Change enables other Realities that exist beyond the momentum of action and thought to form a temporality (akin to the temporary reconciliation of contradictions in the zone of nonresistance). This temporality enables us to express our becoming in ways that are both rhizoid (i.e., anchors entity and conducts energy) and emergent instead of deterministic or causal in the sense we might ordinarily use the terms.

Much research is required to explore the real occurrence of emergence without being dependent on models of causality (Leavy, 2011) [45] and the avoidance of it without clarity in discussion of transdisciplinarity (e.g., Augsburg, 2014) [46]. Herein, I use *ontological emergence* in a specific transdisciplinary way that complements our common understanding of causality based on generative atomism. Regarding the latter, "there exist atomic entities, be they physical, linguistic, logical, or some other kind, and all else is composed of those atoms according to rules of combination and relations of determination" (Humphreys, 2005, para. 2 [47]). Ontological emergence holds that (a) horizontal structures provide processes where earlier stages of systems are causally responsible for later states (i.e., determinism and continuity) *and* (b) vertical structures are a layered ontology of Realities (akin to quantum discontinuity and multiple levels of Reality).

Basically, emergence is not rooted within a single science but is transdisciplinary and appears where a determination model fails to explain a new phenomenon. Something that is ontologically emergent has features that have not been previously observed in the coexistent system and is the result of a dynamic process (see Humphreys, 2016 [48]) resulting in *something* being autonomous, novel and holistic. It is in this sense that I use the term *ontologically emergent.*

When I talk of 'the being of being,' I am referring to the first universal that is common to all entities: their *being.* Birds have being, stones have being, and we, as a genus of beings as human beings, have being. Not only do humans have being, they are always *becoming* (i.e., beginning to be or turning into something). In order to understand the being that we are, we need to struggle with the notion of being *something*, a struggle that has troubled philosophers ancient and new. To do a thing within the notion of mortal being creates a problem that medieval philosophers have struggled with especially around the notion of whether our being can be spoken of in the same way as the being of the Divine (the eternal). Or do we need to identify whether there are commonalities of terrestrial being that may not be applied to eternal being? In trying to resolve these philosophical questions, we need also to deal with a multifaceted set of other issues: causation, emergences, mysteries, Realities and God(s) and Goddesses.

10.4.2 Transcendentals and Actualizing Potential

From the beginning, we are thrown into this world as we are taught it exists, yet we can free ourselves from the constraints of its structure by seeing the world as it might be for ourselves as we *become*. This is done not through the methodologies and calculative thinking of others, academic disciplines or professions but through the oneness exemplified in the onto-theological nature of the *transcendentals* (Latin *transcendens,* 'that which surpasses something') (Harper, 2020) [16]. Transcendentals are the objective properties or concepts of *being*, of all that exists. These properties are called transcendental, because they "exceed in extension all the lower classes into which reality is divided" (Turner, 1911, p. 19) [49].

Of interest to the explanation herein is Saint Thomas Aquinas' (c.1225-1274) five transcendentals: *one, thing, something, true* and *good*. These loosely equate to (a) science (truth and logic), (b) religion (goodness and ethics) and (c) the arts (beauty and aesthetics) (Faber, 2011; Goris, 2019) [50, 51]. The latter three are central to Nicolescu's (2002, 2010b) [2, 5] formulation of TD ontology (see Figure 10.3). The former five transcendentals are a new approach brought to TD ontology in this paper. These concepts of being "add the notions of unity [one], of being in oneself [thing], of being as against other things [something], or being ordered to the intellect [true], and of being ordered to the will [good]" (Faber, 2011, para. 1 [50]). These transcendentals or concepts of *being* align comfortably with Nicolescu's (2002) [2] formulation of TD ontology, which concerns unity, intellect and knowledge, and people being and becoming while working for the good of something greater than themselves.

In the 13th century, John Duns (commonly called Duns Scotus) (c.1266–1308) introduced his theory of transcendentals. Duns Scotus understood transcendental differently than his predecessor Aquinas (Aertsen, 1998) [52]. Scotus held that the one is undivided but *being* is not. Rather, being is "predicated on something of which 'one' is not predicated, namely, 'multitude'" (Aertsen, 1998, p. 50 [52]). Nicolescu (2010b) [5] also held that Reality (being and becoming) is not single but comprises many levels whose transcendence and integration can lead to a new trans-Reality.

Duns Scotus' (2005) [53] theory of actuality included the conception of a non-categorical 'individual difference' to produce an account of the individuality of an individual as their *haecceitas* (the thingness of a thing) (see also Aristotle, 1984) [54]. The distinction between two forms of our species' (a) specific potential (e.g., grow to six feet tall, grow hair, walk upright) and (b) individual potential is considered 'the formal distinction.' Moreover, that which makes us individual cannot, by the nature of its singularity, be categorized at a higher order as in an Aristotelian system of categories while still being part of a species that can indeed so be.

This inability to categorize creates an issue of description, meaning we can only name the individuality by proper name or by indexical pronoun (e.g., she, he, you).

This formal distinction is at the core of a desire to focus on the whole person as an individual in ways that reveal to that person their extended temporal potential to *become*. Succinctly, Duns Scotus' position was "that in each individual there is a principle that accounts for its being the very thing it is and a formally distinct principle that accounts for its being the kind of thing it is. The former is its individual differentia, the latter its common nature" (2005, p. 50) [53].

This approach grounded in the transcendentals applies to people engaging with transdisciplinarity via the Hidden Third. Perceiving the potential for action in the form of the realities of the transcendentals is a way of realizing the potential that resides within us to *become*. This potential capability is an ontological driver of the actuality of becoming what we can desire to be (or may be able to be) cognizant of both the transdisciplinary subject and object as ways of becoming.

In more detail, achievement requires activities full of political, social and economic power, and we make our *being* feasible (a) by questioning the reality of our everyday experience in the knowledge we have of ourselves and (b) with a preparedness and courage to create new knowledge of ourselves from the engagement. Freedom resides in our choice to act on our potential, and potentialities are aligned with the properties of the *haeccetias* (i.e., the thingness of a thing) that determine its power to act. Thus, not all the properties of a thing are equally important to the understanding of the specific activities, relationships, commitments et cetera that give meaning to an individual's identity, yet all contribute to an individual's potentialities to realize their potentiality to *become*.

For people engaged with transdisciplinarity, the exploration of their *being* provides the potential for them to understand and see their life project – to understand that 'being as our becoming' is not deterministic, but neither is it unencumbered; instead, it requires a blending of knowledges and Realities in order that we might have the power to reflect and deliberate about the impact to be achieved by our actions while creating transdisciplinary knowledge.

Most important, this space-time manifold (i.e., many and various folds) is not static but is in constant motion; it is a flow with complexity and causation. This flow of Realities is conceived as an open system in which possible worlds emerge and Realities are (a) perceived and lost in time and space and (b) dependent on the location of the becoming being. It is in this primary sense of becoming as potentiality, as energy and power, that there is capacity to bring about change in another thing or itself. Effecting this change is paramount to creating new transdisciplinary knowledge.

Aristotle (1984) [54] discussed this extensively in Book Θ of chapter 9 of *Metaphysics*. In that work, Aristotle introduced a complementary notion to the identity of the being of a thing fixed in terms of categorical notion of substance, whereby the identity of being can be "distinguished in respect of potentiality and fulfilment, and of function" (1045b, 33) [54] . Nicolescu (2008a) [13] also posited that Reality cannot be reduced to substance, because it is an aggregate. Further, Aristotle's [54] potentiality is evident in two forms: (a) as "a certain motive principle" (1046b, 22) inherent in its being and (b) that of being as agent to be. Aristotle then evoked the notion of fulfilment of our potential and compared it merely as an act of participation or to the full fulfilment of its potential, which, he considered, is doing it well. In this sense, the agent engaged in co-creating transdisciplinary knowledge is compelled to do it well.

This completion (i.e., unity) is linked, I suggest, to the notion of oneness with

Being and the oneness of one's own being and is defined by its motivational powers. This premise basically acknowledges that – that what exists potentially is ontologically dependent on what exists actually. Said another way, what emerges during collaborative engagement with transdisciplinarity depends on the people involved and their ability to realize their potential as beings *being* and becoming (i.e., ontological emergence).

Aristotle (1984) [54] used the term *Dunamis* to describe this concept considering the idea of possible worlds and their Realities as a way in which all sentient, material and spiritual entities – real and actual – are co-created in the process of flow from potentiality to actuality. This includes the process of co-creating TD knowledge, which is mediated by the Hidden Third. This is where the creation of trans-Realities can emerge. This emergence is not grounded in the abstraction of empirical theories but in an experience of engaging in a world reconfigured by the co-creative process of *becoming* as realization of potentiality through the *causal powers* of the *transcendentals.*

This aspect of Aristotle's thinking might be conceived as a space-time manifold (i.e., a chamber branching into several paths or openings) that exists at the convergence of TD-subject and TD-object and where, I want to suggest, causal powers creatively deploy themselves to effect change and emergence. The binary logic that Nicolescu (2010b) [5] resisted reduces 'difference' to disqualification and exclusion instead of inclusion and absorption. Absence of the latter mitigates full actualization of human potential while addressing complex problems using transdisciplinarity.

A way of realizing the potential that resides within us to do this, as a capability to *become*, is to perceive the potential for action in the form of the realities of the transcendentals. This potential capability is an ontological driver of the actuality of becoming what we can desire to be (or may be able to be) while cognizant of both the transdisciplinary subject and object as ways of becoming. The perspective I offer augments Nicolescu's (2008a) [13] premise that trans-Reality cannot emerge unless people actualize their potential. The 'being in being' is in fact new realities emerging through beings *becoming* more; that is ontological emergence.

10.4.3 Power and Ontological Emergence

Of the many levels of Reality (see Figure 10.3), social reality has an ontological depth; it comprises things, properties and powers – a triad that has internal unity. Social objects (i.e., things–properties-powers) are the real manifestations of the idealized types used in discourse and the focus for any enquiry including transdisciplinary enquiry. As Fleetwood suggested, these "things–properties-powers are emergent from, but irreducible to, other things-properties-powers. Things have properties and properties ground powers" (2009, p. 353) [55] including causal powers.

Thus, a power of its properties is borne by a thing and, when activated, brings about that thing's *becoming* in the sense of what it can be. As one thing emerges from other things, so do its properties and powers (Fleetwood, 2009) [55]. This is akin to transdisciplinary knowledge being alive and always in formation and people and the problem itself changing as they work together (McGregor, 2004) [43]. The *being* people *are* when they engage with transdisciplinarity has the potential to change into (*become*) something else. People develop during the transdisciplinary process and arrive as different people than when they started.

Things are structured in various ways, and because of this structure, things possess powers. In most everyday cases, both these things are incomplete, leading to a stasis, a being rather than a becoming, an acceptance of the moderate, which limits the presence of humanity rather than fosters the courage to join the mystical, where "reality is neither apparent to the senses nor obvious to the intelligence" (Merriam-Webster, n.d.) [56]. Rather, reality is becoming, just as the beings creating that reality are *becoming* what they can be, so that complex knowledge can be co-created.

10.4.4 Actualizing Becoming

On a final note, the conscious power of this change can be determined by thinking differently about the transcendental structure of becoming rather than being, although that is romantic and poetic in its first formation instead of logical and calculative. This power recognizes the world of experiences as existing yet is not constrained by it, and it leads to a new configuration of the world. A new reality is possible, because within the power is a force for change instead of stasis.

People flourish when their potentialities are actualized by the positive emergent powers of the transcendentals. These actualize and can manifest themselves in multiforms shaping the patterning of our ways of becoming and are implicitly linked to an appreciation of the attitude toward the transcendentals shaping our identity. This attitude may well seem from the Other to be inconsistent, yet it is still careful of others, for it is not intended to mirror the reality of other people's worlds but to be an expression of one's personal stance within the wholeness of the cosmos.

It is the identity of the individual (the being), not the sameness, that we share in the Hidden Third. We all share the individual potential to actualize *becoming* as we engage with transdisciplinarity. Reality and *being* are not static in transdisciplinary ontology but dynamic and emergent – always *becoming.* Hence, I proposed ontological emergence as informed by the transcendentals.

10.5 Conclusions

While Sue's contribution to understanding Nicolescu's transdisciplinary ontology expanded two quantum science-informed elements of transdisciplinarity (i.e., cyber-space-time and transhumanism), Paul extended a philosophical attitude in the form of ontological emergence and the act of becoming as informed by the transcendentals. Together, we offer new lines of thought pursuant to (a) What is it like to be in the Hidden Third?' and (b) 'the *being* of being' or perhaps 'the being of *becoming'* in the Hidden Third.

An articulation of the value added to Nicolescu's formulation of ontology was woven into our transdisciplinary contributions. While recognizing that our Nicolescuian ontological thoughts are still evolving, we suggest that our musings have added to contemporary thinking on transdisciplinarity (Gibbs & Beavis, 2020) [57]. We propose that the richness of Nicolescu's ontological thinking offers a range of interpretation that is itself transdisciplinary thus fulfilling his wish that transdisciplinary thinking continue to always move forward.

Basarab Nicolescu's work provides the framework for exploration as does any truly worthwhile formulation or conceptualization. We have taken advantage of such genius in our attempts to understand the concepts and question ourselves as to their relevance to our interpretation of Nicolescu's transdisciplinary ontology. As academics and transdisciplinary scholars, we need to be free to allow our imagination to feed from the work of others to respectively flourish through questions, clarification and truth seeking. We have sought this through Nicolescu's work and are grateful for it.

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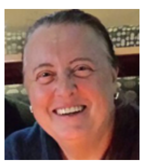

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CHAPTER 11

Evolution and Characteristics of the Transdisciplinary Perspective in the Research: a Literature Review

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In this documentary investigation, we review literature about the transdisciplinary (TD) perspective to generate knowledge, locating its origin, evolution and characteristic features. It is found that: i) This origin is located in France and the United States, although some characteristic features related to self-knowledge, participatory research and the unity of knowledge, were proposed before the creation of this TD term introduced in 1970. ii) The concept of transdisciplinarity has evolved over time involving a transition of vision towards the application of perspective to investigate. Switzerland was the first country to apply the transdisciplinarity in research in the 1990s. iii) The key world events that gave impetus to the transdisciplinarity are the world (1994) and Zurich (2000) congresses, as well as the special edition entitled "the foundation of Academy of Transdisciplinary Learning of Advanced Studies (ATLAS)" of the Journal "Futures" (2004) and the Transdisciplinarity Journal of Engineering & Science (TJES) in 2010. iv) the main features of transdisciplinary research are: a) research for society and with society, i.e. participatory research, b) scientific research under systemic thinking, c) communication of results to the scientific community and disseminated to non-scientific population. v). The number of transdisciplinary research publications have increased over time, along with the quantity of authors per publications and citations thereof. Some contributions from the 90s were the most impactful due to the number of cites today. The transdisciplinary approach could be the best pathway to develop research in Latin American countries and the world, for solving the diverse problems of society.

Keywords: Research process, Transdisciplinarity, definitions, characteristics.

11.1 Introduction

Relevant problems of our era, such as food and water security, health (obesity, cancer, malnutrition, mental illness as depression etc.), poverty and hunger, inequality, climate change, natural resources, environment, disaster risks, epidemics, pandemics, etc. (Hernández et al., 2010, 2016; Thompson et al., 2017; Hernández and Dominguez, 2020) [1-4], cataloged as complex problems, require a change of perspective to generate knowledge and develop research processes. Since these problems cannot be solved from a discipline and likewise without interacting with the empirical and/or problem actors, and without getting involved with the decision makers. A worldwide proposal in the scientific community that has evolved and has been accepted by different research groups is to carry out the research process, under a transdisciplinary vision. One of the characteristics for the generation of knowledge in the mode "two", published in 1994 by Gibbons et al. [5]; establishing a contract between Science and Society, proposing "socially robust" knowledge (Gibbons, 1999) [6]. This research mode is characterized by its orientation towards contextualized problems and results (Gibbons et al., 1997) [7], being a thoughtful and conscious way to rethink science; on the part of the investigators and the leaders of the investigation of the countries.

Rethinking science and its role in society has been repeatedly proposed, to take on the problems of humanity. Einstein, among other scientists, at the end of the Second World War, with the launch of atomic bombs (a result of the Manhattan project), rethought the role of scientists in society [8, 9]. In this sense, Einstein (1946) [10] establishes a campaign to renew the way of thinking after of the disaster of the War: "The world that we have created today as a result of our thinking has problems; which cannot be solved by thinking in the same way what we thought when we created them".

In this way, the Atomic Scientists Emergency Committee (generally called the Einstein Committee) is formed: Albert Einstein (1879-1955), Harold Urey (1893-1981), Linus Pauling (1901-1994), among others participated in the committee [11]. It is an organization that has within its objectives to educate the American people about the nature of nuclear weapons and nuclear war. The educational campaign in society was carried out for five years. In this way for a long period of time, "Peace was an important agenda for many scientists". "Einstein before his death in 1955; signs the Russell-Einstein Manifesto, a call by scientists (including Linus Pauling) for world peace and the abolition of war [12, 13]". At the death of Einstein, Ludwig Philipp Albert Schweitzer (1875-1965), continued this call against arms and nuclear tests by giving lectures on it. He said: "Man has lost his ability to foresee and anticipate, he will end up destroying the earth". However, atomic experiments were resumed in 1962, again insisting in the scientific community a call to the conscience of men of good will that there was no justification for maintaining radioactive contamination on Earth [14,15]. Among others, Schweitzer, Bertrand Russel, Martín Niemöller, Robert Jung, prominent scientists and humanists, write the manifesto entitled "Atomic experiments do not contribute to peace" [16].

At this time in the post-war science another problem arises due to the use of DDT first synthesized by Othmar Zeidler (1850-1911) [Gamboa, 2014] [17,18] and patented in 1939 by Paul Hermann Müller (1899-1965), who was even awarded the Nobel Prize latter in 1948 (Escobar, 2008; Extremera, 2018) [19, 20]. At the beginning of the discovery and its application in World War II to protect the military troops in the Philippines, Japan and Italy from attack by insects [17], it achieved great global impact. In 1944, in Naples it was possible to control a typhus epidemic caused by pediculosis, also in 1945 in Japan. Moreover, also, by the DDT, it was possible to end with lice transmitting typhoid fever and it was also used to control malaria, yellow fever, etc. (Raju, 1999) [21]. Many years it was commercialized and enjoyed its benefits, mainly for productivity in agriculture and to foresee diseases such as malaria [Torres and López, 2007] [22]. However, in the 1960s, Rachel Carson (1907-1964) observed a phenomenon what others did not see to date, since DDT had a negative impact on the environment. What had been considered a safe and effective low-toxic pesticide had an unwanted side effect: "it killed birds" (Carson, 1962) [23]. The modern environmental movement begins with her, in fact, she considers herself the mother of this movement. DDT has a great environmental impact also on people, even studies by Cohn et al (2007) [24] have confirmed in recent years the relationship between DDT and different types of cancer, such as breast cancer, from which Carson died in 1964 (Seager, 2003) [25].

Other scientists in this postwar era addressed societal problems, such as cancer disease. Otto Heinrich Warburg (1883-1970) discovered the cause and prevention of this disease, attributing its existence to acid and without oxygenation environments (Warburg, 1969; Leandro, 2019) [26, 27]. Joahnna Budwig (1908-2003) studies the positive effects of omega 3 fatty acids, finding that they could limit cancer, not just dementia and depression (Budwig, 1992;1996) [28, 29]. Linus Pauling linked prevention of the cancer and heavy doses of vitamin C; he was convinced that the correct administration of vitamin C in the population would decrease the incidence of diseases of any etiology by at least 50%, since its deficiency is the one that causes greater pathologies on the human organism (Pauling, 1971) [30]. Other scientists have investigated more about cancer, such as Max Gerson (1881 - 1959), who proposed the cure of cancer could be through nutrition and detoxification (Gerson, 1958; 1978) [31, 32], and Catherine Kousmine (1904-1992) who affirmed that after the second world war food changed from being agro-livestock to industrial; with the respective great degenerative consequences of civilization, among others cancer (Kousmine, 1959) [33]. Although it is true in her time the proposals were not materialized, over time information has been generated where most of them have been demonstrated; being clear the vision and observation of geniuses of that post-war era, as well as their interest in studying the problems of humanity, in this case in various diseases.

On the other hand, to mention some other scientists of the time, there are the cases of those who dedicated themselves to proposing solutions to the food problem: production and nutrition. Norman Ernest Borlaug (1914-2009), known as "the man who saved a billion lives", proposed the use of hybrid seeds to increase agricultural production in poor countries and he succeeded among others in Mexico, India, Pakistan, Turkey, and Africa [34, 35]. This led to self-sufficiency in wheat production in Mexico in 1956. Another scientist sought a peace centered on the idea of "freeing himself from need": pointing out the importance of the population having their food, this being the priority need. John Boyd Orr (1880-1971) emphasized the importance of children's growing nutrition and health [36, 37]. Before and now it is still a problem for many of the countries, the quantity and quality of foods [38] that in excess produce diverse diseases such as obesity and diabetes, or in deficiency produce malnutrition or anemia, among other diseases. These are some of the relevant problems of our times, marking the need for research that contemplates educating society and adapts to its contextual characteristics. A solution for the world problems, many times cannot be generalized, so it must be adapted to the context of the application. These and other problems, such as climate change that was mentioned in the 1960s and is associated with human activities in 1970 [39, 40], are evidence of the need to investigate closer to society. All these disciplines reported added to an incredible increase in disciplines and sub-disciplines educative/scientific in the year 1250, there were 7, in 1950 there were 54 disciplines. But for 1975 - Higher education statistics Agency of UK-registry 1845 disciplines and 10 years ago (2010) the National Science Foundation archives of the USA pointed out the existence of more than 8000 scientific disciplines and sub-disciplines [41]. It causes an increasingly fragmentation of science, which in turn also leads to a greater need to complement knowledge of some disciplines with others, to propose solutions to contextualized problems, since in isolation it is impossible. The scientific community faces the need to propose systemic solution proposals for sustainable development to the world's problems, i.e. a type of development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Komiyama and Takeuchi, 2006) [42]. So, today's researchers cannot stay permanently in laboratories or cubicles: it is necessary to study the problems of the world, leave laboratories, get closer to society, know the problems and after, return to their workplace. It is necessary to know the problems and propose solutions. For his part, Karl R. Popper (1902-1994), the philosopher of science, was convinced that "We do not study issues, but problems; and problems can cross the boundaries of any object of study or discipline. We are students of problems, not disciplines" [43, 44]. The problems are studied, the origin, their causes, the problems are looked for and the solutions are proposed, the way to know them better, is get closer to them. This implies the paradigm shift of doing science in decision makers of institutes, research centers, governments, and current and future researchers themselves.

In this sense, Funtowicz and Jerry Ravetz (1991) [45] pointed out the need for a science in the context of complexity, a new scientific methodology to tackle global environmental problems. Where the task is from an extended community, not individual experts. Turning the scientific system into inputs for new ways of deciding politics and governance (Funtowicz and Ravetz, 1996) [46]. Then, the science would be support to decision making where the uncertainties of the systems and the risks of the decisions are considered. This implies a change in the scientific paradigm; for which today it is even more understood in the face of the challenging and complex problems of our times by having a globalized world.

In this way, despite the increasing awareness of how favorable a Transdisciplinary approach can be, as stated by Gaihre et al., 2019) [47] and demonstrated by the increase in studies reported in the scientific literature introducing this perspective in the research process [48]. It is still necessary to learn from this vision and train new researchers fulfilling the characteristic features of this perspective. And not only to researchers in training, research institutions and governments, society, civil, etc.

Thus, the objective of the present document is to share a literature review about, the evolution of term and characteristic features of transdisciplinarity; as it could be the way to investigate in the near future in Latin American countries or between countries of different regions of the world; with societies characterized by their respective contexts: social, economic, educational, health, age, physical, climatic variables, ecological, geographic location, cultural, political, etc.

11.2 Pre-Transdisciplinarity

The term transdisciplinarity, for some authors, was introduced in 1970 [49-53], although the notion of the term was found earlier according to Ramadier (2004) [50].

The various benefits that science could have towards society, was glimpsed by various scientists such as Bacon, Bernard, Einstein and Bohr among many others. Einstein already expressed concern that man would evolve towards different holistic levels and feel compassion for others and the other (beings and nature). Bacon defended the collaboration between scientists for the progress of science and its orientation in a good to society, according cited by Hadorn et al. (2008) [54]. Bohr, dedicated part of his life to convince to his colleagues of the need to use the findings of nuclear physics for useful and beneficial purposes to man; the latter scientist was recognized as the one who had the notion of transdisciplinarity before the term Ramadier appeared (2004) [50].

One of the main characteristics of transdisciplinarity is to investigate for and with the communities, but this vision is found before the appearance of the term. Kurt Lewin (1890-1947), the father of action-research (A-R), since he started this type of investigation in 1944, although some authors indicate that it began 10 years before (Lewin, 1944;1946; Miguélez et al., 2000) [55-57]. Regarding this research mode, close to the community, two aspects were identified: the sociological dimension, represented by Lewin and the educational dimension by Paulo Freire (1921-1997), where the problematic actors became participants and co-responsible in solving their own problems. Sol Tax (1907-1995) was another promoter of this type of action research (Rahman and Borda, 1992) [58]. In this sense, research for society and with society (Scholz, 2000a; 2020) [59-60], is practiced since before the introduction of the term. The problems to be tackled were born from the community that lives them. Likewise, the researchers had to propose dialogue strategies with the community, where changes in society and academia are required.

The changes in people, their transformation, which is another characteristic of transdisciplinarity, has also been proposed for many years, before Christ and after Christ. In the 19th century, various thinkers, mystics, spirituals, alchemists proposed walking towards the self-observation, the reflection, the internalization of man, self-inquiry, self-knowledge, etc. [61-64]; in general, to lead to the knowledge of man for the evolution and their transformation. It is worth mentioning the famous aphorism of the Greek sages in the time before Christ: “Know thyself". Marco Aurelio (121-180 AD), stoic philosopher [65]: he reflected on the matter of “Looking within oneself”. Since inside is the source of good, and it will come back, if you keep digging. In addition, for expanding the mind, he stressed the importance of systematically and really investigating everything that is observable in life. Polymaths like Leonardo Da Vinci (1452-1519) - (Scientist, painter, mechanical engineer, sculptor, thinker, city planner, storyteller, musician, architect) [66] claimed to transform oneself to transform, obstinate rigor. Some spoke of transformation towards virtue, e.g. Newton (1642-1727) recognized the virtue of having patience more than other talent for the development of his discoveries. In the case of Benjamin Franklin (1706-1790), visualized cultivate virtues, proposing the development of thirteen virtues, among which are: silence, order, determination, temperance, tranquility, humility, etc. Goethe pointed-out that science involves capacities of observation and thought, but also human faculties that can resonate with the spiritual dimension (Max-Neef, 2016) [67]. The empathy that must exist in research is highlighted by Claude Bernard who rejects research without feeling; as well as proposing that study the phenomena of life in the context in which they develop (De Romo, 2007) [68]. In this sense, from before the origin of the term there was already talked about contextualizing the research, i.e., having a problem or a need focused on space and place and putting it in relation to its environment and at different holistic levels and different dimensions and behavior over time; visualizing the problem in its multivariable dimension. On the one hand and on the other the importance of knowing the himself and the researcher's need to develop virtues.

Many other characteristics have been reflected on and sought throughout the history of the production of knowledge, e.g. the unity of science. It is worth mentioning a world-famous phrase from Plato (427-347 b.c), in the Phaedrus dialogue (cited in Miguélez, 2011) [69]: "*If I find someone capable of seeing things in their multiplicity and, at the same time, in their unity, that is the man I look for as a god*". The unity that implies reconciling and yielding, which then implies humility and many times accepting one's ignorance in certain knowledge, is a process to live, to learn to integrate as an act to unite and link parts that form a whole, one of the bases of transdisciplinarity.

This is clearly reflected in the Systems General Theory (SGT), in the 50's years, which since its creation promotes the integration of disciplines (Bertalanffy, 1986) [70]. With the creation of the "Society for Systems General Theory" (Bertalanffy, 1954; see Cuadrado, 1995) [71], a research program is established, which within its principles was "to promote the unity of science by improving communication between specialists". It is one of the challenges of transdisciplinarity today. Where the language that is used is relevant, such as behaving with the other, with a different culture, a different country, a different level of knowledge, different interests, etc. So, a change in attitude of the scientist (now more commonly called researcher) was established. Schrödinger (1887-1961) [72] stressed that the scientific attitude must be rebuilt; science must be redone again.

In the 1960s, at the beginning, the United Nations for Development reflected on the development process, stating "development not only refers to the material needs of man but to the improvement of social living conditions and to his noblest aspirations. Development is not only economic growth; it is growth added to evolution" (ONU, 1960) [73]. A possible evolution of the man who was, is and will be necessary for his own survival.

11.3 Origin and 1st Stage of Development

For Miller (2008) [74], the origin of transdisciplinarity goes back to the 50s, after the 2nd. World War at the same time as the SGT. Others like Groß y Stauffacher (2014) [75] indicated the beginnings of the TD debate in 1969, when the UNESCO meeting was held in Genova, Italy. The vast majority of authors point, in general, to 1970 as the year in which the term is introduced in France (Ramadier, 2004; McGregor, 2007; Jahn, 2008; Cronin, 2008; Basarab, 2010;2014; Sholz and Steiner, 2015a) [50,51, 76-80] and there is talk about it in the United States (Bernstein, 2015) [52]. Coinciding precisely with the international year of education (Maheu, 1970) [81]. On the one hand, in Nice, France is recognized to Jean Piaget (1896-1980) as who introduced the term during the Conference titled "interdisciplinarity, problems of teaching and education in universities" (Jahn, 2012) [82].

André Lichnerowicz (1915-1998) and Jantsch (1929-1980), French mathematician and Austrian astrophysicist, respectively; related the term with the logic and set theory and education and planning issues. Jantsch defines it as the synthesis of disciplines, overcoming the multidisciplinarity and interdisciplinarity (Miller, 2008;

Nicolescu, 2010) [74, 78]. Jantsch (1970) [83] visualized social need as the creative force to direct, shape and organize education and research. He suggested a transdisciplinary university including systems design laboratories powered by disciplines, and departments oriented to build capacity for self-renewal of societies (Jantsch, 1970; 1972; Sholz and Steiner, 2015b; Osborne, 2015) [83-86]. In this way initially, some associate the term of transdisciplinarity with the application of SGT in the educational policy (Osborne, 2015) [86].

On the other hand, in the same year of 1970, as reported by Bernstein (2015) [52], in the United States, Jack Lee Mahan (1970) discuss about TD, incorporating ethical and humanistic considerations in this transdisciplinary approach to research. Highlighting the “reverence for life, man and the human condition". He proposes transdisciplinary research would be characterized among other aspects by a) the transcendence of disciplinary limits, b) attention to the context of the research, c) respect to the life and dignity of the human being, and d) applying knowledge to the improvement of society. In this sense, the origin of the term transdisciplinarity is found in Europe and America. It is worth mentioning that at the same time of the 70s, when the processes of environmental deterioration and degradation of the Earth become evident, Gaylord Nelson, (1970) [87], calls for awareness to protect the Earth and the life that the habitat, a message that transcended the ONU worldwide, an organization that, in 1971, decrees World Earth Day and begins a series of actions in this same consciousness.

At the end of the 70s, Kockelmans (1979a;1979b) [88, 89], distinguished the transdisciplinary approach as the unit of science. The author proposes to be continually "provoked" through reflection, where it is required to do the task for everyone, not only for disciplinary philosophers, in a critical attitude. A critical attitude that implies participation, this is various actions on everyone’s part. It is necessary to integrate in the research process scientists representing various disciplines, as well as other representatives outside the scientific field, the users or actors of the problem. Transdisciplinarity could then be a scientific and non-scientific work, with the intention of overcoming the negative effects of specialization. In education and research, it would be a matter of both being relevant to society.

Mittelstrass (2011) [90], self-recognizes who introduced the concept into philosophy in 1987; same year in which the CIRET (International Center for Transdisciplinary Studies) opens in Paris, France. Already previously in 1973 another Center for trans-disciplinary studies had been opened, the first of its kind, directed among others by Edgar Morín (Ramadier, 2004) [50].

11.4 Transdisciplinarity in the Decade of the 90s

Despite the date on which the term TD is introduced, and it reflects on the need for another way to investigate to participate in the world’s problems. It is in the 90s; after the environmental crisis started in the 70s and later aggravated in the 80s added to other world crises. Almost 25 years after those initial ideas of TD (Scholz and Steiner, 2015b) [85], when the approach to research is resumed and it could be considered it begins to take impulse; it could be said that a first evolution of the term begins to take place to produce knowledge and mainly it is moved towards its application.

In 1991, the Swiss Environmental Priority Program began, and projects were asked to go under transdisciplinary research (Scholz, 2020) [60]. In 1992, Mittelstraß [91], asked the scientific community to reconnect research with real-world problems, transcending disciplinary limits (Hoffmann et al., 2017) [92]. It is even necessary to reconnect different disciplines, different knowledge (scientific and empirical), etc. Even within the same discipline, within the same institute, "stop rowing" each one on their own. Focus everyone in the same direction to get ahead, in the face of problems that sometimes they are even survival. Paraphrasing Brewer (1999) [52-93], “The world has problems, but universities have departments" (Cronin, 2008; Pohl, 2011) [77, 94]. Department sometimes without orientation, each walking in unknown directions, even the researchers that make up each department. For this reason, is primordial the oriented research. Where the institutes have the country’s problems, in common agreement with the governments; so each one is assigned complementary tasks according to their specialties, but integrating and complementing each other, to this way redirect the course of the investigation. This process is based on current and future anticipated needs in the real world. According to the literature review and the context of the time, it was apparently the great impetus given to this vision with the contribution published in 1994 by Gibbons et al. [5], whose contribution allowed them to rethink how to do science. It should be noted that it is the document from the introduction of the term of transdisciplinarity to date (within which they provide definitions and characteristics), with the highest number of citations (according to Google academic, more than 10,000). Along with the contributions of Gibbons et al. (1994; 1997) [5,7] an important event is also highlighted, the World Congress of transdisciplinarity celebrated in a region of Portugal: Arrábida. According to McGregor (2015a) [95], in this event there were diverse assistants such as the president of the country, civil society, representatives of industry, government and academics; among which were Freitas, René Berger, Ubiratan D’ambrosio, Roberto Juarroz, Edgar Morín and Nicolescu Basarab, etc. who collaborated in the writing of the transdisciplinarity charter that was one of the results of this meeting (Anes et al., 1994) [96].

Basarab Nicolescu defines transdisciplinarity as a generalized transgression that opens a space for freedom, knowledge and love (Basarab, 1996) [97]. On the other hand, Julie Klein (1996) [98] defines transdisciplinarity as the perfect interdiscipline. In this decade begins to be mentioned, the need for a language and attitude of transdisciplinary [99]. The latter term being introduced by Roberto Juarroz, recognized by Basarab (Ramadier, 2004) [50].

The TD language allows a researcher to communicate with another of his own discipline, with another of a different discipline and with the problem actor, where a reflective thought of the investigator-subject is relevant. Subsequently, Gibbons (1997;1999) [6,7] in the second quinquennium of the 90s, continues to publish about Mode 2 to produce knowledge, where his article of 1999 stands out, at the journal “Nature”, where it is incorporated the term “socially robust knowledge". He also proposes the need for science to establish a contract with society. Meanwhile, Basarab (1997) [100], proposes self-transformation, based on self-knowledge, for a new way of living. In this same year, was celebrated the International Congress in Locarno, Switzerland entitled: “The transdisciplinary evolution in the University”, same that was organized by CIRET and UNESCO deriving from that event, Locarno’s statement. An aspects established was the emergence of a new tolerance to achieve the exchange of knowledge. A new tolerance that allows the acceptance of differences, the acceptance of ignorance, the acceptance of the new and unknown, etc. The investigator would have to learn to deal tactfully to other disciplinary and non-disciplinary. Paraphrasing Newton: (1643–1727). “the tact is the ability to get to a point without making an enemy"

The following decade, from the year 2000, is marked by another trascendental event: The Transdisciplinarity Conference held in Zurich, where that conference could be considered another relevant event related to the evolution of the TD perspective.

11.5 Transdisciplinarity from 2000

Transdisciplinarity, at the conference held in Zurich was defined as: a manner of learning and solving problems with the cooperation of society and academy to face the challenges of the societies. According to Klein et al. (2001a) [49], some participants who stand out in this event are Michael Gibbons, Helga Nowotny, Rudolf Hiiberli, Charles Kleiber, Rita Colwell, Thomas von Waldkirch, Roland Sholz, David Marks, Perrig-Chiello, Richard Ernst, Thomas Jahn, Christian Pohl and Julie Klein; the latter being the one who led the edition of the Event Report, entitled: “Transdisciplinarity: Joint solution of problems between science, technology and society. An effective way to manage complexity”.

It should be noted that there were more than 220 contributions from various participants from different parts of the world such as India, Denmark, Nigeria, Holland, Spain, Indonesia, Germany, Russia, Italy, Austria, United States, Portugal, United Kingdom, Sweden, Belgium, Brazil, Ukraine, France, Bulgaria, Greece, Croatia, Ethiopia, Japan, China, Colombia, Slovenia, Israel and Switzerland, among others. In this way, the transdisciplinarity perspective in research is increased. At the initiative of the Swiss academies of arts and sciences, the “Network for transdisciplinary research (td-net)" was opened at congress of Zurich (Td-net, 2020) [101].

In the year 2000 the Academy of Transdisciplinary Learning & Advanced Studies (ATLAS) was created by Dr. Atila Ertas, to serve universities around the world. Dr. Atila Ertas, Dr. George Kozmetsky and Dr. Raymond T. Yeh were the co-founders of ATLAS (ATLAS, 2020) [102]. Association affiliated to the Transdisciplinarity Journal of Engineering & Science (TJES), which is dedicated to Professor John Nelson Warfield (father of systems science) by his transdisciplinary knowledge and culture of peace. It should be noted that the first article written by Julie Klein (2010) [103] in the (TJES) [104] is dedicated to Professor John Nelson Warfield memory. The journal’s edition has represented another boost in the growing adoption of perspective to investigate in the world’s universities. It started with 10 articles published and last year it reached double (20 articles), having a multiplier effect through its more than 350 cite and 122 articles to the current date. Researchers from various countries have published in this journal.

Contributions by Christian Pohl (2010) [105] and Lawrence (2010) [106], have been the most cited in the TJES with 81 and 76 citations, respectively. Pohl, among other aspects, reaffirms the characteristics and challenges of transdisciplinarity and Lawrence revises the ambiguity of the term, synthesizing some characteristics which some authors have given. Furthermore, publications by Dr. Basarab Nicolescu, who proposes the Transdisciplinary methodology to investigate , stand out (2010; 2011;2012;2016) [78, 107-109].

Basarab (2010) [78] defends within the etymological meaning of transdisciplinarity the "beyond the disciplines", where the social field introduces that dimension, but the individual human being and his spiritual dimension should not be left aside. As well as, the scientific spirit, which is the center of TD; the transdisciplinary methodology and the scientific method complement each other.

In the interview with Basarab (2011) [107] by Professor Augusta Thereza de Alvarenga (University of Sao Paulo, Brazil), Basarab highlighted the importance of the various international conferences: previous (Conference of Venice "Science and the Boundaries of Knowledge", in 1986; Congress "Science and tradition: Transdisiplinary Prospects for the 21st Century", Paris, in 1991) and later (International Congress of Transdisciplinaryty "Which University for tomorrow?", Locarno in 1997, Second World Congress of transdisciplinarity, Vitória, Brazil, in 2005), to the first world congress in 1994; because these have contributed to the emergence of transdisciplinarity, from the emergence of a community until the already formed community, and have subsequently contributed to the training of educators and students.

These events and contributions from the beginning of the decade of 2000s and the end of the 90s, perhaps have been, among others, the most relevant for the creation of a transdisciplinary culture in the world. Adding to the passage of time more researchers convinced of the paradigm shift to investigate.

Of this manner, in a review by Kueffer et al. (2007) [110] in the "web of science", indicate that the quantity of articles with the word transdisciplinarity has increased over time. The authors analyzed articles from 1970-2000; where the number of publications per year was increasing over time. They reported a significant increase since 2000; highlighting the publications in the years 2004 and 2005, where 60 and 70 articles published were reached, respectively. Some of the journals that have published transdisciplinary research particularly in the area of environmental sciences, according to the authors are: *Communication, Cooperation, Participation; EcoHealth, Ecological Economics, Ecology and Society, Society Futures, Nature + Culture, International Journal of Transdisciplinary Research, Journal of Transdisciplinary Environmental Studies, Ecology and Society, Environmental Sciences: Journal of Integrative Environmental Research, Bulletin Interactif du CIRET, co-design,* etc. Zscheischler and Rogga (2015) [48] in another literature review consulting the databases of "ISI Web of Knowledge" and "Scopus" they also point to the increase in publications in the area of sustainability with a transdisciplinary approach since 2000. The acceptance of the scientific community in this area is appreciated in this article, mentioning 217 different provenances which carried out a TD-RP. Presenting a great evolution of the Transdisciplinary perspective towards its application. Other relevant events are included in the year 2004; the special publication of the subject about transdisciplinarity in the English Journal "Futures" with a total of eight publications by different authors and nationalities: Lawrence and Després (Switzerland and Canada), Balsiger (Germany), Ramadier (France), Jones and Sime (United Kingdom and United States), Bruce et al., (United Kingdom), Pinson (France) and ending with Klein (United States).

In this sense, the transdisciplinarity, has undergone an increasingly integrative practical evolution (Espina et al., 2004) [111], increasingly systemic thought, which do see to the world of a different way (Max-Neef, 2005) [112]. Among other requirements for a TD-RP is the collaboration between disciplines and participatory research (Pohl and Hadorn, 2007) [113]. For this there are among others, some requirements such as a transdisciplinary training of new researchers and therefore transdisciplinary trainers of future researchers are necessary. In the declaration of the 2nd World

Congress of Transdisciplinarity held in Vitória, Brazil (2005); it is pointed out that the action TD, articulates the relationship with the world (eco-formation), the relationship with the other (hetero and co-formation), the relationship with oneself (self-formation) and relationships with the being (onto-formation) (Espinosa, 2005) [114]: being one of the urgent actions proposed by Nicolescu: Transdisciplinary education, i.e. influence the training of transdisciplinary researchers; representing this one of the great current and future challenges.

Complying with the characteristic features requires knowing-self-investigating and self-transforming. In this sense, Jahn et al. (2012) [82] points out others characteristic features in the research TD, this is: a) critical, b) self-reflective, and c) relates society and scientific problems. Transdisciplinary approaches for Méndez (2013) [115], could include academic scientific disciplines, as well as different knowledge systems (e.g. empirical experience, local knowledge, indigenous knowledge, etc.) aimed at solving problems. Groß and Stauffacher (2014) [75] reported that the type of knowledge generated not only discovers laws, but also is to provide solutions to socially relevant problems. For this, heterogeneous groups are formed to produce scientific knowledge.

Then it leads to solving problems present in the real world. For which, as Miller (2008) [74] mentions, transdisciplinary research requires a social responsibility. Social responsibility implies an important individual and introspective work because it implies being responsible for the other. Paraphrasing Emmanuel Lévinas (1905-1995) “When I see you, I feel intrinsically responsible for you”, implying seeing beyond ourselves (Jiménez, 2017; Martos, 2011) [116, 117]. Therefore, as McGregor (2004) [118] indicates, whoever wants to adopt a TD approach should consider profound internal changes which could lead to, according to Max-Neef (2005) [67], to a different way of seeing the world that could represent a challenge as pointed out by Pohl (2010) [105].

Pohl (2010) [105] distinguishes mainly three challenges: 1) Structuring the problem together, 2) integration of participants group and 3) intervention in society. Structuring the problem together is one of the challenges, using methods that allow having the different views of the problem of the different participants of the research project, who will act, interrelationships between the participants, dialogue methods, the joint formulation of hypotheses, etc. They are aspects considered and carrying it out represents a challenge in the practice of transdisciplinarity. Another challenge that he analyzes is the integration, how to reconcile points of view between scientists and non-scientists, that is a real challenge, to establish the problem together, to define the hypothesis, from different value systems and ideas and beliefs, to reach integrate and reconcile academic research and experience. The third challenge of Transdisciplinarity is to successfully carry out the results, which implies reaching intervention in society. Projects could then take years to reach implementation. The stages of the project are to communicate results to civil society, the private and public sectors, but now it is to implement the solution proposal. Then you enter a cybernetic, recursive process, planning research, establishing it, developing solutions, implementing, verifying the impact on society, learning, analyzing, reformulating problems, new research questions, etc. and so on, a process that can take years, even decades.

It is for this reason that to overcome the challenges in the practice of transdisciplinary research, a different intelligence is proposed by the participants and constant introspective work, for strengthen the spiritual dimension.

Ubitaran D'Ambrosio who participated in the elaboration of the transdisciplinarity charter (1996) [119] notes that to face the complexity of the world and its self-destruction of the species, an intelligence is required that visualizes the planetary dimension, among others. Additionally, it mentions that an ethic is required where to change is necessary: from competition to cooperation, from separation to human interconnection, from dependence to human interdependence, from fear to love and from individualism to altruism (D'Ambrosio, 2014) [120]. In this way, there is a need for deep transformations in the investigater subject that longs to be a TD researcher, requiring in it, a training that allows to become aware of that need for self-investigation for its self-transformation, where critical Self-knowledge is essential. From where knowledge could be co-constructed as co-creators of transdisciplinary knowledge (Iván Illich, 1976; see, Vargas, 2015) [121]. The leaders of transdisciplinary research have to develop certain capabilities noted Hoffmann et al. (2017) [92]. Among which stand out: a) integrative vision, b) skills for intellectual between-disciplinary exchange between disciplinary, c) project planning, evaluate, monitoring, etc., d) reconcile multiple interests and possible conflicts, etc. In such a way, the role of the scientist takes wide relevance and transcendence. Wiek (2007) [122] reflects that the role of the scientist as an epistemological mediator between science and practice must be reconfigured. As well as reconsidering the role of the scientist as a figure to create a culture of peace, which for D'Ambrosio (2011) [123] covers four dimensions: military, environmental, social and individual peace, this being the most universal problem facing humanity (De Holanda and Medeiros, 2014) [124].

Pohl (2010) [64] pointed out several characteristics of TD, among which he highlights: 1) develop knowledge and carry out practices for the common good, 2) adopt a comprehensive, multi-perspective approach, 3) tackle problems and solutions transgressing scientific disciplines, etc. Then, the spirit of transdisciplinarity is to develop research to serve society, i.e. with mainly social sense. The perspective of transdisciplinary research would be focused on the common good (Enengel, 2012) [125].

In this way, the borders of the researchers, of the disciplines and of the specific problems themselves are transcended, seeing a complex and interconnected whole, where the unity of sciences and consciences is invited. Stokols et al. (2003) [126] suggests caution in the use of terms: transdisciplinary collaboration and transdisciplinarity to do science (TD science), because they are not synonyms. Doing science under the transdisciplinary approach is not to form coalitions involving collaborations, whose mission is for example to promote improvements in health, educational or economic conditions. Transdisciplinary collaborations aim to generate intellectual results that are their hallmark; carry out scientific research activities and generate knowledge.

Transdisciplinarity according to Klein (2001b) [127] does not begin in a specific discipline. If not, it is based on a practical problem (Hult, 2010) [128], which seeks the generation of practice-oriented solutions and their dissemination among the target population (Bergmann et al., 2005) [129]. Others authors Jahn (2003) [130] retake what was pointed out by Krott (2002) [131], indicating that the specific added value of a research project TD does not stop with the explanation of the world, but even intervenes directly in the problem or situation. In order to persist, in the intervention of the problem situation, collaboration with different disciplines, collaboration with the different actors in the problem, etc., a constant openness to change is required. Then, it will be essential for researchers and participants to continually transition mutual and transformational learning, as recommended by Mitchell et al. (2015)

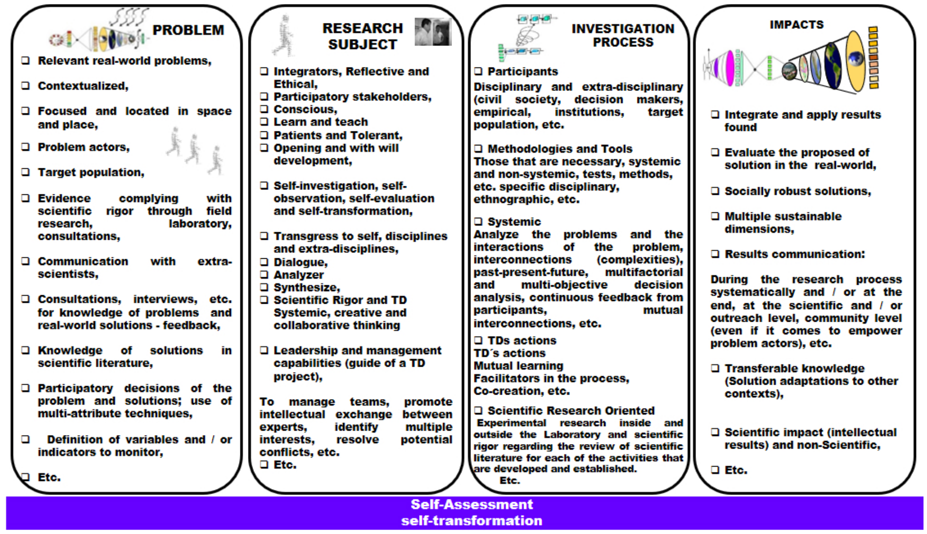

Figure 11.1: Characteristic features of transdisciplinarity.

[132]. One of the challenges that the Transdisciplinary group faces, among many others, is to stay in unity. Starting from the differences that may exist between everyone, maintain unity and learn to agree with the other, hence the importance of continuous self-transformation. To learn to listen and not impose, etc. The members of the research project (TD) from the beginning to enter of manner individual, must be aware that it must self-transgressed, causing continuous change through self-evaluation. On the other hand, research assessment permanently is also proposed by some authors for quality assurance in the RP-TD (Balsiger and Kötter, 2005) [133].

In summary, it is possible to observe in Table 1 (see Appendix), a list that integrates some definitions and characteristic features of transdisciplinarity. A perspective to address the research in these poly-critical times, where the challenges will be to make it operable according to the contexts of the various countries and consciences of scientists and extra-scientists involved.

The trainers of future generations have various challenges in the process of researchers training, which must be transformed in order to re-educate towards a transdisciplinary perspective. The trainer must live and teach to live alongside the research process, self-research, self-knowledge due to that is useful for self-transformation. Being this basic aspect in compliance with the characteristic features of a TD research process, as shown in Figure 11.1, column 2.

According to the reviewed literature, Figure 11.2 shows by decades the behavior of the number of authors, citations of contributions and number of papers in the last fifty years. It is possible to observe in Figure 11.2a, how the number of authors by paper in average has been increasing over time. Starting in the 70s and 80s with a single author and the average number of authors in the last decades has increased to almost three authors. It is worth mentioning that there were articles from this literature review with 20 and 14 authors such as Axelsson et al. (2013) [121] and Benesh et al. (2015) [125], being a trend of increasing number of authors in scientific contributions from a transdisciplinary perspective.

Regarding the number of citations of contributions per decade (Fig 11.2b), it was found that the decade of the 1990s had the greatest impact. This is also evidenced by the number of papers, which have been increasing from decade to decade, increasing by more than 100% with respect to the beginnings of transdisciplinarity (Figure 11.2c). Among the papers reviewed, the most cited by decade are observed in Table 2 (see in Appendix). It is possible to observe that since the appearance of the term transdisciplinarity until today, the ones that have been most cited are the contributions of Gibbons et al. (1994), Klein (1996), Gibbons (1999), Max-Neef (2005) and Hadorn et al. (2008) [5, 57, 6, 72, 54].

Figure 11.3a shows the number of authors from each country who have contributed to this perspective according to the literature review carried out. Finding that the countries with the highest number of authors who have researched and promoted this perspective are mainly Switzerland, USA, Germany, Austria, Sweden, France and UK.

The transdisciplinary perspective in these critical times of COVID-19, can be a support to approach the investigation, in diverse aspects, from the integration of diverse investigators coming from different disciplines, from the sustainable results that can be offered, from the participants and their spiritual dimension that they would have to work on and in this way decide in a transdisciplinary systemic way and especially today in training researchers (Figure 11.4).

In such, a way that addressing the problems that are experienced require the proposal of solutions from different scientists in collaboration with those who experience the problems; as the findings occur, sensitizing and re-educating the population is necessary. Hence, the importance of another perspective to investigate, where contemplating re-education and awareness of society would be relevant. It might be up to the scientific community, in part, to teach and work with society. This would be of great impact and would allow the transformation and evolution of societies and not involution.

Our students, and future Transdisciplinary researchers: The advantage they would have is that they could have developed the necessary resilience in these difficult times, which will help them not to fall into mental problems, to avoid problems of anguish, depression, loneliness, etc. These are difficult times, the transition to a new era, but you must maintain hope to be part of the reconstruction of a better world and to reconstruct new ways of doing science and of being human in science and in the world. Adapting to the changes of the new life will be necessary, awakening consciousness and joining the actions aimed at reconstruction or resurrection. This will fulfill what Basarab (1996) [97] said: that Transdisciplinary researchers appear more and more as hope-makers.

As is known, evaluating a project is a strategy for continuous improvement. In this way, there are proposals to evaluate both the effectiveness of the collaborating team and the aspects to be covered in a transdisciplinary project [111, 184]. In the case of the evaluation of transdisciplinary projects, Klein (2004) [111] proposes a questionnaire of 47 questions divided into five categories: A) initial phase, B) organizational and conceptual framework, C) learning and social communication, D) collaboration and integration and E) evaluation, innovation and dissemination related to various aspects that can be observed in Figure 11.5.

Other basic guiding supports for the researcher are various methodologies that have been reported in the literature. Which are based on general phases to develop

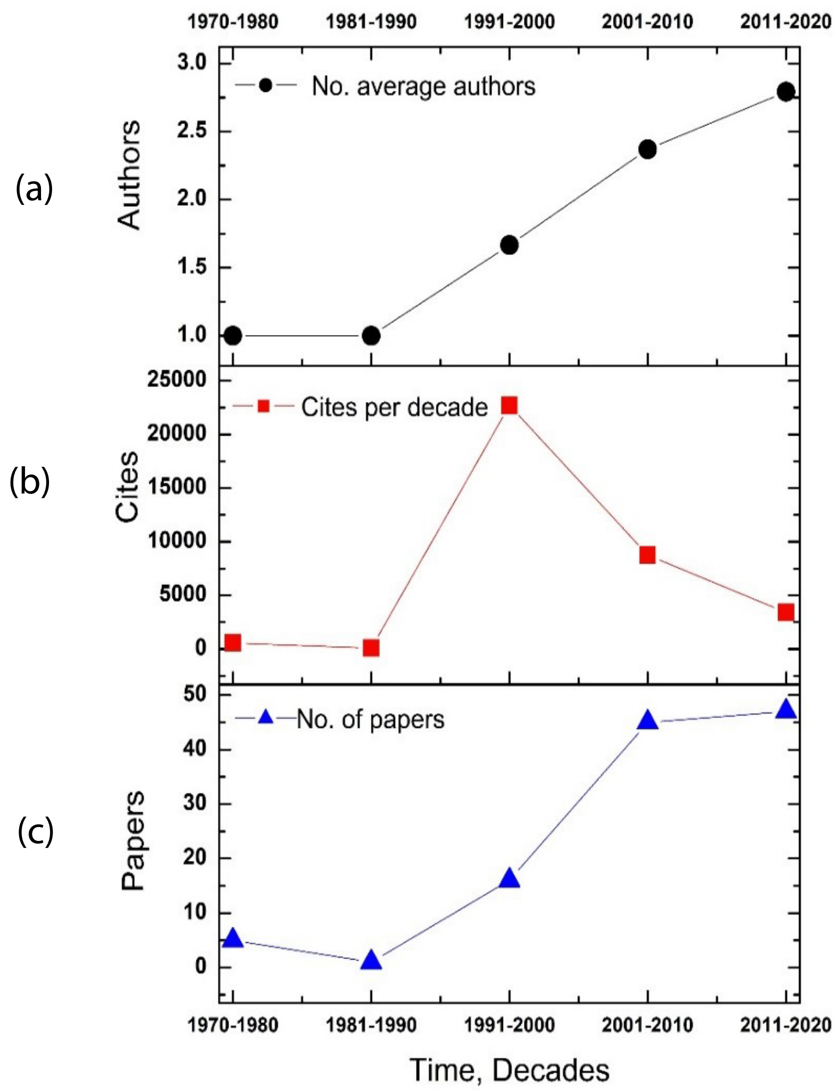

Figure 11.2: Contributions to the term and/or to characteristic features of Transdisciplinarity in the last 50 years (1970-2020), according to the literature review carried out: a) Average number of authors per paper, b) Total number of citations per decade c) Publications per decade.

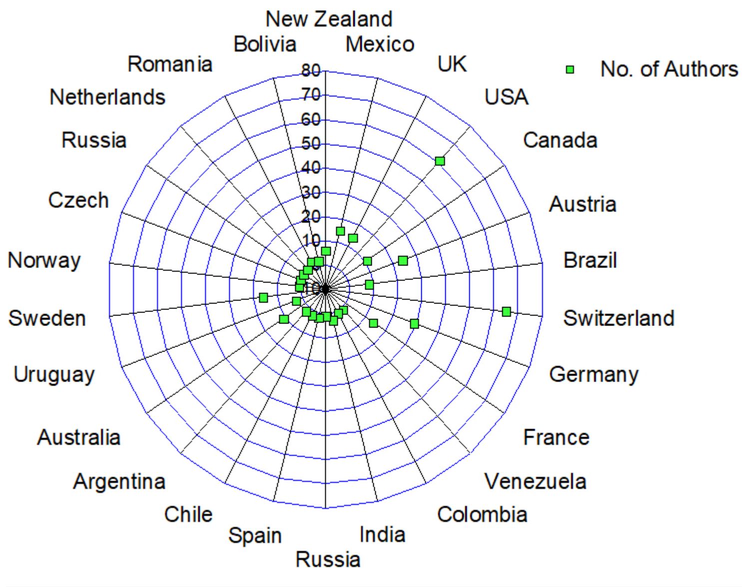

Figure 11.3: Number of authors per country who have made contributions to transdisciplinarity according to the literature review carried out.

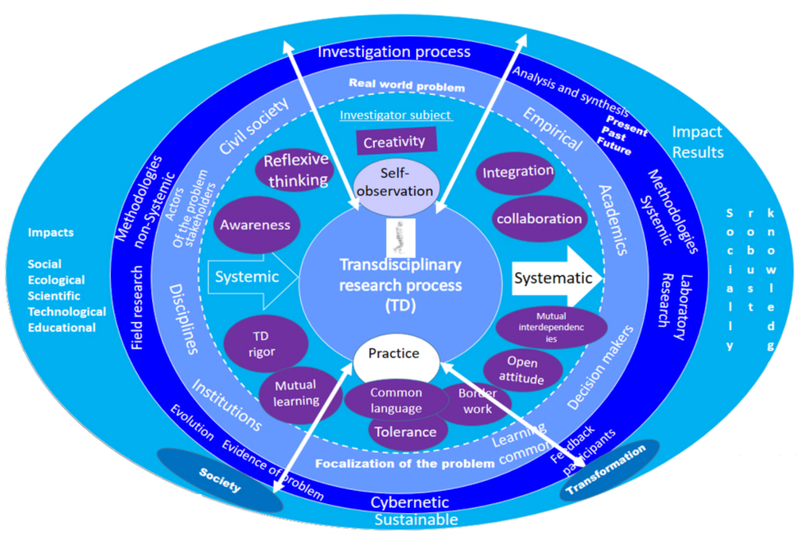

Figure 11.4: Model of the research process TD.

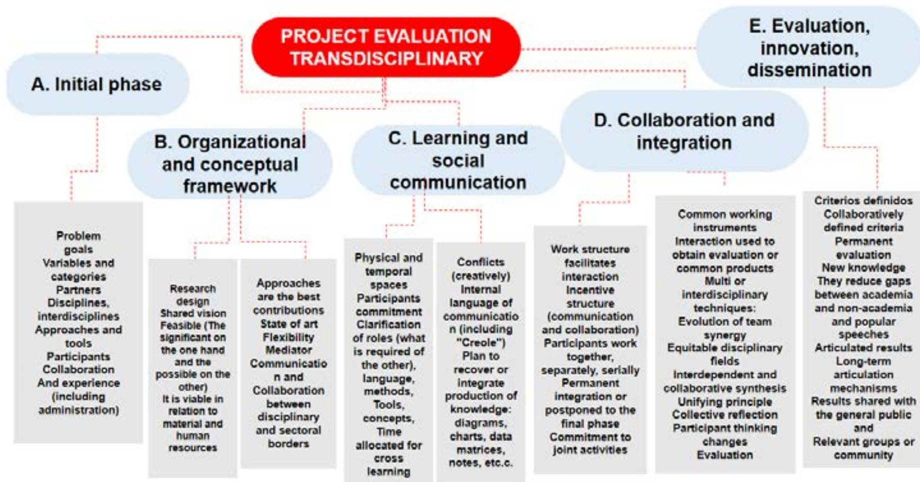

Figure 11.5: Transdisciplinary projects evaluation according to Klein (2004) [111].

the research process (see, Table 3 in Appendix). Basically, they coincide in: 1) the need to collaboratively define and understand the problem (including its various actors), 2) the design and planning of the research process, with the participation of the actors in all phases and 3) Preparation of the research synthesis, conclusions, recommendations and communication of results in the scientific field and to the public.

Only one of the methodologies (Hernández, 2018) [177], addresses a phase to develop the self-investigation of the subjects who investigate that is necessary to carry out the research process and can serve to maintain integration and close collaboration. In addition to develop, among other dimensions, the spiritual one that is decisive in a research process of this type and finally achieve self-transformation as one progresses along the path of research, becoming more aware of oneself, the others and the other.

Finally we can say that knowing the history of transdisciplinarity, its evolution, its characteristic features, etc. could allow current and future generations to work to fulfill them and in this way co-participate in the survival of man and his world.

11.6 Conclusions

The transdisciplinary approach could represent the best pathway to develop research in Latin America countries to face the diverse problems of society. The main countries that have developed this approach and have marked some characteristic features are Switzerland, Germany, the United Kingdom, the United States, Canada, France, and some of Latin America such as Bolivia, Colombia, Brazil, Chile and Mexico; where they are performing Research under this perspective and move on in the fulfillment of characteristic features of it.

The approach is in evolution and as time passes, various characteristic features are added according to the experiences that researchers face in the practice of transdisciplinarity. It is a challenge for researchers today, above all to make individual changes that must be made that demand their self-investigation and self-transformation that allows their evolution as the research carried out evolves, also evolve each one of them.

There is increasing acceptance in the world scientific community, increasing the number of articles by more than 100% compared to the last century, but there must be a change in the policies of those responsible for making them, so that transdisciplinary research achieves its objective of intervene in systems and thus evolve societies and nations.

Transdisciplinarity presents an evolution that allows complementing its concept and its characteristic features over time.

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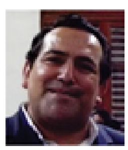

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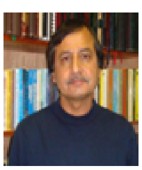

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Dr. Alfredo Cruz Orea completed his undergraduate studies at Escuela Superior de Fisica y Matemáticas del Instituto Politécnico Nacional. His Master and PhD studies in Physics were carried out at Universidade Estadual de Campinas, Sao Paulo, Brazil. From March 1994 to March 1999, he was a researcher at Programa Multidisciplinario en Ciencia Aplicada y Tecnología Avanzada at Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV - IPN). Since April 1999 he is a researcher at the Physics Department in CINVESTAV - IPN. Dr. Cruz is member of the Mexican Academy of Sciences since 2004, also he is member of Sistema Nacional de Investigadores, level III since 2008. His research is focused on the study of optical and thermal properties of materials by using Photothermal techniques. Dr. Cruz has published more than 200 articles in indexed international journals, five chapters in books, and around 900 citations from his articles (without self-citations). He has directed and co-directed 11 PhD theses, 14 Master's theses and 7 Bachelor's theses. He has been visiting professor at the Katholieke Universiteit Leuven, Belgium. Dr. Cruz also has been invited to teach courses on Photothermal Techniques at Universidad de Concepción, Chile and Universidad Surcolombiana, Colombia.

Dr. Jose Ordonez-Miranda is a CNRS researcher at the Institute Pprime in Futuroscope, France. His research area is the transport of heat by phonons, photons, electrons, and polaritons propagating in nanomaterials with applications in thermotronics. The Boltzmann transport equation and Maxwell's equations of electromagnetism are his main tools of theoretical modelling. He obtained his bachelor degree in applied physics at the National University Jorge Basadre Grohmann (UNJBG) in Tacna, Peru and received his Master in Physics from CINVESTAV in Merida, Mexico. Jose holds a Ph. D. degree in physics granted by CINVESTAV in collaboration with the University of Colorado in Boulder, USA. He performed a postdoc in the laboratory EM2C at the Ecole Centrale Paris, and was recruited by the CNRS in October 2015, for which he currently works as a full researcher (CRCN). Jose was awarded the prize of outstanding young researcher granted by the International Photoacoustic and Photothermal Association (IPPA), in 2014, Shanghai, China. In addition, In 2018, Jose received the medal Jorge Basadre as a distinguished researcher graduated from the UNJBG, Peru

APPENDIX

Table 1a. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Edgar Morin (1988)	In TD, "the knowledge operator must at the same time become an object of knowledge" (see, Carrizo and Gallicio, 2006) [134].	Paris, France
	Transdisciplinarity in the decade of the 90s.	
Mittelstraß (1992)	TD is a way of investigating that transcends disciplines to propose solutions to problems in the world of life, as quoted by Pohl (2008) [135].	Konstanz University, Germany
Arber (1993)	TD transfer concepts or methods from one discipline to another (see Scholz et al., 2000b) [136]	University of Basel, Switzerland
Kim (1998) [137]	TD is the "intellectual space" where problems are thought about, their alternative solutions and interrelationships are observed. "Co-operative work"= "sinergon"	UNESCO
Basarab (1999) [138]	Transdisciplinarity implies an ethical attitude of opening and dialog. Strengthens the physical, emotional and intellectual balance of the Subjec. Who bridges with itself, with others and with the nature to reconstruct, from the honesty and the commitment those social, environmental, cultural and affective. Strengthens their integral formation.	French nationalized
	Transdisciplinarity from 2000.	
TD Conference in Zurich in 2000 (Klein et al., 2001) [49]	Transdisciplinarity is a way of learning and solving problems through the participation of the academy and society. Facing the challenges of this last.	Zurich, Suiza
Flyvbjerg (2001)	TD is based on general theory of systems, complexity, contextualization, etc. Collect information from different disciplines to act wisely, etc. (Flyvbjerg, 2001; see, Montouri, 2013) [139].	Oxford University
Hadorn et al. (2002) [140]	Empirical and theoretical knowledge is necessary to know the system and its relationships. Noted another feature: mutual interdependencies	ETH Zurich, Switzerland
Hoffman-Riem (2002) [141]	Environmental research has to establish reliable knowledge that can be transformed into effective measures. This requires a combination of experiments and field observations based on different disciplinary perspectives.	Universität Bielefeld, Germany
Cicovacki (2003) [142]	Transdisciplinarity is a vision of humanity for the human knowledge and human relationships.	Department of Philosophy, Holy Cross College, Worcester, USA
Lawrence and Després (2004) [143]	TD challenges the fragmentation of knowledge. Characteristics: hybrid nature, nonlinearity, reflective, transcends disciplinary structure, accepts contexts of uncertainty, knowledge based on the specific context, collaboration in all phases of the research project, is usually oriented to action.	University of Geneva, Centre for Human Ecology and Environmental Sciences Universite Laval, Quebec, Canada
Balsiger (2004) [144]	TD research is scientific research and scientific rules are followed. TD does not compete with disciplinary approaches.	Interdisciplinary Institute of Philosophy and History of Science University of Erlangen-Nurenberg, Germany
Jones and Sime (2004) [145]	Connections are made between disciplinary boundaries, between academic and experimental research. Border work is required	University School of Social Sciences, Cardiff Wales- United Kingdom University of Utah, Salt Lake City, USA
Bruce et al. (2004) [146]	"Expand the mind" through the participation of the potential user to know their needs.	Scottish Universities Policy Research and advice network Institute for the study of Science, Technology and innovation, University of Edinburgh, United Kingdom.
Pinson (2004) [147]	Requirement: Cooperation between identifiable disciplines, dialogue with other specialties, etc. This cooperation will be more effective as each discipline defines its specific contribution.	University of Droit, Marseilles, France
Klein (2004) [148]	TD has become an important imperative in all sectors or domains of society and knowledge, which makes it an essential way of thinking and action. Transdisciplinary attitude is required to cultivate.	Department of Interdisciplinary Studies (CULMA), Wayne State University, Detroit, USA.

Table 1b. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Pohl (2005) [149]	TD takes into account: a) the complexity of a topic that jointly explains the current state of the topic and its dynamics, b) the different perceptions of science and society, and c) the separation of the idealized context of science to produce knowledge practically relevant.	Federal Technological Institute, Switzerland
McGregor (2005) [150]	Participants in a TD research project could be: academics, civil society, government authorities, companies, artists, etc. They propose the TD as a process to achieve peace.	Universidad Mount Saint Vincent, Halifax, Canada
Vitória's statement (2005)	"Transdisciplinary action articulates relationship with the world (ecoformation), the relationship with the other (hetero and co-formation), the relationship with ourselves (self-training) and the relationships with being (onto-formation)" (Cetrans, 2005; see, Casella, 2009) [151].	Victoria, Brazil
Wickson *et al.* (2006) [152]	Researchers who operate regularly in a TD manner would encourage the development of the integrative and collaborative required in research. Features: 1) The TD integrates various methodologies, it is not one, 2) collaboration with actors of the problem (affected people).	Wollongong University, and University of Sydney, Australia
Galvani (2006) [153]	Transdiscipline must be understood as an attitude of intellectual rigor, which allows the researcher to be aware of their own limits and the limits of their discipline. "Being transdisciplinary" for this author means being aware that everything cannot be explained through the lens of our profession or particular area, but we must accept that we need other professions and fields of knowledge, to gather all or the greatest possible number of perspectives that allow us to form a more complete idea of reality. Demanding openness not only to other disciplines, but also to classical and popular knowledge, and to the cross-cultural, including art, philosophy, spirituality, science, etc.	
Congress in Barcelona (2007)	Pineau points out contributions in ecological training, contemplating respect for nature (ecology) and others (otherness) [154].	Barcelona, Spain Pineau of the Rabelais Tours University, France.
Hadorn *et al.* (2008; 2010) [54, 155]	Research that addresses issues in the world of life. Phases: 1) problem identification and structuring phase, 2) problem investigation and 3) outcome phases. Transdisciplinary have three types of knowledge: systems, objective, of transformation, and reflects the mutual dependence.	ETH Zurich, Switzerland
Peón and Hernández (2009) [156]	The transdisciplinary research process is service oriented, useful to share with others or others. It always implies universal values and ethics. In addition to observing the object studied, it requires self-observation. We work for tolerance between different ideas of disciplined experts and even beyond, we work to understand the undisciplined, the empirical, the common citizen, etc. Constant awareness of unity. Focused not only on doing but also on being (Hernández-Aguilar).	National Polytechnic Institute Mexico
Casella *et al.* (2010) [157]	TD is a way of conceiving, thinking and analyzing the reality that surrounds. Seeks to relate knowledge with life. Born for to meet the need to deal with the unprecedented challenges of the problematic world in which we live and require a multi-referential treatment because they are complex.	Arkos University Studies Center, Puerto Vallarta, Mexico
Pinson (2004) [147]	Requirement: Cooperation between identifiable disciplines, dialogue with other specialties, etc. This cooperation will be more effective as each discipline defines its specific contribution.	University of Droit, Marseilles, France
Klein (2004) [148]	TD has become an important imperative in all sectors or domains of society and knowledge, which makes it an essential way of thinking and action. Transdisciplinary attitude is required to cultivate.	Department of Interdisciplinary Studies (CULMA), Wayne State University, Detroit, USA
Pohl (2005) [149]	TD takes into account: a) the complexity of a topic that jointly explains the current state of the topic and its dynamics, b) the different perceptions of science and society, and c) the separation of the idealized context of science to produce knowledge practically relevant.	Federal Technological Institute, Switzerland
McGregor (2005) [150]	Participants in a TD research project could be: academics, civil society, government authorities, companies, artists, etc. They propose the TD as a process to achieve peace.	Universidad Mount Saint Vincent, Halifax, Canada
Vitória's statement (2005) (151)	"Transdisciplinary action articulates relationship with the world (ecoformation), the relationship with the other (hetero and co-formation), the relationship with ourselves (self-training) and the relationships with being (onto-formation)" (Cetrans, 2005; see, Casella, 2009) [151].	Victoria, Brazil

Table 1c. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	Description	Nationality and / or Universities
Wickson *et al.* (2006) [152]	Researchers who operate regularly in a TD manner would encourage the development of the integrative and collaborative required in research. Features: 1) The TD integrates various methodologies, it is not one, 2) collaboration with actors of the problem (affected people).	Wollongong University, and University of Sydney, Australia
Galvani (2006) [153]	Transdiscipline must be understood as an attitude of intellectual rigor, which allows the researcher to be aware of their own limits and the limits of their discipline. “Being transdisciplinary” for this author means being aware that everything cannot be explained through the lens of our profession or particular area, but we must accept that we need other professions and fields of knowledge, to gather all or the greatest possible number of perspectives that allow us to form a more complete idea of reality. Demanding openness not only to other disciplines, but also to classical and popular knowledge, and to the cross-cultural, including art, philosophy, spirituality, science, etc.	
Congress in Barcelona (2007)	Pineau points out contributions in ecological training, contemplating respect for nature (ecology) and others (otherness) [154].	Barcelona, Spain Pineau of the Rabelais Tours University, France.
Hadorn *et al.* (2008; 2010) [54, 155]	Research that addresses issues in the world of life. Phases: 1) problem identification and structuring phase, 2) problem investigation and 3) outcome phases. Transdisciplinary have three types of knowledge: systems, objective, of transformation, and reflects the mutual dependence.	ETH Zurich, Switzerland
Peón and Hernández (2009) [156]	The transdisciplinary research process is service oriented, useful to share with others or others. It always implies universal values and ethics. In addition to observing the object studied, it requires self-observation. We work for tolerance between different ideas of disciplined experts and even beyond, we work to understand the undisciplined, the empirical, the common citizen, etc. Constant awareness of unity. Focused not only on doing but also on being (Hernández-Aguilar).	National Polytechnic Institute Mexico
Casella *et al.* (2010) [157]	TD is a way of conceiving, thinking and analyzing the reality that surrounds. Seeks to relate knowledge with life. Born for to meet the need to deal with the unprecedented challenges of the problematic world in which we live and require a multi-referential treatment because they are complex.	Arkos University Studies Center, Puerto Vallarta, Mexico
Núñez (2012) [158]	TD is a transformative experience, self-transformation process, where there permanent questions and reflective dialogues within different levels of Reality.	Veracruzana University, Mexico
Basarab (2013) [159] Congress of Higher Education held in Istanbul, Turkey	In his speech made a comparison between Disciplinary and Transdisciplinary Education: Disciplinary (D) and Transdisciplinary (TD): *e.g.* 1D. In vitro -1TD in Vivo; 2D. a level of reality-2TD Several levels of reality; 3D. accumulated knowledge - 3TD Comprehension; 4D. Analytical intelligence- 4TD New intelligence – harmony between mind, emotions and body, 5D. Binary Logic - 5TD Logic of the third included, 6D. Exclusion of human values-6TD Inclusion of human values, etc.	CIRET, Paris, Francia
Angelstam *et al.* (2013) [160]	Transdisciplinary research is based on: 1). integration of multiple disciplines and 2) of stakeholders- included levels of governance (representatives of different social sectors participate and have active inclusion in formulating problems, knowledge production and learning).	Swedish University of Agricultural Sciences Sweden and U.K.
Axelsson *et al.* (2013) [161]	Self-reflection, evaluation of the problem-solving process, multi-level collaboration.	Swedish University of Agricultural Sciences Sweden, Czech Republic, Austria, Canada,
Mauser *et al.* (2013) [162]	Stakeholders and academic, involvement in co-design and co-production of knowledgment. Co-design: 1) Joint framming (topic depent on societal emergence), 2) research definition (researc scale, research question), implementation (fulling calls, proposals, review, etc.). Co-production: 1) scientific integration (interdisciplinary, consistency, uncertainly), 2) Relevance (transdisciplinaryty, stakeholder, involvement), 3) Dissemination of results (translation, transparency dialogue, responsivity)	University Munich Germany, Australia, Netherlands France

Table 1d. Characteristic features and some definitions of transdisciplinarity.

AUTHOR (S)	DESCRIPTION	NATIONALITY AND / OR UNIVERSITIES
Augsburg Tanya (2014) [163]	Characteristics of a person who decides to do a TD job: moving from a traditional comfort zone, working outside one's own discipline, participating in different ways of thinking and acting, breaking the paradigm that science offers "the best solution", joy to see from another look, develop trust and mutual needs, be modest, build networks outside the family, etc.	San Francisco State University, California, USA
Benesh *et al.* (2014) [164]	TD research is a collaboration between investigators with several backgrounds, where their co-generate ideas.	Washington University School of Medicine
Darbellay (2015) [165]	Transdisciplinarity can be considered as a research method that brings together political, social and economic actors, as well as ordinary citizens, in the research process itself, in a perspective of "problem solving"	University of Geneva, Switzerland
Brenner (2015) [166]	Transdisciplinarity is a philosophical movement which can provide a new approach to current problems and paradoxes of human thought, science and philosophy.	Chemin du College Switzerland
Vilsmaier *et al.* (2015) [167]	TD research needs deep reflection, transformation of attitudes and capacity building by all participants; to overcome cultural differences that cause difficulties in the mutual learning process (Hirsch Hadorn *et al.*).	Lüneburg University, Germany
Mateescu *et al.* (2015) [168]	The TD leads to the change of man for access and participation in the socio-cultural and spiritual life.	University of Constanţa Romania
Wiesmann *et al.* (2016) [169]	Proposals to strengthen TD research process: among which are: Definition, scope and relevance, recursive processes, forms of knowledge, contextuality and generality, specialization and innovation, participation and mutual learning, values and uncertainty, management and leadership, education and career building, evaluation and quality control, etc.	Bern University, Switzerland
Hurni Hadorn and Wiesmann *et al.* (2016) [170]	They suggest that a transdisciplinary approach requires that the investigated phenomena be considered from a perspective that goes beyond specific disciplines and is based on a broad-spectrum participation characterized by systematic cooperation with those involved.	Bern University, Switzerland
McGregor (2017) [171]	Individual and collective diversities profoundly affect communications and collaborations during transdisciplinary work.	Mount Saint Vincent University, Halifax, Canada
Pohl *et al.* (2017) [172]	They propose reflective levels to interpret socially relevant problems.	ETH Zurich, Switzerland
Jim Morin (2017) [173]	TD is characterized by a paradigm shift to produce knowledge, overcoming the division of academic work and segmented into separate departments.	Universidad católica del Maule, Chile
Morales (2017) [174]	Participants in research projects TD must employ traditional scientific methods, research skills, even employ research methods such as the used in an art or design study. She uses the term of an individual transdisciplinarity.	Boston College USA
Appel (2018) [175]	TD are the efforts carried out in research by academics from different disciplines who work together to create conceptual, theoretical, methodological innovations, etc. for go beyond disciplines addressing complex problems.	Tiffin University, USA
Carol Costley and Nicola Pizzolato (2018) [176]	Qualities to promote in PhDs students: Researching collaboratively with stakeholders, diversity of disciplinary and assessment criteria, Integration of methodologies, situating of the research in multiple contexts, Impact on 'situation' with procedures or products news, Ethics and trust.	Middlesex University London
Hernández-Aguilar (2018) [177]	Proposes four phases for transdisciplinary training and research: 1) Contextual and documentary research, focusing on the problem and taking scientific evidence of it, 2) Self-research, 3) Experimental research, in search of the solution and its demonstration, 4) impact investigation.	National Polytechnic Institute Mexico City, Mexico
Fam *et al.* (2018) [178]	'science for society' is modified to 'science with the society (Fam)	University of Technology, Sydney Australia

Table 2. Contributions to transdisciplinarity most cited in the last 50 years according to the literature review carried out.

2011-2020	2001-2010	1991-2000	1981-1990	1970-1980
[1] Jahn *et al*. (2012) [41] [2] 675	Max-Neef (2005) [72] 1073	Gibbons *et al*. (1994) [5] 18630	Bertalanffy (1986) [29] 87	Jantsch (1970) [42] 353
Mauser *et al*. (2013) [122] 481	Hadorn *et al*. (2008) [54] 856	Klein (1996) [57] 1669		Kockelmans (1979a) [47] 158
Basarab (2014) [38] 378	Klein (2004) [108] 700	Gibbons *et al*. (1999) [6] 1028		
Pohl (2011) [53] 204	Klein (2001a) [8] 640	Brewer (1999) [52] 430		
Bernstein (2015) [11] 187	Wickson *et al*. (2006) [112] 585	Basarab (1996) [56] 347		
Scholz and Steiner (2015a) [39] 142	Pohl and Hadorn (2007) [73] 492	Basarab (1999) [98] 154		
	Miller *et al*. (2008) [33] 462			
	Lawrence and Després (2004) [103] 401			

Table 3. Some base methodologies in Transdisciplinary research processes

AUTHOR (S)	PHASES	APPLICATION
Scholz *et al*. (2000b; 2003; 2006) [136, 179, 180]	I. Preparation (choosing and knowing the case, including empathy) II. Realization III. Epilogue (synthesized group reports and case report presented to the public)	Groundwater management
Hadorn *et al*. (2008) [54]	I. Problem identification and structuring II. Problem analysis III. Provide results to a good end	Transdisciplinary research processes
Jahn, T. (2008), Jahn *et al*., (2012) [76, 82]	I. Constitution of a common object of investigation II. New transferable knowledge III. Transdisciplinary integration	Mainstreaming and marginalization
Enengel *et al*. (2012) [125]	I. History of the problem II. Problem identification and structuring III. Research design, method selection IV. Data collection V. Analysis of data VI. Reflection / Interpretation, synthesis VII. Dissemination of results	Development—an analysis of actor roles and knowledge types in different research phases
Lang *et al*. (2012) [182]	I. Frame research problem and team building II. Co-creation of solution III. Reintegration and application of created knowledge	Transdisciplinary sustainable research
Enengel *et al*. (2014) [181]	I. Concept II. Analytical network III. Collection and selection of case studies IV. Questionnaires and guidelines V. Triangulation, case-sensitive and inter-case results VI. Conclusions and recommendations for action VII. Feedback all with Knowledge of literature review And exploratory interviews with experts.	Stakeholder's perspective on efforts, benefits and risks
Richter *et al*. (2015) [183]	I. Transdisciplinary II. Systemic III. Adaptive management	Ecosystem approaches to health
Miah *et al*. (2015) [184]	I. Problem specification II. Generation of ideas III. Solution development III. Application IV. Knowledge dissemination	Academy-industry
Berger *et al*. (2016) [185]	I. Knowledge of facets of variable to study II. System analysis III. Final Synthesis IV. Project goals (guiding question) V. Terminal focal variable	Cancer knowledge
Hernández et al. (2018) [177]	I. Contextual, field and documentary research - (Focus and evidence of oak in the real world (MR)) II. Investigation of the investigating subject- Self-research III. Experimental research, in search of the solution, its demonstration and new proposal design IV. Investigation of the impact of the proposal (Including impact research and communication of results (scientific and social level))	Training of transdisciplinary researchers
Gebhardt et al. (2019) [186]	I. Understand users in their everyday context, II. Describe and identify the various types of users III. Developing ideas and concepts, testing and evaluating in the Real World Laboratory	Sustainable mobility system

CHAPTER 12

Advancing with Transdisciplinarity: Effective Responses for Coronavirus

Roderick Lawrence

The term 'transdisciplinarity' was discussed 50 years ago at the International Seminar on Interdisciplinarity in Universities in Nice, France. Then, transdisciplinary contributions were defined as those establishing a common system of axioms for a set of disciplines using systemic logics and the synthesis of higher order disciplinary relationships that distinguish transdisciplinary from multidisciplinary and interdisciplinary contributions. These key principles are recalled because societal challenges and problems, such as the current coronavirus pandemic, highlight the difficulty of many scientists, public administrators and politicians to think systemically within and beyond the conceptual and methodological boundaries of their discipline and profession. Although discipline-based expertise is needed about coronavirus, alone, it cannot provide a comprehensive understanding necessary for effective responses to its multiple impacts within and beyond the public health sector. This chapter proposes that the coronavirus SARS-CoV-2 pandemic should be considered as an emergent, complex, contextual, and systemic societal challenge that requires concerted actions involving not only disciplinary and professional expertise but also other types of knowledge and know-how. The chapter includes a conceptual framework that represents this transdisciplinarity.

Keywords: Conceptual framework, coronavirus, disciplinary confinement, science-society relations, societal challenges, systemic thinking, transdisciplinarity.

12.1 Introduction

On 11 March 2020, the World Health Organization declared the current coronavirus SARS-CoV-2 pandemic and underlined that the multiple impacts of COVID-19 disease are unknown, emergent, contextual and unpredictable [1]. Since then there is a growing concern about the rapid expansion of thousands of scientific publications that complement omnipresent mass media coverage about the coronavirus SARS-CoV-2 pandemic, and ongoing treatments for patients diagnosed with COVID-19 [2]. Many scientific articles published in peer review journals report ongoing biomedical or epidemiological research as well as testing treatments and cures of patients by medical practitioners and others [3]. Concurrently, the partisan claims of politicians and elected officials, whether at national, state, or local geo-political levels in some countries, have also been reported. They confirm the political instrumentalisation of emerging data and information about the pandemic and that we are living in a post-truth era.

In a recent commentary on research gaps about coronavirus, Trudie Lang (2020) [4] noted that over 2000 clinical trials had been registered around the world, mostly in hospital settings in countries with high gross domestic product (GDP). She also noted that these contributions repeat the custom of much medical research that benefits only about 10 per cent of the world population. This is one outcome of the increasing privatisation and commodification of medical and health care since the 1970s. It recalls a fundamental ethical principle about the societal impact of specialised research and teaching. It also raises the question about how societal challenges, including the current coronavirus pandemic and other infectious diseases, are interpreted as scientific problems that can be resolved by empirically validated knowledge produced for decision makers in the public and private sectors (see later).

The common ground and differences between scientific, political and public responses to the current coronavirus pandemic illustrate how divergent, sometimes conflicting interpretations of emergent situations and persistent problems are interpreted and confronted by societies at national, state and local geo-political levels [5]. These differences highlight the need to account for individual, social and cultural values that coexist in human societies. We underline that too little attention has been attributed to human beliefs, intentions, motives, preferences, and fundamental values that frame the societal responses to the current pandemic, as well as individual and collective behaviours. We regret that too few contributions from authors and institutions in the scientific, professional and public policy domains have addressed these subjects, and these omissions highlight the limits of scientific research and professional expertise to address the current complex and unpredictable global health challenge [5]. Based on real-world situations in cities and countries around the world, we argue and illustrate that interdisciplinary collaboration, cross-sector professional co-ordination, political commitment and leadership, and social adherence to behavioural norms and rules are all needed; they should be combined creatively to understand multiple meanings, perceptions and values in order to collectively define and implement effective transdisciplinary responses to the current pandemic.

In her contribution about research gaps on the current pandemic, Trudie Lang (2020) [4] included fundamental questions about the medicalisation of scientific research on COVID-19 that ignores behavioural, cultural and economic variables which influence individual and population health, especially infectious diseases including Ebola and Zika. These variables cannot be dissociated from human behaviour, perceptions and values. Accordingly, we have analysed, synthesised and explained the virtuous relations between three prerequisite conditions - multilevel governance; different types of knowledge and other kinds of resources; and community adherence to individual and collective behaviours - that should be combined and synthesised in transdisciplinary responses to the coronavirus pandemic at several geo-political levels [5].

This chapter highlights the advantages of these kinds of human-centred responses, because they confirm the pertinence of key principles about the societal impact of interdisciplinary scientific research discussed 50 years ago at the International Seminar on Interdisciplinarity in Universities held in Nice, France, in September 1970 [6]. A half century later, our reading of the seminar papers and other literature indicates that some of these key principles are sorely missed in research, policy making and interventions in countries and cities, whereas they have been implemented successively in others [5]. For this reason, this chapter is written to mark the 50th anniversary of this public use of the term transdisciplinarity; it presents a transdisciplinary conceptual framework that can facilitate shared understanding and responses to the current pandemic.

This chapter reports conceptual research that has examined plausible interrelations between specific concepts and principles proposed to define transdisciplinarity in 1970, and applications of these concepts and principles to study specific subjects, problems, or situations in the world. This approach recognises that a key concern among academics 50 years ago was the purpose of scientific research and education as well as their social purpose. We endorse the pertinence of foundation concepts of transdisciplinarity proposed by the first generation of scholars in the 1970s to deal with complex societal challenges, such as the current coronavirus pandemic, other infectious diseases, loss of biodiversity, climate change and mass migration, provided that fundamental human beliefs, meanings, perceptions, values, and worldviews are included.

The next section of this chapter briefly recalls some key concepts and core principles discussed at the at the International Seminar on Interdisciplinarity in Universities in 1970, as well as in other publications about that time. We argue that these concepts and principles are pertinent for effective responses to the current coronavirus, whereas disciplinary confinement has meant that they have rarely been included explicitly in scientific publications, public policies, or general public media about the pandemic.

12.2 Sense of Purpose of Scientific Research for Societal Challenges

Participants at the International Seminar on Interdisciplinarity in Universities held in Nice, France, in 1970, discussed the academic and institutional organization of scientific research and higher education according to autonomous disciplines. This custom not only supported the segmentation and specialisation of research and teaching; it also endorsed a strong bias positioning scientific knowledge above all other types of knowledge and know-how (see later). During the seminar, Swiss psychologist Jean Piaget's (1896-1980) distinguished between multi-, inter- and trans- according to the properties of relations between several discipline-based components. Notably, extra-scientific knowledge was not included. Piaget posited that transdisciplinarity denotes a higher stage of interrelations that succeed interdisciplinary relationships to create a multi-level order [7]. Erich Jantsch (1929-1980), an Austrian astrophysicist, complemented Piaget and proposed principles of general systems theory applied to science. He explained that "... objectivity does not reside in facts, but in relationships to be found in reality" [8, p.98]. Then, the participants defined transdisciplinary contributions as those establishing a common system of axioms for a set of disciplines using systemic logics and the synthesis of higher order disciplinary relationships that distinguish transdisciplinary from multidisciplinary and interdisciplinary contributions.

We agree with Piaget and Jantsch that transdisciplinarity has multiple interpretations and it can denote a verb; notably it designates communication, collaboration, interactions and interrelations that may not lead to integration or fusion during specific projects (see later). This core principle has been forgotten by those researchers who have endorsed a unity of knowledge using 'the integration imperative' so aptly described by Nicole Klenk and Katie Meehan (2015) [9] in relation to research on climate change. We propose that conflicting beliefs, meanings and values attributed to societal challenges, illustrated by the current coronavirus pandemic, confirm that achieving consensus and integration or fusion should not be assumed (see later).

Jantsch's contribution in 1970 also proposed an ongoing debate about the fundamental contribution of a human-centred interpretation of the purpose of science and technology:

> "... the crucial question is whether science and its internal system, or "structures", of relationships is independent of human or social purpose, or whether there is a feedback link tying them together. We have learned part of the answer by recognizing that not only scientific facts, but also scientific structures can be grasped by the human mind only through what we may call anthropomorphic modes of organization ... " [8, p.98].

Jantsch asked his audience to consider whether "science is an autonomous cultural expression" which challenges the conventional interpretation of science founded on individual curiosity and creativity; or whether science "is a social overhead investment" assuming that science "underlies all the purposes of society, and is therefore to be carried out in an organisational structure which is patterned on the conceptual structure of knowledge" [8, p.98].

Similar ideas had already been published in 1939 by John Desmond Bernal (1901-1971) about the scope and purpose of science, technology and public policy [10]. Bernal was an Irish physicist who argued that science should not be an autonomous and protected field of intellectual inquiry; instead it should contribute to improving human livelihood, thus becoming an agent of change rather than isolated in institutions. In 1970, René Dubos (1901-1982), a well-known micro-biologist, expressed his concern about how scientific knowledge could be used to understand human problems [11]. We note that problem solving has been an important motivation for both interdisciplinary and transdisciplinary research, while underlining that specialised disciplinary research has also made important contributions to understanding societal problems.

Nonetheless, about 50 years ago the fundamental limitations of scientific analyses of social policy problems, including public health challenges, were discussed by Horst Rittel and Melvin Webber at a meeting of the American Association for the Advancement of Science in December 1969:

> "The search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems. They are 'wicked problems', whereas science has developed to deal with 'tame' problems" [12, p.155].

The distinction between tame and wicked problems proposed by Rittel and Webber in 1969 is pertinent for the debate about the limitations of science to respond effectively to complex ecological and societal challenges. However, we underscore that science should make specific and unique contributions by providing empirically validated data and information to the general public. This was well illustrated by the contribution of science to identifying and monitoring the depletion of the ozone layer before international organisations, national authorities and private enterprises formulated and implemented effective responses.

12.2.1 Lessons from Concerted Action on the Ozone Layer

In 1974, scientists discovered that chlorofluorocarbon (CFCs) gases were depleting the ozone in the stratosphere. These gases were common propellant in spray cans, and they were also used as refrigerants and solvents. In the 1980s, scientists observed a measurable thinning of the ozone layer over Antarctica. The scientific discovery that human-made CFCs were a major agent in the depletion of the ozone layer soon followed. On 16th September 1987, politicians from 24 countries signed the Montreal Protocol on Substances that Deplete the Ozone Layer which came into force on 1st January 1989. This Multilateral Agreement established legally binding measures for the national production and consumption of ozone depleting substances. These substances should be phased out of use by the mid-21st century [13,14].

The causes of the depletion of the ozone layer were clearly identified by researchers in disciplines of the natural/physical sciences. However, alone, access to scientific knowledge cannot resolve this global problem; the depletion of the ozone layer is not just a scientific problem (nor one requiring an innovative technical solution), because the know-how required to restore and sustain the constitution of the ozone layer already existed but had to be applied globally. Hence, this is a complex societal problem, comprising ten properties of wicked problems proposed by Rittel and Webber (1973) [12], that requires synergies between political recognition (rather than denial), and pertinent regulatory means and measures (rather than *laissez-faire*), the allocation of appropriate financial incentives, funds and other resources for implementation (for the public good), and broad public adherence based on effective communication. In order to implement these multiple measures, a coalition of scientists, policy-makers, politicians and representatives of the private sector is needed to reach an agreement on the causes before they negotiate how to proceed from empirical knowledge to policy definition and then effective measures prior to implementation. This is precisely what has been achieved by extensive transboundary communication and negotiation processes between scientists and a wide range of actors and institutions at international and national geo-political levels. This transdisciplinary achievement has rarely been repeated but it is sorely needed to respond effectively to the current coronavirus pandemic and other public health challenges.

12.2.2 Rethinking Human Values

Elsewhere, we have argued that an important barrier to societal change is not lack of data, information, and knowledge about persistent problems. Instead, inertia is grounded in human beliefs, intentionality, preferences, values, and worldviews that influence individual and collective behaviour [15]. We live in a value-laden world; therefore, it is the personal and shared beliefs, experience, perceptions, and values associated with societal problems and global challenges that count, not just the addition of the number of people concerned. Fundamental values should be identified and understood, whereas they are generally excluded from so-called ‘objective’ scientific research which is claimed to be ‘value neutral’ and a-political. In contrast, Rittel and Webber (1973) [12] explained that human beliefs, values, and worldviews are embedded in interpretations of societal problems.

Values convey the relative importance of objects, events, situations, challenges and problems. They are guiding principles that influence human aspirations, choices, intentions, and goals that are embedded in human interpretations of these challenges and problems and responses to them [16]. Individual, societal and fundamental cultural values coexist in precise localities with respect to specific subjects and situations. Dyball and Newell (2015) [17] confirmed that human ecologists have accounted for values, but they have often used the term narrowly, referring to a numerical amount, magnitude or monetary values of objects, or a quantity of material things (e.g. the stocks of ecosystems). We enlarge common interpretations of value to include aesthetic, cultural, moral and spiritual values because these are embedded in people-society-environment-biosphere interrelations that are contextual and dynamic. All decision making involves choices and trade-offs between these different values [12].

Values are incorporated in the anthropo-logic of the human ecology framework we proposed 20 years ago [18]. In the fields of interdisciplinary and transdisciplinary research, whether theoretical or pragmatic, it is difficult to understand why much more attention has not been attributed to improved understanding of the diversity of human beliefs, intentions, priorities, and values that coexist in heterogenous societies. Notably, different, and especially conflicting experiences, intentions, perceptions, and values should be understood and dealt with more effectively than they are by conventional processes for consensus building which rarely confront incommensurability.

12.3 Core Principles of Transdisciplinary Contributions

From the 1970s, interdisciplinary curricula and research gathered momentum in the cognitive sciences, environmental sciences, gender studies and urban studies [19,20]. However, these contributions were often prescribed only by combinations of scientific knowledge produced by empirical research that applied methods and reasoning developed and validated in the natural/physical sciences, and to a lesser extent, the social/human sciences. The hegemony of scientific knowledge was rarely challenged before the 1990s even though authors including Michael Polanyi (1969) [21] - like Jean Piaget and Erich Jantsch - had challenged positivism and reductionism, and instrumental rationalism that excluded those types of knowledge and ways of knowing that were not scientific, objective, or validated empirically by research protocols.

Between 1970 and 1990, the field of transdisciplinarity did not develop as extensively as interdisciplinarity. In both cases, many project-based contributions in real world situations were defined and implemented by funding agencies for academic researchers who collaborated in increasingly large research consortiums to share knowledge collected, synthesised and validated by disciplinary concepts, methods and protocols in several scientific disciplines. Until the 1990s, extra-scientific types of knowledge were rarely included [22]. When other types of knowledge were introduced there were two dominant currents of thought that proposed how they should be included in theory and practice; the first proposed integration to create a fusion or unity of knowledge, whereas the second promoted joint problem solving by the co-production of knowledge in precise situations. These will be briefly summarised in the next two subsections.

12.3.1 Integration for Unity of Knowledge

At the International seminar in 1970, Jantsch explained that models of society influence the organization of sciences and disciplines, and this ordering confirmed the importance of human values. From the 1980s, one main current of thought about transdisciplinarity included the search for unity of knowledge which the Preface to the OECD publication described as "... a nostalgia of world unity" [8, p.1]. The theoretical contributions of Basarab Nicolescu and French speaking scholars at the International Centre for Transdisciplinary Research (CIRET), in Paris, founded in 1987, are examples of this current of thought [23,24]. These French language contributions raised important questions about the conventional production of scientific knowledge. Like Piaget and Jantsch, they challenged the fragmentation of discipline-based knowledge, and they proposed the search for a unity of knowledge. Nicolescu proposed a fusion of different types of knowledge including objective scientific knowledge and subjective experiential knowledge in real-world situations:

> Transdisciplinarity "... concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines" and its aim is the unity of knowledge together with the unity of our being: "Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge" [23, p.44].

Nicolescu also proposed 'multiple levels of Reality' which are complex, dynamic, and emergent. Notably, transdisciplinary processes create shared values between the participants. We consider that these important contributions to the epistemology of transdisciplinary knowledge should acknowledge that human values are fundamental foundations of human agency and culture, and they influence transdisciplinary projects. They may be shared or conflicting, and perhaps incommensurable, as we noted in the case of the current coronavirus pandemic [5]. Although certain human values may be shared between participants during specific projects, others that are incommensurable cannot be integrated, such that fusion or unification is impossible.

12.3.2 Co-Producing Knowledge for Solving Problems

From the 1990s, a second current of thought about trandisciplinarity followed the issues raised by Jantsch in 1970 about the interrelations between science and society. This became a long and ongoing debate about the science-policy tandem and the science-practice tandem. This current of thought includes post-normal science, co-production of knowledge, and Mode 2. Following Gibbons et al. (1994), [25] debates about Mode 2 science and post-normal science have acknowledged the importance of accounting for the diversity of meanings attributed to real-world projects. In 2001, discussions about Mode 2 science were extended by Mode 2 knowledge and Mode 2 society (Nowotny et al. 2001) [26]. This enlarged discussion extended debates in the 1970s about mutual relations between knowledge creation and the society in which this occurs. Lawrence (2015) [22,27] emphasised that these contributions highlighted the need to explore the cultural and political contexts in which any subject or situation occurs, as well as the human beliefs, intentions, motives, perceptions, and values envisaged to change them, but such contributions are rare.

A German Speaking School, sometimes mislabelled the Zurich School, [28] received large funding in the 1990s from public authorities who sought responses to ecological challenges, such as reducing negative impacts on natural ecosystems, especially loss of biodiversity, whether in alpine, forest, or wetland ecosystems. These interdisciplinary projects in German speaking countries in Europe were dominated by natural/physical scientists who were meant to identify, understand, and propose solutions to specific problems. For example, in 1991, the Swiss National Science Foundation funded the Swiss Environmental Priority Programme which included transdisciplinary research projects [29]. According to explicit terms of reference, this meant that projects had to propose joint problem definition, involving researchers and professional practitioners, joint problem solving and also the joint evaluation of project outcomes by representatives of these two groups. These projects were founded on the assumption that scientific research is the main resource for solving environmental problems provided they included contributions from representatives of society. Many projects followed the custom of social research methods applied after 1945. This meant that many of these projects involved participatory research, or participatory action research. Based on the accumulation of research projects during the 1990s, an International Transdisciplinary Conference was held in Zurich at the Swiss Federal Institute of Technology (ETHZ) in 2000 [30].

The International Transdisciplinary Conference in Zurich included numerous presentations by international participants (not only German speaking), about collaborative projects that involve researchers and non-academic participants from society jointly concerned about resolving problematic situations [30]. These projects were examples of the shift from 'science for society' to 'science with and for society' that had expanded during the 1990 in tandem with research on sustainable development. Many of these projects were managed by scientific researchers in academic institutions who were committed to problem solving. They were examples of participatory action research that adopted the term transdisciplinary and combined knowledge from different disciplines, sometimes including both the natural/physical sciences and the human/social sciences. However, the content of the post-conference book indicates that many projects rarely employed other core components of transdisciplinarity discussed from the 1970s, notably a common system of axioms using a logic of systemic relations between different types of scientific and extra-scientific knowledge that would be ordered creatively to provide a higher order of understanding than conventional multi- and inter-disciplinary contributions [31].

12.4 A Transdisciplinary Conceptual Framework

Conceptual frameworks are sets of assumptions, beliefs and concepts that are used implicitly or explicitly to represent real-world phenomena. The value of conceptual frameworks and models as aids to thinking about complex subjects gained importance with the development of systems theory from the 1960s [17]. These frameworks can be derived from literature reviews, observational studies, and other kinds of empirical research. They are representations of complex, real-world subjects. They are useful in order to represent diverse components of extant subjects and situations according to logical patterns and interrelationships. The crucial challenge is to ensure that all key variables are accounted for before the direct and indirect interrelations between them are deciphered.

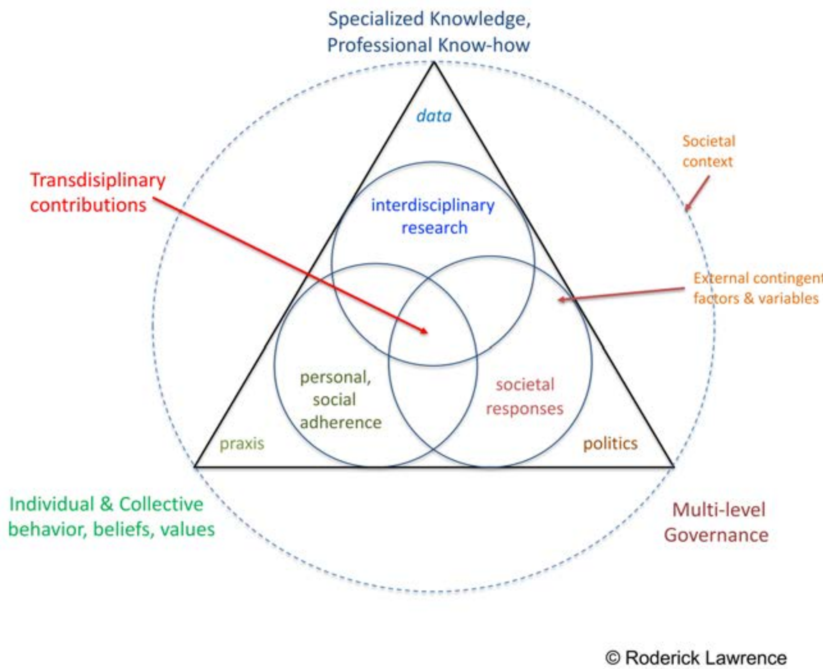

Figure 12.1: This transdisciplinary conceptual framework represents a complex and dynamic system in which each set of variables has unique properties that are influenced by mutual interactions with other sets of internal and external variables. Effective responses to the emergence, complexity and uncertainty of coronavirus SARS-CoV-2 and the compound health, economic and social impacts of Covid-19 disease, require collective understanding before implementing concerted action involving disciplinary knowledge and professional know-how, several types of resources, coordinated multi-level governance, and individual and collective behaviours, that should be combined in transdisciplinary contributions.

Figure 12.1 is a conceptual framework that represents a transdisciplinary triad including three key sets of variables and the mutual interaction between them and other external variables. These three sets of contextual and dynamic variables are not fused or unified but retain their specific and unique characteristics as components of a complex and dynamic system [32]. The components and the mutual relations between them can facilitate our understanding of the incidence and propagation of the coronavirus pandemic in precise localities; for example, the differences between large cities such as Hong Kong, Melbourne, New York, Stockholm, and Taipei.

This framework represents an open system given that the emergence of the pandemic, and its impacts on population health, is influenced by both internal and external variables and dynamic relationships. The framework can be used to identify and monitor pertinent variables as well as the mutual interaction between them.

We argue that this has rarely been done systematically to understand the complexity, emergence and diffusion of coronavirus SARS-CoV-2 and Covid-19 disease. One consequence of this conceptual framework is that disciplinary confinement is challenged and the need for intersectoral collaboration is highlighted. Different types of discipline-based research methods - both quantitative and qualitative - are required and should be co-ordinated. Another consequence is that a spectrum of interventions founded on scientific research, public policies, and communal and private initiatives need shared agreements and the allocation of resources prior to interventions. Moreover, these initiatives should be monitored to assess whether desired impacts are achieved; if they are not realized concerted action can facilitate adaptations. This capacity to adjust has been illustrated by evolving public policies and collective behaviors to contain the coronavirus in some cities [5].

This transdisciplinary conceptual framework is broader in content, scope and purpose than the two dominant interpretations of transdisciplinarity mentioned earlier. It acknowledges the relative importance of multiple types of knowledge, know-how and ways of knowing that are contextually embedded in specific localities and situations. It confirms that scientific knowledge can contribute to understanding and monitoring societal challenges and facilitate human well-being. Recalling the debate in 1970, this systemic framework also acknowledges that not only the key sets of variables but also the mutual relations between them should replace linear cause-effect relations. The framework also accommodates heterogenous sets of human beliefs, intentions, perceptions, meanings, and values. It confirms the fundamental role of human values that was recognised in the 1970s but have been devalued since then in much research, policy, and practice [27]. In the wake of the coronavirus pandemic, these distinctions are sorely missed, and many controversies based on false claims and partisan divisions have been published [33].

12.4.1 A Transdisciplinary Triad

In the 1970s, the distinction between societal problems and scientific problems was proposed but rarely adopted in academic research grounded in the science-policy interface. Notably, Rittel and Webber (1973) [12] explained that scientific problems are usually isolated from their extant situations before they are studied, and a solution is proposed using explicit rational knowledge derived from scientific research protocols. They emphasized that scientific problems are meant to be definable, objective, static and neutral. The development of a vaccine for COVID-19 is one example because it will prevent the symptoms of this disease but not eradicate multiple causes of coronavirus. In contrast, Rittel and Webber explained that societal problems of this kind should not be isolated from their cultural, political and temporal context, because they are emergent, systemic and unpredictable, and they have no definite resolution. This is clearly the case with the current coronavirus pandemic. We now have ample evidence that societal responses to the current coronavirus are not determined only by scientific data, information, or protocols as scientists have often assumed. The following paragraphs briefly present and illustrate the three core sets of variables included in the transdisciplinary triad presented in Figure 1.

First, multi-level governance of this global pandemic, shown at the bottom right of Figure 1, is fundamental and explained in Lawrence (2020) [5]. Governance denotes the way that governments, public administrations, private enterprises, and community associations interpret the pandemic; whether and how they decide collectively to respond to it. In order to reduce known unknowns about this beta-type coronavirus with species jump, the coordinated synthesis of disciplinary expertise, interdisciplinary knowledge, professional know-how and social perceptions is necessary; then this improved understanding can be applied to define the appropriate public health policies and those interventions required to implement effective responses.

The second prerequisite condition, shown at the top of Figure 1, is the importance of specialized biological, epidemiological, medical and veterinary knowledge and professional know-how required to understand and counteract a new virus for which there is still no proven medical or pharmaceutical remedy. The known unknowns about this coronavirus can be identified and studied by applying key principles of One health, Ecological public health, and Planetary health during transdisciplinary research and practice in community settings to 'collect facts on the ground' beyond the walls of laboratories. Lawrence (2020) [5] explained that this pandemic confirms the crucial function and contribution of access to many types of resources when they are needed at the appropriate time; in particular, sufficient stocks of medical equipment; hospital wards with specialized infrastructure; replenished supplies of pharmaceutical products; adequate numbers of trained and qualified medical doctors, nursing staff and auxiliary personnel in hospitals, medical centers and nursing homes for elderly persons; and coordinated uses of all these resources when the virus is first diagnosed in specific localities.

The third prerequisite condition that influences effective national, city and communal responses to counteract the transmission of coronavirus is individual, household and community adherence to behavioural norms and new regulations introduced by national and local governments – see bottom left of Figure 1. Some interventions by governments and public administrations concern regulating personal behaviour and interpersonal contacts. For example, norms and rules include different degrees of confinement, controlled access to outdoor public spaces, markets and shops, social distancing, quarantine, wearing masks and washing hands. Lawrence (2020) [5] explained that public adherence to these norms and rules cannot be assumed owing to cultural, social, and psychological reasons including religious customs, spiritual beliefs, group identity and the notion of individual liberty.

12.5 Synthesis and Conclusion

The extraordinary situation of the current pandemic should be a catalyst for rethinking the foundations of science-society relationships. The organization and coordinated uses of different types of knowledge need to be reconsidered, while accounting for human beliefs, intentions, meanings, perceptions and values used implicitly and explicitly to fund and conduct scientific research about societal challenges within and beyond the domain of public health (e.g. housing, malnutrition, obesity etc.). We now have ample examples of the strengths and limits of scientific research to deal with the current SARS-CoV-2 pandemic knowing that the emergent, complex and unpredictable nature of this coronavirus cannot be prescribed by conventional scientific protocols. It should also be the occasion for sceptics of interdisciplinary research and transdisciplinary projects in and beyond the medical and health sectors to question their adherence to disciplinary confinement based on the limitations and strengths of uncoordinated sector-based approaches that have been implemented to tackle the current pandemic.

We underline that the capacity of scientific knowledge alone to provide a pertinent framework for understanding and responding to the current pandemic should not be taken for granted. There is an urgent need for more in-depth and wholistic understanding of the biological, cultural, medical, para-medical, and societal variables that influence health and quality of life in specific localities. This means that many types of knowledge and ways of knowing need to be understood. The transdisciplinary triad of multilevel governance; multiple types of knowledge, know-how and resources; and individual and community adherence to behavioral norms and rules, should become the foundations of more coordinated, systemic and communal responses to public health risks and vulnerability in these and future extraordinary circumstances.

12.5.1 Conclusion

During the last 20 years, it has been increasingly realized that, alone, the accumulation of scientific knowledge, and professional expertise, will not automatically prescribe individual or collective responses to persistent problems and societal challenges [34]. The joint contribution and commitment of pertinent actors and institutions in both the public and private sectors is necessary to implement effective responses to societal challenges including the current coronavirus pandemic. It is crucial to identify and understand the multiple types of knowledge, know-how, and ways of knowing that coexist and are pertinent when defining and implementing societal responses.

Finally, since the 1970s, the ongoing quarrel about the advantages of collaborative research projects compared with conventional disciplinary contributions has focused on the breadth and depth of knowledge required to understand and respond to real-world challenges that surpass the boundaries of any single discipline. This narrow focus is founded on a common assumption that these societal challenges are inscribed within several (not one) disciplinary knowledge domain. Major interventions, such as the positive response to the current coronavirus pandemic in several cities and countries, confirm that the subject is more complex: In principle, scientific knowledge is only one component of collective thinking and action that are inscribed in a cultural context with a specific political agenda. Consequently, transdisciplinary contributions can make a crucial contribution in defining the contingent factors that enable or inhibit decision making to deal with societal challenges in our post-truth era. This has been well documented by a recent publication of the OECD [35]; it presents 28 transdisciplinary projects 50 years after the international seminar in Nice discussed the pertinence of such contributions.

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CHAPTER 13

Cooperation of the Western Balkans States: Opportunity to Overcome Security Challenges

Bejtush Gashi and Gurakuç Kuçi

The Western Balkans is dominated by its geographical position, which, after the end of the Cold War in the 1990s, was one of the regions that experienced the most difficult transition because this process was accompanied by bilateral and multilateral conflicts, with local and regional wars, with political and ethnic clashes. As a consequence, it was also politically fragmented on its map. The international community actively intervened in the Balkans with various civilian and military missions, respectively during the conflict in Bosnia and Herzegovina, Kosovo and North Macedonia (former FYROM). These international interventions have yielded concrete results in the process of overall democratic reforms of the countries of the region, with particular emphasis on the security field, as well as the aspect of integration reforms in both NATO and the EU. Fragmentation of the Western Balkans came for many historical, political, economic, military, geopolitical and strategic reasons. This process also had consequences for the integration process of this region. But it is currently fully oriented towards European and Euro-Atlantic structures. No Balkan countries including Kosovo have any other orientations besides these (there are doubts about Serbia). Serbia has stated that it does not want NATO membership, while Russia has tried and is constantly trying to cause chaos in the Western Balkans. How this chaos is caused and how the cooperation of the countries of this region has affected and is influenced is the essence of our work that will draw conclusions about how to act in the future.

Keywords: : Western Balkans, regional peace, theory of chaos, regional security, COVID19.

13.1 Introduction

The democratic processes of the 1990s in the Western Balkans, with particular emphasis after the fall of the Berlin Wall, were followed entirely by different challenges compared to those during the Cold War. This phase brought about major changes in the political and security scene, as the scenario of the German Union and the dissolution of the Soviet Union in 1991 was realized, which affected the course of many conflicts around the world, including many conflicts and the breakup of federal states in South Africa, in the Middle East, in some parts of Europe as well as conflicts in the Western Balkans (Gashi, Hidri, 2008, 2009, [1]).

The Western Balkans was one of the regions that experienced the most difficult transition, because this process was accompanied by bilateral and multilateral conflicts, local and regional wars, political and ethnic clashes. Consequently, the Balkans were politically fragmented on its map as well. Of the six main Balkans states that we had after World War II, which included Albania, Greece, Turkey, Yugoslavia, Bulgaria and Romania, after the Cold War we have a Balkans with new states such as Slovenia, Croatia, Bosnia and Herzegovina, Northern Macedonia, Montenegro and Kosovo. Fragmentation of the Balkans came for many historical, political, economic, military, geopolitical and strategic reasons. This process also had consequences for the integration process of this region. The international community has actively intervened in the Balkans, namely in the conflict period in Bosnia and Herzegovina, Kosovo and Northern Macedonia, the international presence being civilian and military. In these international engagements, the USA, NATO, the EU, the UN, the OSCE, the EC and a number of regional organization and non-political bodies have played a decisive role.

Actually, the Western Balkans is entirely oriented towards European and Euro-Atlantic structures. No Western Balkans country including Kosovo has any other orientations besides these. This makes the process easier because we are dealing with the acceptance of the same values and access to the same regional, European and global interests.

Regional cooperation, in order to create a new spirit and order through dialogue, cooperation and trust, should be the objective of the security institutions in the short and long term of the Western Balkans states. Basically this strategic vision is the recognition of the state of Kosovo by neighboring states and its return to a factor of security and stability in Southeast Europe. The Republic of Kosovo aims to be a factor of stability and peace in the region and does not express hostility and territorial claims for changing the boundaries with the use of force. Kosovo is against creating regional crises and conflicts and resolving them by means of violence. In this context, one of the strategic goals is to build the structure of the security system and to provide the capacity to develop peace support operations, in support of international law and humanitarian principles, under the guidance of the United Nations, NATO[1] and the European Union.

The strategic objective of Kosovo's security policy is to integrate into Euro- Atlantic security structures. The membership of Kosovo in NATO and EU is a primary and long-term objective, which has the full support of the people of Kosovo and the political spectrum. Kosovo does not rely on the security of the country simply on its own forces, but on joint efforts, integration and cooperation with international organizations.simply on its own forces, but on joint efforts, integration and cooperation with international organizations.

An important factor in the security issue is the COVID19 pandemic. This pandemic, in addition to the negative influences on health, has also caused negative influences on the economy, politics and external influences. States seeking to extend

[1]NATO is considered / conceived as a community, where countries come together to provide collective defense and the maintenance of peace and security through the contributions that each member state provides for collective security and defense.

their interests, or as it is otherwise called ‘donation diplomacy’, have used aid to extend their influence. A special part of this is devoted at the end to this kind of diplomacy and the way of dealing with it within the theme of the paper.

In relation to the Western Balkans, the approach of the United States of America has been continuous regardless of whether the administration was Democratic or Republican, but with the administration of President Joe Biden a new spirit of transatlantic relations is expected, because under President Donald Trump relations USA with the European Union have had tensions. Peninsula politics has received a different response than that of the Trump administration. Therefore, the Western Balkans is now facing new energies but with the aim of preserving conventional geopolitical lines, which are as much in the interests of the West as they are in the interests of the Western Balkan countries.

13.2 Theoretical review of the cooperation of the Western Balkans countries

The Western Balkans region (Kosovo, Albania, Northern Macedonia, Montenegro and Serbia) where you can find part of the peer-reviewed research on the two methodical approaches created from us. The first approach is *widespread regional inland* and the second approach will give us the mutual protection of the Western Balkans *beyond and interaction the region*, for example, Balkan countries with EU countries and vice versa. To elaborate on these two approaches we have taken five theories relating to international relations and security policies by elaborating on them from a transdisciplinary perspective that are: domino theory, prisoner dilemma, security theory, functionalist theory and chaos (Gerasimov’s) theory. Within these two approaches and five theories we provide a historical and analyti- cal treatment of events by drawing conclusions of the region’s imposing cooperation which we explain at the end of the paper.

Domino Theory – The domino theory emerged during the 1950s and 1980s and was being used as a requirement by the USA government to justify its foreign policy actions. Domino theory was a subordinate to the Truman Doctrine, or rather Kenann’s, where this doctrine foresaw the suppression of communism in every country in the world where it appeared.

It was Dwight Eisenhower, the USA President, who stated this theory during a conference on April 7, 1954, referring to the problems that were emerging in Indochina. At the conference he said: “Finally, you have broader considerations that might follow what you would call the "falling domino" principle. You have a row of dominoes set up, you knock over the first one, and what will happen to the last one is the certainty that it will go over very quickly. So you could have a beginning of a disintegration that would have the most profound influences (Eisenhower 2020, [2])”.

Eisenhower warned that the collapse of a state in a particular region under communism meant that the whole region would be swept away by communism and states would begin to fall one by one under communism. He called this the “dominoes collapse” where then a collapse of states would be almost unstoppable as in Indochina. If Vietnam had fallen into communism, then the surrounding countries such as Laos, Cambodia and other surrounding countries were also in the queue.

Today the “effect of domino theory” has gone beyond the Cold War use and regional dimensions. Domino theory is now used in economics as Baldwin (Baldwin, 1993, [3]) argues and in many other fields, whether political, economic, social, ecological, etc. One effect of domino theory today can be traced back to the spread of viral diseases that the world faces from time to time, such as now with Coronavirus or earlier with Sars, Ebola, etc.

The effect of domino theory has also been applied during the 1990s in the Western Balkans by UN and NATO forces using preventive measures to escalate war from state to state, as in the case of Northern Macedonia or Albania, deployed peacekeeping forces under the UN mission. But that theory still holds true today in the Western Balkans in the field of security when it comes to regional co-operation in preventing vicious campaigns like Russia's "chaos theory" created by Russian General Gerasimov, or tendencies to change boundaries through the public release of "non-papers".

Prisoner Dilemma – is an example of a game theory similar to probability theory, where it shows the rationality of the parties' action in a scheme that can pull both winning parties or only one winning party, or all losers. Even this strategy was created during the Cold War of 1950 by Melvin Dresher and Albert Tucker. The theory says: Two members of a criminal gang are arrested and jailed. Each of the prisoners is in isolation and has no means of communicating with the other.

Prosecutors don't have enough evidence to convict the party on the main charge, but they have enough to convict both on a lesser charge. At the same time, prosecutors offer each prisoner a deal. Each prisoner is given the opportunity to either betray the other by proving that the other has committed the crime, or to cooperate with the other by remaining silent. The possible outcomes are:ommitted the crime, or to cooperate with the other by remaining silent. The possible outcomes are:

- If A and B each betray the other, they each serve two years in prison;
- If A betrays B but B remains silent, A will be released and B will serve three years in prison (and vice versa);
- If A and B both remain silent, both will serve only one year in prison (on a lesser charge) (Nicholas, 2014, [4]).

Indeed, this theory shows that treachery test rationality of the realpolitik style where it shows that the parties are in fact more likely to betray, but in another version the prisoner's dilemma pushed states into solidarity for two reasons: since they can have the same fate in another case where they will be betrayed and have the bad image of a traitor in a world where the image of a country is the most important element and in the second case the betrayed country will seek revenge and he will do this without choosing the means or becoming an ally with the enemies of the traitor. In this case, we have to move towards co-operation in order to achieve faster the states towards the promotion and elimination of waste and revenge. So betrayal is a zero-sum game.

Theory of Security – or International Security has been put into prominent studies shortly after World War II, but as an area it is not new as security issues and is old as history itself.

Kolodziej compared international security with the Tower of Babel (Kolodziej, 2005, 11, [5]), so as a space the higher you try to get, the more it is destroyed and changed. Walter Lippman viewed security as a country's ability to safeguard its core values, while David Baldwin emphasized that pursuing security sometimes requires sacrificing some values (Ullman, 1983, [6]). Barry Buzan views security as a study of international security rather than just a threat study, but also as a study of threats that require immediate action and that security is something between peace and power (Croft, Terriff, 2000, [7]). So, the theory of security being completely uncertain in the future requires the cooperation and sacrifice of some values which can make a future safer.

Today the security sphere extends not only to the classical military, but also to terrorism, ecology and the political, social and economic spheres. In states and regions that are powerless to face such challenges alone, then cooperation is an inevitable means of ensuring the existence, development and integration of something as a matter of peace and power, as something between progress and sovereignty or as something between anger and good or something between history and the future. Functionalist theory - Functionalism is a theory of regional and global international integration and as such it developed mainly during the Cold War era but its origin can also be traced to Immanuel Kant or early.

This theory of integration is based on classical alliances, alliances that comprise regional and international organizations such as the European Union, NATO, UN, IMF, NAFTA, OPEC, etc. Functionalism proposes to build a form of authority based on functions and requirement, which link authority with requirements, scientific knowledge, etc., thus providing a supranational concept of authority. This approach rejects realization in interpreting the proliferation of international organizations (Wolf, 1973, [8]).

Functionalism has also changed over time and has become a more regional approach and has been termed neofunctionalism, as a more pragmatic method of making supraterritorial, supranational initiatives or international governmental and non-governmental organizations operational. This approach offers the space and opportunity that cooperation is a need in the world of interdependence and as such drives states to necessarily cooperate because of needs in different spheres.

Doctrine of Chaos (Gerasimov's Doctrine) - In February 2013, Russia's Chief of General Staff, Valery Gerasimov, developed a hybrid theory in a published article.

According to Molly McKew in that document, "the value of science is foresight". Gerasimov took the tactics developed by the Soviets by mixing them with strategic military thinking for total war, and put forward a new theory of modern warfare, one that looks more like revenge on enemy society than an attack on the leader (Mckew, Glorioso, 2020, [9]).

Explaining Gerasimov's doctrine, Zev Shalev says that doctrine foreshadows a "hybrid war" where information and protests are more effective weaponry than tanks and nuclear weapons or tanks. "Non-military means to achieve political and strategic goals ... have outstripped the power of the weapons force in their effectiveness." In other words, use propaganda and protests to polarize a population and plant chaos behind enemy lines (Shalev, 2017, [10]).

We have seen this theory in practice in the Western Balkans in Serbia through Sputnik, Montenegro and Macedonia through the tendency for coups and in other countries with direct or indirect interference with different funding.

13.3 The Two Histories of Intra-Balkan and Outside-Balkan Cooperation

The first approach: intra-Balkan cooperation from 1912

The history of Balkan cooperation doesn't have a good track record, namely the cooperation of the Balkan countries is in fact alliances of war for the persecution of an invader (Balkan Wars 1912-1913), the seizure of lands of any people (Albania) or the creation of circumstances for the existence of kingdoms or federations (Yugoslavia 1 & 2). The Western Balkans had been a space occupied and ruled by the Ottoman Empire excluding the present-days Croatia and Slovenia. But even under this empire, this region differed in its rule as regions such as the Servian/Serbian, Bulgarian or Greek kingdoms had wide autonomy, while the Albanian lands were under pure Ottoman rule.

The First Balkan War had united the Balkan Slavs in the fight against the Ottoman Empire in October 1912. Serbia, Montenegro, Greece and Bulgaria had an alliance with each, and even a guarantor of the alliance between Serbia and Bulgaria was Russia. This agreement also provided for the division of territories after the war.

An invasion of Albania with the intention of Serbia's exit into the Adriatic Sea was seen as a danger to Serbia's domination of the Adriatic, and Serbia's bases were also conceived as Russian bases by the then Austro-Hungarian and Italian diplomats (Hall, 2000, 54, [11]). Particular attention to the agreement between Greece and Serbia was the disregard of Albanian existence as a political entity. The agreement stipulated that the borders of Serbia and Greece would meet on the Shkumbin River, which separates northern Albania from the south. (Ion, 1918, [12]).

According to this two-part treaty (a secret part) Serbia gained after the war the Albanian territories north of the Shkumbin River, while Greece to the south of it, while Montenegro agreed with Serbia to keep Shkodra, Peja, Deçani and Gjakova under its occupation. (Bytyçi, 2012, 28, [13]).

One such idea was brought to light in 1992 during Slobodan Milosevic's visit to the Greek Riviera that had begun on June 26th (Ajvazi, 2009, [14]). He had even gone further when he publicly proposed a confederation between Greece, Macedonia and Serbia (Reuters, 1992, [15]). Such an idea had received support, and this idea was most liked by some politicians in Macedonia (Liqui Search).

Cooperation in the Western Balkans was also attempted by the second Yugoslavia under the leadership of Josip Broz-Tito. An agreement for a Balkan confederacy had also been reached by 1941 between the Kingdom of Yugoslavia (Serbia, Croatia and Slovenia) and Greece with the mediation of Great Britain, but with the intention of uniting Bulgaria and Romania as well (History Commons).

Even a feasible project of work was the project of the "Balkan Federation" that would include Yugoslavia, Bulgaria and Albania. (Buxhovi) However, Tito wanted hegemony in the region, including Albania, and to fix the historical problem of Macedonia where he wanted to unify the entire territory of Macedonia from Vardar, then with Pireun of Macedonia in Bulgaria, with the exit of Macedonia to the Aegean to Greece, and thus creating a large federation that would include Bulgaria and Greece (Perovic, 2007, [16]), as Albania was already economically and culturally integrated within Yugoslavia under an agreement (Buxhovi).

These plans would spur Stalin's demise with Tito, and Russia wouldn't allow such actions as it would disrupt the geostrategic balances established after World War II but also allow competition within the communist bloc. Arben Xhaferi said today's Macedonia exists because of its role as a buffer zone, which prevents friction between Balkan states (Robelli, 2011, 139, [17]).

All this cooperation would change radically after the beginning of the destruction of Yugoslavia, the start of the war in Bosnia and Herzegovina, and the Christmas Ultimatum by George H. W. Bush in 1992.

Second Approach: Outside Cooperation for the Balkans "Preventive Diplomacy"

The coming to power of Slobodan Milosevic in Serbia and the beginning of the destruction of Yugoslavia due to Serbian megalo-ideas for the creation of a Greater Serbia and the disappearance of Albanians based on the memorandum of the Serbian academy SUNA, created new circumstances not only for the region but also for the international community.

These events immediately after the Cold War and during the Gulf War crisis, where Iraq had invaded Kuwait, and the US-led international community was preparing to intervene there were intentions for Milosevic to surprise the international community for invasion of communist Yugoslavia under the national-chauvinist Greater Serbia.

Moreover, when the change of administration in the USA in late 1992 from the old Bush to Bill Clinton was taking place, Serbia had taken action in the Albanian search for weapons, enabling the creation of an occupied and surrendered territory that under international law would be known as a *fait accompli.*

But Bush hadn't fallen prey to this tactic and sent a letter to Milosevic on December 25, 1992, stating: "In the event of a conflict in Kosovo caused by Serbian actions, the United States have prepared 50,000 troops to intervene with its military forces against Serbs in Kosovo and Serbia" (The New York Times, 1999, [18]). The same was repeated on February 13, 1993 by Secretary of State, Warren Christopher, who said: "We remain prepared to respond to the Serbs in the event of a conflict in Kosovo caused by Serbia's actions" (The New York Times, 1999, [18]).

After these events, then began the development of the second approach to the Western Balkans, the Carrington Conference which was about solving the problem of Yugoslavia, also known as the International Conference on the Former Yugoslavia where Kosovo wasn't part of it.

In Kosovo, Sandzak and Vojvodina would be a mission of the Security and Cooperation Council in Europe (CSCE later OSCE). Then came the London Conference, which was to be held on August 26-27, 1992, where Kosovo was still not part of the conference. After all these events then more than ever the EU, US, NATO, CSCE/OSCE and the UN would be involved in the Western Balkans.

The new of all this external engagement under the second approach in the Western Balkans was with the beginnings of "preventive diplomacy". This was a new doctrine that we could draw in parallel with Truman's old doctrine of curbing communism, but that was about curbing Milosevic to pass the conflict in Macedonia and potentially Albania.

This kind of diplomacy began when some former Yugoslav countries signed a ceasefire and a UN mission was established with UNPROFOR peacekeeping purposes under Resolution 743 of 21 February 1992 (UN S/RES/743, 1992), which would then extend to Bosnia and Herzegovina. Whereas, by Resolution 795 of December 11, UNPROFOR required that it extend its authority and forces to the territory of Macedonia and have full coordination with the OSCE mission operating there (UN S/RES/795, 199, [19]).

The introduction of UN peacekeeping forces in Macedonia has been seen as a success of “preventive diplomacy”. Such a mission was undertaken for the first time in the world in Macedonia, and its success in Macedonia in stopping any inter-ethnic crisis or conflict showed that potentially such actions were taken earlier in other countries of the former Yugoslavia, wars could be prevented (Cvetkovska, 1999, [20]).

This commitment would prevent the escalation of the war in Macedonia, but an external commitment to the Balkans to resolve the Bosnian issue couldn’t be made until 1995 after the Dayton agreement, after a long war, thousands of victims, the Srebrenica massacre and NATO bombing for fifteen days over Serbian military targets.

After this turn came to Kosovo, Milosevic would have hoped that after Bosnia and the concessions there he could invade and cleanse Kosovo based on the “Horseshoe” plan. However, the international community, especially the West, didn’t allow this to happen and after many negotiations led by Cristofer Hill, then Richard Holbrook, and negotiations in Rambouillet, it would be the turn of the NATO bombing of Serbian military targets in Kosovo and Serbia, which would end with the capitulation of Milosevic and the withdrawal of Serbian forces from Kosovo.

13.4 The Two Approaches Incorporated for Stability and Peace in the Western Balkans

With the end of the Kosovo War, a new phase was beginning for the entire Western Balkans, a phase where cooperation within the region and abroad would be primary to maintaining peace in the region and beyond. Many governmental and non-governmental organizations were involved in the process, including the EU, USA and UN with key roles both through UNMIK, KFOR, EULEX missions and through direct actions.

The EU would also begin to create space for EU membership and aspirations for the Western Balkan countries, as the stabilization process was long and painful. Kosovo was under the management of a foreign mission until independence, while other countries were all strained by the post-Yugoslav processes and wars, including Albania.

However, countries in the region did not have many options for accessing each other internally and externally because:

- The Western Balkan countries couldn’t cross each other for cooperation with other neighbors as they were confined to countries that were already or would soon become part of the European Union and NATO.- The Western Balkan countries also had no better option than cooperating over- seas with the EU, US and NATO while options such as Russia were irrelevant because the country itself was already in economic turmoil.
- The remaining option of approaching the West was that the latter required first stabilization and integration of the region internally with external assistance to continue integration with the outside.

This process of EU integration of the Western Balkans would begin in 2003, during the European Council meeting in Thessaloniki, the decision was made to open the European Union Programs to countries outside the EU and the EEA, which were in the process of Stabilization and Association. The aim of the participation of candidate countries and potential candidates in EU programs is to support their EU accession, to make them familiar with EU methods and policies and to strengthen cooperation between countries in different fields: research and innovation, education, culture, health, environmental protection, customs and taxation, justice, etc.

This process required the region to have internal stability and cooperation as the EU refuses to import the region's problems within it. On the other hand, NATO was also involved in peacekeeping with its military mission in Kosovo called KFOR and cooperative missions and agreements with countries such as Albania and Macedonia.

The region would remain stable and continue to do so even when Montenegro in 2006 and Kosovo in 2008 declared their independence, because external oversight of stability was overwhelming and from the inside there was no significant interest to be undermined, only Serbia was opposed to peace and to these two declarations of independence. That functionalism and security were crucial before the other ends of the war would also prove the recognition of Kosovo by its two neighbors, Macedonia and Montenegro.

The Western Balkans has been traveling through this integration process without Slovenia since 1 May 2004, which had joined the EU and later without Croatia, which would join on 1 July 2013. The Western Balkans were also integrating in the economic sphere, first with the Stability Pact for South Eastern Europe, and with 2006 the extension of the CEFTA agreement (Central European Free Trade Agreement).

But in the whole process there was no particular security cooperation between the Western Balkan countries, and where it was done only through NATO.

13.5 New Global Spheres and Western Balkans Cooperation as Security

Post-Cold War ideals for the end of history never came to fruition, but American hegemony as an unchallenged power had begun to fall, especially after the 2003 invasion of Iraq, the latter would continue to lead as a major but not contested superpower, because nuclear weapons, the revival of civilizations, the emergence of new powers, and the creation of new spheres of interest all constituted a balance of powers.

In 2005 Russian President Vladimir Putin had declared that USSR's breakup was a mistake (Putin, 2005, [21]). Whereas, following Kosovo's declaration of independence on February 17, 2008, in response to the West and especially the United States, Putin would intervene to break up Georgia's two provinces, South Ossetia and Abkhazia. On the other hand, Turkey had begun to show signs of leaving the West after many rejections by the EU, now Turkey had its own geo-strategy divided by the West devised by Ahmet Davutoglu implemented by Erdogan. The economic challenge of 2008 that had overwhelmed the world and the threats of terrorism, all these exits and polarizations of the world, would in fact for the Western Balkans be the impetus for deeper integration within it and wider cooperation abroad, with EU and NATO.

Russia in the Western Balkans, through Gerasimov's strategy of causing chaos, had seriously begun to undermine integration into the EU and NATO, but also towards peace in the region through its interventions as in the case of Montenegro, where it had sought It was a coup d'etat in the case of Macedonia as well, but various reports testify to influence in countries such as Albania and Kosovo and declaratively in Serbia.

13.6 COVID19 Pandemic and Donation Diplomacy: Influence in the Western Balkans

With the onset of crises, both benefactors and beneficiaries usually appear, and sometimes benefactors take advantage of the opportunity. The emergence of COVID19 pandemics was not at all a factor in the states abandoning their raison d'etat style interests. It's just that this crisis has led many countries to use coronavirus to help extend their geopolitical interests. The Chinese government had provided assistance to 82 countries in the fight against coronavirus, and had even come to Italy's aid before the EU. (news.cgtn.com, 2020)

The lack of EU assistance had provoked so many reactions in Italy that in April a survey found that 49% of citizens were in favor of Italy leaving the European Union (Gotev, 2020, [22]). The EU's response was almost immediate after the poll, in which, in addition to aid, they publicly apologized to Italy (Deutsche Welle , 2020, [23]). China's aid has also been dubbed "Donation Diplomacy (Wong 2020,' [24])". China has also helped the Western Balkans with aid in the fight against coronavirus, such as in Albania, Serbia and other countries, but not in Kosovo. While Turkey has helped all the countries of the Western Balkans, which has been done by both the US and the EU.

Russia, too, has taken a step beyond China and Turkey to strengthen its influence in the Balkans, especially with Serbia. It is worth noting the form of Moscow's assistance to Serbia, which was made through the control of the army, and the Russian soldiers carried out the operations together with the Serbian soldiers. The opportunity has not gone away for these soldiers to remain in Serbia even after the pandemic on the so-called "united front" against new challenges (Goble, 2020, [25]). The Kremlin seems committed to supporting its perceived success, hoping it can further increase Russian power in Belgrade and the Balkans against not only the West but also China (Goble, 2020, [25]). This attitude of the Russian army, even after the pandemic and their approach, is happening at a time when the United States is insisting on a final agreement between Kosovo and Serbia.

The diplomacy and ability of the three non-Western countries to intervene in times of crisis is great. Such crises in small and incapable countries can easily be overcome by the influence of neo-imperialist powers and even terrorist groups without the help of any superpower. To stop this, Kissinger says the United States should take post-pandemic measures based on the Marshall Plan and the Manhattan Project, which creates a global resistance to infectious diseases, heal economic wounds and protect the principles of the global liberal order, adding that the democracies in the world must defend and preserve their Enlightenment values (Kissinger, 2020, [26]).

The Western Balkans should be unique and to maintain its order it should become part of projects by the USA and the EU, because these projects will not come for specific countries but as a general measure, a cooperative approach of the region will to facilitate the exit from the economic crisis and the preparation in the future that in such cases the measures will be more effective in terms of health and economy. A strong expansion in the Balkans, as in Europe, has been done by China through the Belt and Road Initiative (BRI), hiding a surprising skill and strategic goal. With

16 countries from Europe, members of the BRI, China today has become the third most prominent player in this part of the European Union's neighborhood, and can be called a European country both for the extent and in the heart of Europe as in the case of Italy. This success of building coalitions with the countries of the Western Balkans was also a result of the low efficiency of the economic measures and the differential policy of the administration of President Trump. But the rise to power of Joe Biden has given new impetus to international politics. The Western Balkans, in its internal cooperation and external security, has benefited from NATO, especially the United States, without excluding Turkey.

The Western Balkans has consistently shown a destabilizing trend from within. Finally, there was the case of the publication of unofficial documents requesting the change of borders and all kinds of dangerous versions that lead to the destabilization of the region and beyond.

Biden seems to have chosen to rely more on conventional forms of security by realizing them in modern terms. Recently, the White House has been harsh with the entire Western Balkans, as many politicians from the region have come up with dangerous ideas that destabilize but also jeopardize global security and American interests. There were two unofficial documents that appeared recently in the Balkans. The first unofficial document showed the tendency for border changes in the Balkans by right-wing extremists (Kuçi, 2021, [27]) that could cause a domino-type problem. While, the second unofficial document showed the tendencies for normalization of relations between Kosovo and Serbia (Ewb & Tanjug, 2021, [28]), but it went in the style of creating a second dysfunctional state in the Western Balkans, as for Bosnia and Kosovo.

However, all these tendencies were put to an end by the USA with an executive order from President Biden. The order said whoever did not abide by the agreements reached for peace and stability in the Western Balkans would be sanctioned by the US. (Biden, 2021, [29])

Biden's arrival did not allow the Western Balkans to deviate further toward China and Russia, but he is playing a strategy similar to that of Reagan in his day, so Biden is strengthening USA positions and maintaining conventional security by modern means. Consequently, this has pushed the Western Balkans towards internal and external cooperation due to the seriousness of the United States in this issue and other better alternatives for the Balkans.

13.7 Conclusions According to Theories

Domino theory - this theory in the case of the Western Balkans warns that the wrong moves of each country can lead to uncontrolled events with effects outside the region that would in turn lead to the potential disappearance of states like Kosovo, North Macedonia or Montenegro. As such, the domino theory in this case teaches us about the inevitability of the region's cooperation towards preserving itself first and secondly peace in the region and beyond. Any movement or collapse of one would mean breaking down a complicated historical and political system.

Prisoner's Dilemma - this theoretical example guides us that the cooperation of the Western Balkan countries is destined to be mandatory because every other variant sends us back to bloody history but also to total destruction of uncontrollable proportions. Also, this theory convinces us that any form of action of the countries of this region based on the principles of raison d'etat which affect the biting, destroying or damaging the other party, in fact has the domino and revenge effect that brings the game to points with many zeros.

Theory of Security- instructs the region that in order to preserve its existence, its values, its space, its state systems and continuity, it must find the form of internal cooperation and external secure support that doesn't require the disappearance of core values but only a necessary evolution as Baldwin points out. This form of functioning of the region, from the region's requirements for external support, then turns into a support that both sides need each other as in the case NATO-Western Balkans, when the latter had the need for NATO at the next stage and cooperation is deepening and security is not only stability but also peace and progress.

Functionalist Theory as Integration - this theory placing its importance on the integration of states and peoples, and especially its neo-functionalist version, in a world heading for multi-polarity, is essential to the ranking of the region. The region is inevitably of one-time importance and cannot be divided because in a small region with many great powers functionalist peace doesn't exist. Thus, neo-functionalism, seeking pragmatism, instructs us to pursue integration as a goal of peoples towards freedom and progress. Neo-functionalism makes it easier for the Western Balkans to integrate internally and externally into the EU and NATO.

Doctrine of Chaos (Gerasimov's Doctrine) -this doctrine originated by the Russian general and attempting to create irregularities in the Balkans, is a prophetic teaching of the region how cooperation and support with Russia doesn't bring freedom, progress and democracy, but corruption, oligarchy and autocracy. Among other things, the intentions of this doctrine are, in fact, to create chaos and disruption of order created by the West, which beyond the reach of influence is chaos and bloodshed. States aim for influence but when the influence shifts to chaos it leads to wars and genocides.

13.7.1 Practical Conclusions

The debate during the paper also includes conclusions and recommendations, but to facilitate the understanding of the paper we will summarize in some points the explanation of the paper, the inevitability of the region's actions and the importance of the practice.

- The Western Balkans region, due to its borders on the one hand with EU member states and geography as a peninsula, constitutes an inevitable regional cooperation. From land borders, the region finds it almost impossible to play real political neighborly policies with countries that are part of the EU, and examples of Peninsula and Islands show that co-operation solutions outside geographical constraints are compelling, especially when in the Western Balkans region that the other restriction is with EU countries.
- The EU doesn't carry within itself the Balkanization problems of the region, doesn't accept separate countries within itself to avoid a veto vote on the Balkan countries and disunity, and also doesn't accept countries that aren't integrated with each other and this imposes inevitable co-operation on the Western Balkans.

- The small geographical area of the Western Balkans makes its stability impossible by having states that belong to different global polarizations and if such a thing exists peace, security and stability become impossible, therefore the unity of the region towards the EU and NATO remains the opportunity to integrate and preserve values without alienating but evolving.
- Looking at the history and the aftermath of the breakup of Yugoslavia makes it essential to preserve the current political structure of the region and integrate it only towards the prospect of preserving this form of sharing and cooperation that is guaranteed only by NATO, the EU and the USA.t of preserving this form of sharing and cooperation that is guaranteed only by NATO, the EU and the USA.
- Small geographic space and large historical divisions are the two problems that need to be incorporated to bring development back to the region because in a world economy where large companies require large markets, none of them will invest in the single market, a regional country but as a whole the opportunities are real, as well as in a tense and divisive region where uncertainty is high the economy and investments remain far away from demand and this only enables destabilization and even depletion of the region.
- Theories that are part of our research and practices teach us in the last case with pandemic COVID19, that we must cooperate and create a more cooperative and responsive approach not only to pandemic crises, but also to natural disasters and risk issues. The current single approach reduces the capacity of each country to deal with any threat, and as such, exit from threat control has domino effects.
- The tendencies of some countries for major geopolitical changes are destabilization not only at the micro-level but also at the macro-level and these tendencies should be put aside, because the reaction of the great powers in favor of peacekeeping in a world full of weapons unconventional is harsh.

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CHAPTER 14

Electrome & Cognition Modes in Plants: A Transdisciplinary Approach to the Eco-Sensitiveness of the World

Marc-Williams Debono

Recent studies on plant-environment and plant-human relationships reveal the need to reassess the scales of perception, sensitiveness and cognition of living systems. The complexity of plant's emerging behaviors in interaction with the environment is supported by the signature of the electrome and the plant sensorium, a strong argument to establish the singularity of the living and weights its consequences in evolutionary, ecological or socioeconomic terms. This paper highlights the cognitive value of access to the experience of plants and its fundamentally mesological or ecoplastic nature, that is to say in direct connection with a singular milieu. This dynamic coupling makes it possible to explain the co-construction of an intelligible and sensible world without the use of a brain, principle that reframes the concept of intelligent behavior while revealing both the frontiers in cognition and the strong transdisciplinary challenges of an acute awareness of the man's fragility as of the planetary ecosystem at the era of the Antropocene.

Keywords: Plant behavior, environment, electrome signature, sensitiveness, mesological plasticity, cognitive processes, plastic interfaces, transdisciplinarity.

14.1 Introduction

The electrome, defined in analogy to the biome or genome, as the electrical dimension of plant life (De Loof 2016, Toledo et al., 2019) [1, 2], represents, among the various cell signaling systems, one of the major means of treatment information in plants, and by extension for all living systems. At a plant cell level, it is characterized in particular by the presence of proton pumps and the permanent opening / closing of ion channels anchored in the plasma membrane by the cytoskeleton at the origin of action potentials (PA), by plasmodesms for the propagation of signals at short distance (cell to cell communication) and by the vascular and hydraulic systems at the xylem or phloem level depending on the direction of circulation for the transport of material or nutrients like sugar, hormone or chemical mediators, liquids... (Hedrich et al. 2016, Choi et al. 2017) [3, 4]. These electrochemical gradients generate potential differences (PDs) that can be collected by intracellular recordings (membrane potentials and action potentials modeled by the Hodgkin-Huxley equation applying to excitable cells) and extracellular ones (collected with non-polarizable Ag/AgCl electrodes placed in situ on the surface of a leaf or in the tissues of a stem or root). The latter allows, once stabilized in situ, to observe the mathematical derivative or the algebraic summation of the signals underlying all of the tissue PDs by so-called electrophytographic techniques (EPG). Their permanent experimental presence has been demonstrated and characterized in the form of "surface potentials" or spontaneous electrical variations of low amplitude (25-500μV) interspersed with spikes at the level of the whole plant in Kalanchoë D. by Debono et al. (1992, 2013) [5, 6].

The presence of these electrophytograms or EPGs has recently been validated by several independent international teams, including those of Masi et al. [7] (spatiotemporal course of spontaneous EPGs and synchronization of long-distance spikes recorded by MEA 60 channels on roots of maize, 2009); of Cabral et al. (modeling of complex oscillatory bioelectric signals, 2011) [8] and Saraiva et al. and Souza et al., (2017) (recording of spontaneous EPGs and spikelets induced after osmotic shocks by high resolution spectral analysis on shoots of soy) [9,10] with whom we are now collaborating (Toledo et al. 2019, Debono and Souza, 2019) [2, 11]. In all these models and with different technologies, long-term EPG recordings with the same signal-to-noise ratio, complex oscillatory behaviors and similar reactivity to stimuli were found. EPG-type electrophysiological activities are then added to the directory of all classic PA-type emissions, systemic potentials or bioelectric fields and generate a specific signature of the electrome. Its biodynamics can turn out to be totally different before and after a stimulus, spreads over a long distance or even can be synchronized in order to cover the sensory information flows that constantly assails plants.

14.2 Signature of the Electrome: Self-organized Complex (SOC) and Recording of Electrophytograms (EPGs)

The initial question that we asked about the physiological role of these biosensors and their non-linear dynamic impact on active plant perception systems [5] thus begins to have solid experimental answers indicating: 1/ that the chemical communication through volatile substances etc. is not the only one brought into play and 2/ that EPGs are an integral part of the plant's electrome, considered as a self-organized complex with "multicolored" noise summing up all of the ionic, systemic and electrical directories repertoires of plant tissues [4, 10]. To the detailed classification of the different types of plant electrophysiological activities (action, variation, systemic and local potentials, ROS, Ca2+ waves..) established by Fromm & Lautner (2007) [12], we must therefore now add the EPGs. They are analogous in terms of amplitude to EEGs conventionally recorded in animals (mathematical derivative representing the algebraic sum of biomolecular signals associated with polarization-depolarization processes), but present neither the same temporality, nor the same degree of synchronization or correlation.

More specifically, the spontaneous EPGs that we collected at tissue level are interspersed with sharp oscillations or isolated spikes which can be organized as discharges lasting several seconds or minutes after a stimulation, whether natural or evoked [5, 6]. Souza et al. (2017) recently showed that the EPGs follow a power law which represents the mathematical relation between two quantities defined by the constants a (proportionality) and k (exponent) and are used at the level of large systems presenting invariant scales. Under certain conditions, they can push them towards a self-organized critical state (SOC or self-organized criticality) representative of nonlinear dynamic systems [9, 10]. The working hypothesis that we support regarding these SOCs is that a constant EPG monitoring of plants would allow to discriminate and manage environmental stimuli in real time (water supply during drought, new climatological conditions, interaction with neighboring species, osmotic shock, stress...) in order to ensure the plant optimal growth in its environment (Debono and Souza 2019) [11]. As a result, the EPGs - whose power density spectrum (PSD) and mathematical analysis of autocorrelations respectively show a distribution according to the power law -, SOCs and nonlinear dynamic behaviors include different patterns and colored noises. These values depend on the type of stimuli (cold, low light, mannitol) as well as on temporal correlations on large scales, indicating the treatment of complex information emerging from different temporospatial patterns propagating at the level of the whole plant [9].

14.2.1 The Bioelectrical Continuum: Rule in Plant Behavior

Without going back to the pioneering works of Darwin, Burdon Sanderson and particularly Bose (*The nervous mechanism of plants*, Longmans, Green & Co, 1926) at the level of plant bioelectricity, modern electrophysiology presents a range of bioelectric potentials well defined in the literature at the cellular or multicellular scale [12], but much less at the level of the whole organism. In this fiels, EPGs have long been considered as noise or non-physiological activities for contextual reasons (linked to the so-called 'Backster effect' in the 80th), which has had the consequence of stopping this field of research and the questioning relating to it for about three decades. The questions I asked following my first discovery of the EPGs (published in 1992) like some researchers such as Pickard or Karlsson (see refs. in [5]) are still relevant today. By what mechanisms are plants capable of constantly analyzing and scrutinizing the space and the environment that surrounds them? How do plants manage to sort such a quantity of signals in real time, some of which are relevant and others not? Are they not saturated with these informations and what kind of perceptive level is in use? The answer given in the light of our recent work is that the permanent emission of spontaneous EPGs is a reflection of effective monitoring systems, reactivity and discriminatory filtering in front of permanent stimuli and stress that the plant fixed to the ground in a singular environment can only undergo (Debono 2013, Souza et al., 2017) [6, 10]. They thus constitute a decisive part of the spectrum, defined as the set of the ionic dynamics of the bioelectric spectrum delivered by a given plant (its specific signature) or a population of plants (De Loof, 2016, Toledo 2019, Souza et al, 2017) [1, 2, 10]. They can synchronize and spread over a long distance at the level of the whole plant, thanks to network activities, thus sustaining high perceptive and communicative levels [7].

Several teams have recently automated the classification of EPG-type electrophysiological activities including variations in extracellular potential and the emission of spikes in real time following various stimulations or stresses by mathematical modeling or using machine learning (Pereira et al. 2018; Tran et al, 2019) [13, 14]. They reveal, thanks to the use of specific electrodes, the interest of the practice of monitoring in real time the physiological activity of plants without Faraday's cage, which could be applied with success using EPGs. Used as monitoring kits in fields dedicated to agriculture or agronomic studies, they would indeed be able to inform the observer of the physiological changes of a given species or individual and of the mechanisms of propagation of the bio-molecular signals. It concerns particularly wounding potentials or slow wave potentials, which have a hydraulic component and can go in both directions of the plant axis [stem-leaf/up-down] or exchange with the medium. These operations can be used to measure the surface potentials of the leaves and their long-range propagation after injury (Mousavi et al., 2014) [15] or be parameterized by mathematical models of simulation or learning and electrical circuits mimicking biological responses in natural conditions.

Moreover, a recent publication (Simmi et al. 2020) that we will detail later [98], showed, as it was previously the case for osmotic stress [9], that infection with pathogens affected the dynamics of the electrome, and that these alterations, which could be located far from the site of infection (thus implying the propagation of long-distance signals during plant-pathogen interactions), were detectable by EPG before the visible effects of infection on tomato plants. This study validates the interest of EPGs as *in situ* diagnostic tools, but above all indicates the active role of this electrogenesis in the sensory area of the whole plant. It is thus now a question of advancing on these tracks and in particular on the role of the electrome, considering plants as subjects able of modifying their biodynamism and their behaviors depending on the stimuli, which means to have an access to the experience (or reality) whose degree of cognition should be precized.

Be that as it may, we have already shown following the work of Souza et al. that the permanent spontaneous emission of EPGs within the electrome largely favored these transfers by constituting a permanent monitoring system and threshold clipping or discrimination via self-organized critical systems (SOCs) linked to the emission of oscillations or spikes according to a power law. Our working hypothesis is therefore that this permanent discriminatory management of environmental stimuli allows the establishment of extended or embodied cognitive exchanges that ensures the plant's balance, its growth, its communication and its exchanges with the environment in response to biotic or abiotic stimuli, its possible formation of symbionts and its rapid adaptation to new situations or stress, parasitic or microbial attacks. This presupposes self-recognition in a competitive environment, benefit-cost analyzes, internalization capacities and operational choice among the informations collected (improve resources, grow optimally, avoid danger, colonize or not, etc.) and problem solving in a given environment. More generally, the results of our pioneering work [5] republished in 2013 in PSB [6] and new approaches in collaboration with the team of Prof. Souza from the University of Pelotas (Brazil) [11] support the hypothesis of a vegetal cognition by showing that a behavioral unit - which is not taken for granted in plants where the process of individuation is not a key factor in evolution - can be observed via hypersensitive integrated biological systems anchored in the environment. If chemical communication is fundamental in inter- as well as intra-species exchanges in plants, our working hypothesis is that the bioelectric continuum provided by continuous EPG surface monitoring (EPGs) and its underlying synchronized networks allows us to link active perceptions, although not conscious with actions. In other words, they would play the role of pseudo-innervation acting both on the surface and within the various plant tissues and membranes. An important fact, which, if it turned out to be proved, could explain the gap between autonomy or certain observed behaviors (whether they are qualified as sensitive, intelligent, or even conscious) and the absence of centralizing structures in the different plant modules. There is therefore a contradiction between a modular anatomy that does not require a pilot and access to experience, although often requiring marked reactivity, and operational choices outside the scope of classical adaptation.

14.3 The Mesological Plasticity of Plants

It emerges from this permanent management of the flow of sessile organs, a perception-action loop, cognitive abilities (Calvo 2011, 2017) [16,17] or intelligent behaviors (Trevawas 2014), [18]. It recently became the subject of an in-depth examination concluding to the benefit that this brings them in natural or real-world conditions in terms of sensory coding, learning, directed individual variation and adaptability (Calvo et al. 2020) [19]. Plants Intelligent behaviors and goal-directed changes (but also bacteria's and unicellular organisms) to face adverse or competitive environments are indeed considered by the authors as the best response to adapt and improve their survival. These elements make plants unmatched autonomous biosensors capable of interacting directly with their natural environment and to be almost inexhaustible bioenergetic tanks. They indicate that the individual variation probably sustained by learning mechanisms is not purely random within a repertory of characters inherited by the plant or resulting from the only natural selection (that Darwin who published *The power of movements in plants* in 1880 - John Murray, London, considered as operating at the level of the individual), but well related to the plants plasticity that we are dealing with through an active process.

This 'intentional' behavior links here to complex adaptability (learning, memory, competition and regeneration processes... and not the molecular or genetic background, itself linked to quantitative adaptability only) but also to intelligence, differentiating their mechanisms of action at the level of animals or humans and plants, even if they use the same kind of electrochemical communication and functions (perception, sensory inputs, hormonal system, growth, reproduction, development, memory, learning or cognition maps described here for niche construction..). These assumptions validate low voltage potentials using power law relations and bioelectrical protoneural networks [6] as early activity markers and/or diagnostic tools usable in the field as much in agronomy or agroforestry, as for the detection and discrimination of the stimuli when dynamic coupling occurs via SOCs between the plant and its environment [10, 15]. Equivalent to a radar or watch system, they would allow plants to prioritize or better manage warning or defense signals (and therefore their survival) via hormonal or biochemical responses while saving energy and preserving optimal growth.

As recently published, in this context, we assimilate plants to plastic interfaces having an "electromic" nature (that is to say using primarily the electric dimension of life) [2] and that can display cognitive abilities (in the biological meaning of the term) into interactive ecosystems [11]. In addition to facilitating the transfer of information via membrane bioelectric networks and ion channels or symplasmatic gap junction, this ability to discriminate and respond quickly and efficiently to environmental stimuli on the scale of the whole plant, would avoid the mobilization of sub-structures and could explain the apparent functioning unit of the plant, especially in face of a new situation, despite its functional modularity, its impermanence or its versatility and its non-individuality. Indeed, the signature of the plant electrome is inextricably linked to the ternary complex [plant-environment-world] which means a developed sensitiveness, an anchored plant body and a mesological plasticity (Debono, 2020) [16]. However, the management of these flows takes place precisely at the plant-environment interface, which is distinguished by its locality and its singularity of exchanges with the environment. As we have recently shown it, plants are hypersensitive ecoplastic interfaces to the environment, defining a form of plasticity that is neither purely phenotypic nor epigenetic, but mesological [11, 1], that is to say an intrinsically and inseparable subjects (and not an automata) from thier local ecosystem. This hypothesis is linked to the ecophenomenological approaches of Berque who establishes for living systems, a matrix-imprint relationship or medial relation between the being and its environment subjected to trajection. It is a continuation of the work of von Uexküll on the Umwelt and of Watsuji on the fûdoron (Berque, 2014) [26, 27] taking into account the status of plant-subject registered in a singular milieu and its dynamic coupling (or mediance) which fundamentally presents a trajectory nature. The mesology or "science des milieux" (Umweltlehre from von Uexküll in opposition to raw environmental data) is indeed detached from the scientific ecology (objective environmental science from which the observer is external) and has mainly had as subject of study, the relations between animals or humans (defining an "ecoumene" following Leroi-Gourhan's work in Berque, 2008) [28] and their environments.

For the first time reported about plants by Debono (2016, 2018) [12, 17] who adapted the concept of plasticity (Table 1) he developed [29, 30] to their behavior (i.e. developing a mesological plasticity), that highlights the plant body anchored in the soil (Table 1). This body anchored to the soil being typically medial (that is to say dynamically coupled to its environment), and the evolution of the plant-environment-world system being trajective by definition (that is to say neither subjective nor objective), but linked to a process of transfer between the raw environmental data (the Umgebung of Uexküll) and the lived environment (the Umwelt) of a given subject [27]. Finally, plasticity can only be integrated into it by nature by being situated in the "as-is" (where the slash of the "as-is" signifies that the trajection and plants can act as interacting subjects with their natural habitat) of the equation r=S/P where r is reality, S the logical subject (here involved) and P the predicate (Berque, 2016) [31]. Plants can therefore interact as subjects with their singular environment or their natural habitat, and mesological plasticity plays a major role in this trajection by allowing plants to directly interpret the signals of the environment without resorting to a brain, just like their unique ability to transform light energy. This direct interpretation is at the source of emerging behaviors that we can qualify as intelligent, but which define for us very precisely a cognitive access to experience, in the mesological sense of the term (Table 2).

Table 1: Comparative study of the concepts of Plasticity & Mesology (Adapted from Debono, Cerisy conference,France, 2017).

PLASTIC INTERFACES	PLASTICITY COMPLEXES	CO-MEANING RANGES	EPISTEMIC PROCESS
Matter-Form Matter-Energy Matter-Mind Object-World Subject-World	Thresholds of active perception ↓ Dynamic bond ↓ Complexion	Co-Inherency Co-Construction Co-Evolution	Metadynamic Systems *Plasticity of the living* *Plasticity of the mind* Ternarity Third included
PLASTICITY	IRREVERSIBILITY	METAPLASTICITY	TRANSVERSALITY

MESOLOGICAL INTERFACES	DYNAMIC COUPLING	CO-MEANING RANGES	TRAJECTIVE PROCESS
Imprint-Matrix Being-Environment Milieu *(Fûdo, Umwelt)* Singular *(living beings as subjects)* vs Multiple Reality *(Places, loci, cultures)* Non objectal relation	Coupling *Active-passive/ Subject-object/A-non A* Reciprocity Ambivalence Structural Moment *Humain being, Cosmisation and embodiement of the environment* Correlation *Historial, Nature/Culture*	Co-Arousal Co-Elicitation Co-Construction Morphosis of the living *« Taking shape = getting into being »* Subjectity	Trajective chains *r=S/P, Predicates* Medial & Ecoumenal Access *Human environment, Phenomenality, Plato's Chorâ* Trajection *Mahāyāna buddhist, Grecian Tetralemma, Lupascian Third included, Midle treatise by Nāgārjuna*
MILIEU	MEDIANCE	MESOLOGY	TRAJECTION

Table 2: Mesological Plasticity.

1/ **r = S/P** is the **mesological relation** established by Berque (2016) where r, the reality, is the subject (S) as a predicate (P).
2/ **Plasticity** would be situated in the **'as-that'**, i.e. the slash of the mesological relation and any individual or collective subject is supposed to develop its own world.
3/ This 'as-that' incorporate a **trajection** where Berque (2017) describes a subjectivation of the environment and an environmentalisation of the subject. It can include **P, P' or P''** predicates assuming: 1- a clear distinction between the living and the machine and an extension beyond the subject/ object dualism; 2- causal and not univocal relationships between the environment and behaviors (a cosmization of the body and a somatization of the world).
4/ This trajective plasticity, added to the notion of **subjecthood** (in place of subjectiveness) as a proprioceptive or a self-perceptive system with a certain degree of awareness or self-consciousness depending on the species, allow each living being to be a subject rather than an object. This expanded status may relate to the plant-environment relationship and the modes of plant cognition that we question.

14.3.1 Plant 'Intelligence' and Sensitiveness: Why is All This Possible Without a Brain?

If this hypothesis was adopted, added to the sensible vs sensitive nature recently admitted by the scientific community about the sensory system of plants, it would constitute a big step in our classification of the living kingdoms and in the modeling of sensory perception modes [34]. This could help solve the apparent conundrum of cognitive scales disproportionate to the size of the brain of animals like birds (recent works show that the delta observed between the small size of the brains of birds and their high cognitive abilities are probably due to a high density of neurons: see Olkowicz et al. 2019) [28] or lemurs having relatively small brains for primates (Fichtel et al., 2020) [29], without mentioning one of the great puzzles of contemporary science, i.e. the unicellular unclassifiable organisms such as the *Polycephalum physarum* that are able to execute high cognitive tasks without brain. Same observations in terms of proprioceptive capacities are observed in bacteria, which allows them to recognize surfaces thanks to specialized mechanoreceptors or by pathogens to colonize their hosts (Hug et al., 2017) [30]. This would also explain the effectiveness of the perception-action loop emerging from an eco-sensitive interface - the organism (here the plant) and its environment - considered as the poor relation of the somatomotor universe, as well as its intelligent or resilient behaviors (including complex defense, communication or coping strategies). Given the complexity of the surface electrogenic activities recorded in EPGs and their ability to manage external stimuli as well as to represent the synchronized bioelectric networks of different types of tissues or multicellular connections (phloem, xylem, symplasm) distributed over the entire medial body of the plant, we cannot rule out the presence of such dynamic perception systems (not limited to rapid movements in plants but existing at the level of several different kind of perceptions or interpretation of the milieu) or of a minimal integration of input-output or receiver-transmitter signals capable of leading to the co-construction of an intelligible world and/or of a sensible reality.

This is exactly the definition of a cognitive system (not conscious), taken out of its cerebral connotation (Table 3). It is therefore a question, as previously indicated, of considering the ‘body-medium-world’ entity as the significant reality of a sensible subject (and not only a sensitive one) via a set of reciprocal, emerging and confluent interactions, rather than reattaching it to anthropomorphic characteristics to plants. Intelligent behavior is one, with an added value so strong that it goes beyond the subject but which is necessary to question in a truly transdisciplinary (TD) way [31]. Considering it today outside of a brain, and not only related to the global functioning of nerves or the living is already a considerable step. However, there are two possible approaches if we place ourselves on this unique criterion of an external measure of living subject intelligence, knowing that AI presents characteristics close to human intelligence in terms of information, but that Big data treatments are in no way equivalent to the singularity of biological systems facing the logic of the flows and dataism. The myth of the singularity must indeed be reanalyzed taking into account the specificity of the living (Debono, 2020) [32].

Indeed, plants are undeniably intelligent if we look at them from the point of view of their behavior, their communication or learning capacities, but doesn’t it more often come from the intelligence of any living system from the bacterial stage? Probably yes, with different abilities and gradations from bacteria to man implying, or not, conscious systems. Mancuso considers on his side the resolution of problems or new situations by plants as a clear sign of intelligence [33]. However, if we replace this criterion of intelligence by that of sensitiveness or otherness and even more if we consider the purely introspective side of the mind, the prerogative of plant intelligence no longer holds. A point of equilibrium would be to take into account all of the adaptive sensory modalities implying a perceptual link with the environment and able to generate non-centralized global dynamic receptive or perceptive states (GPS) conducing to non-representational cognitive states (see Debono in TJES 4, 2013) [34]. This state could be linked, not to a form of intelligence *per se*, but to an unconscious access to experience and to the world of the sensible made possible thanks to the medial plasticity of plants (dynamic coupling with their singular environment). More generally, it could be related to an agentive or intellectual behavior in the sense of Averroes [20] and to the field we defined as the mesological plasticity of plants.

14.4 Transdisciplinary Stakes Linked to the Plant Sensorium

The singularity of living systems (Benasayag, 2017) [35], the evolution of nature-culture relationships and the request for an urgent consideration of a sensible ecology (Tassin, 2020) [36] are all arguments justifying the assimilation of plants to autonomous eco-sensible plastic units which perceive and process for their benefit and in real time a whole set of environmental information and data without resorting to animal or human intelligence [11]. For all these reasons or conjunctions, we will admit that the result of this complex and interactive biodynamic process may be sufficient in itself. It authorizes *de facto* an access to observable experience at the scale of the whole plant or of a given species subject to a singular medium and to environmental stimuli, without the need to resort to metaphorical arguments or transposition. We thus see that one of the main problems facing researchers in their positioning as regards the sensory capacities of plants is of a semantic nature.

14.4.1 Semantic Traps

Following the current of thought of plant neurobiology (Brenner et al., 2006 Baluska et al. 2006) [37 a, b], it does not seem to be necessarily a matter of recreating new words, although this would in itself be rather beneficial for the scientific community, but rather of trying to strictly balance existing terminology (neural attribute, sensitiveness, intelligence, behavior, cognition, sentience, awareness) by using it wisely. The metaphor of the brain-computer compared to the brain as a representation of reality is a good example on a human scale. The use of a vocabulary intrinsically linked to the animal or human condition such as the concept of play, motherhood, compassion or the fact of lending feelings or a mentality to plants is to be banished because false and counterproductive. However, the semantic shift is frequent as the temptation is strong and the behaviors comparable. For example, physical evidence of the increase in a maternal hormone, auxin (among other signals), during the development of the plant's embryo (Robert et al., 2018) [38], or even sending chemical messages between plants using volatile molecules are undeniable scientific observations. To conclude that plants "mother their children" or "warn their neighbors" as some authors mediate is an abuse of language. Neural similarities shared by plants and animals are clear, however, as noticed by Msimang [39] the implicit recognition of Brenner, Calvo and other authors about the school of plant neurobiology, is that we are here more faced with a disanalogy than an analogy (ex: memory assimilated to a basic process like in the immune systems or to a real encoding of information with propositional effects) and the turning point taken by this discipline (plant signaling and behavior), which is at the origin of a recognized and prolific field of research, is directly linked to this observation and to the Alpi controversy previously mentioned. It is a question of determining to what category of behavior we are dealing with: a purely computational model of information processing, a direct perception with cognitive access to the experience, or even an eco-psychological model (Calvo 2017) [40].

In the same way, aforementioned taxonomic approach of Sterelny about control system categories can help guide the debate [55]. However, as I previously mentioned it, taking as model a neuronal plant or a brain-like system seems to me counterproductive. While building blocks and evolutionary stages common to all living beings are evident, the divergence of the plant-animal kingdoms has led to different defense, survival or adaptation mechanisms. If we follow the course of time of evolution, it is not surprising to note that certain ionic channels present in the bacterium are still effective and that plants have developed protoneural systems [6], which were used for the development of future brains. However, this in no way justifies that the cerebral metaphor applies to plants and that they have the need to centralize information or to show intentionality in their actions.

On the other hand, their anchoring to the ground, their increased sensitiveness in direct link with the environment and the natural elements has undoubtedly brought about the emergence of intelligent ecosocial behaviors in the literal sense of the term which are related to forms of cognition "neither inferior nor superior”. . . but singular. Seeking to animalize or humanize them is futile. Conversely, to consider perception as isolated from action and a minimal degree of interaction seems nonsense to us. For Alva Noë [41], contrarily to neurocomputationists like Churchland [42], perception is not a process originating from the brain, but a form of activity concerning the body as a whole. In line with enactivits or neurophenomenologists like Varela and Thomson [43] or Di Paolo et al. (2010) [44], the author tells us that we are enacting our perceptual experience. However, the autonomy and hypersensitiveness of plants – now evident and accepted by the scientific community, which is not the case with intelligence – are precisely undifferentiated experiences of the plant body in relation to its environment.

The key word here is experience which, linked to observable behaviors at the macroscopic scale, implies not a centralization as at the level of the nervous system, but another type of apprehension of reality or access to unconscious experience, (in the sense that we understand it with animals or humans), not limited to pure reactivity, i.e. the ability for plants to perceive their shapes, their deformations, their aggressors, theirs congeners and to give, not only existent tailored answers, but highly complex and interactive ones. Is it all about intelligence? Not necessarily, although we can clearly see here the limits of our vocabulary and the difficulty in finding a terminology which is capable of describing similar and different qualities at the same time (living intelligence and awareness: possibly, mental or introspective intelligence: no). That said, sensitiveness or the information-driven behavior criteria taken in isolation are insufficient for us. It must be necessarily accompanied by an access to experience (as minimal as it is) and a loop of perception-action-feedback via a cognitive or enactive system (revisited by many authors like Calvo (minimally cognitive systems, sentience) [40, 45] or Trevawas (intelligent behavior, ubiquitous systems) [46, 47] (Table 3).

For us, the plant cognitive dimension is not yet qualified because we are starting to explore it only according to criteria from animal or human biology (see next chapter) or in a strictly “neural way”, either not taking into account cognition without representation or mental states, or using a phytoneuronal semantics which muddies the tracks for the neophyte. What seems to us to be taken for granted, is that vegetal cognitive states are highly supported by the electrome (preponderant dimension acting sometimes in synergy with, but often differently to the chemical pathways) and a set of non-localized somatotopic properties favoring its deployment on the scale of the whole plant body. This synergetic perceptive apparatus involves cognizing agents directly acting upon the plant sens orium, i.e. the totality of sensory reception and experience involved in such an open exchange between the plant body and its environment [34].

According to this point of view, the signature of the electrome would reflect, not an intelligent system in the introspective and representational sense of the term, but a cognitive system in its post-cognitivist meaning of access to experience or awareness. This last meaning differs from a computational intelligence being disembodied and linked to informational treatments of the information, as notably shown by the work of Maturana and Varela in the West [48, 49] – operational cloture and auto-poïesis, cognition theory, embodied cognition and enaction – [43] and by the mesological assumption of a mediance and a co-extensiveness between living beings and their milieu – different from the environment as raw material (Berque, 2019) [50]. All living beings present this type of cognition, different from the neural one, from the unicellular stage and at varying degrees of elaboration, which is inherent in any form of perception and essential to survive in a changing environment. However, hypersensitiveness to the milieu of trees and the permanent struggle between modularity and active plasticity of the plant body are two essential factors for the survival of plants in an often hostile environment. They define an otherness specific to plants, with its codes and identifiers (sessility, divisibility, autotrophy, slow mobility, modularity, decentralization, direct interactions with the elements...), rather than cloned or superimposed on an animal or human identity (inseparable from rapid movement and nerve centralization).

14.4.2 Behavioral Activities and Perceptive Levels in Plants

Let us take concrete examples: *Codariocalyx motorius or Desmodium Gyrans* is genetically programmed to move its leaves to capture the maximum of light present in its natural environment (undergrowth in tropical zone). We can also see that it requires learning to respond more and more efficiently with identical sequences of complex movements to the sound vibrations without fully understanding the sensory mechanism involved. Research continues about the nature of this sensitiveness to sound and about these consecutive erratic rapid movements; some hypotheses point to a possible mimicry of the rapid rotation of a butterfly wings by their leaves to fool its predators (Lev-Yadun, 2013) [44]. Most plant species react in a graded manner to stimuli by making their leaves unappetizing to toxic by making tannins, for example, depending on the type of herbivore or threats encountered. A lot of others like *Pisum sativum* or *Arabidopsis thaliana* have advanced management strategies related to decision-making or growth for the various stimuli that reach their roots (salt gradients, osmotic shocks, stress, presence of competitors, distribution of resources, etc.). *Mimosa pudica*, of which the mechanism of motor reactivity is well known, has recently been shown to be capable of serialization and memorization. Indeed, it no longer reacts with rapid movements to reiterated stimuli as soon as they are considered non-dangerous, without it being a 'fatigue' phenomenon, and is able to memorize the nature of the stimuli to which it is subjected over an evaluated period of 28 days (Gagliano, 2014) [86a]. Furthermore, recent experiments presented by the same researcher on pea plants have concluded that associative learning behavior is involved, which could imply epigenetic reprogramming [86b].

Another example of astonishing mimetic polymorphism, the South American chameleon liana *Boquila trifoliolata*, capable of imitating the plants on which it climbs, allowing its leaves to take a great diversity of forms and sometimes several at the same time. Finally, in addition to the clearly established perception of gravity via the statocysts, and around twenty other senses, trees display memory, adaptive and proprioceptive behaviors when they are subjected to violent stimuli (wind, fire, torrential rain). Actually, proprioception or the ability to feel its shape and/or its bodily pattern and potentially those of others (example of canopy, morphogenesis and/or active responses of trees and plants to stimuli like wind or gravity), concerns the entire plant body which responds to it in a biomolecular way. This happens by the action of growth factors, notably at the level of the meristems, and, with certain mechanical, geometric and/or morphological constraints, which do not prevent their control from the scale of the whole plant. This indicates a degree of perception of a cognitive type hitherto unheard of in plants, in particular when it affects posture control (via the statocysts) and resilience, which requires adopting a much more integrative view of the development of the living (Moulia and Fournier 2009; Hamant and Moulia, 2016) [53, 54].

14.5 Frontiers in Cognition: A Comparative Study of Neural vs Non-Neural Systems

14.5.1 The evolutionary Taxonomy of Cognitive Control

Before opening the debate on the possible operating modes of plant cognition, it is important to specify the criteria delineating plant cognition (Table 3). In this way, an interesting study developed by Sterelny in 2003 [55] about the evolutionary taxonomy of cognitive control was recently presented by Msimang [39] as a possible method of establishing general principles discriminating what cognitive abilities that are or are not at play in plants. Indeed, apart from their adaptative responses to environmental cues and their active control of growth or development, Msimang highlights Sterelny's taxonomy in the evolutionary sensitive context of plants. This approach takes into account the complexity of the environment and the fact that cognition is above all a mechanism for controlling behavior. In this regard, the author cites the work of Godfrey-Smith (2002) showing in particular that species subjected to the same selection pressure manage it differently depending on their evolutionary lineage and their ability to adapt. It is therefore a matter of classifying the different types of behavioral control, which Sterelny does by describing three main types of behavior: 1/ detection systems (flight responses, tropisms), 2/ robust tracking systems (transparent environments, hostility of the predator-prey relations), 3/ the response breath including false positives or negatives, internal signals and informational complex systems and 4/ the decoupled representation (represented targets, environmental features not coupled functionally to specific responses, trial and error, mimicry) often describing animal or human cognition, and possibly some “neurobiological" aptitudes of plants.

These criteria are used in Msimang's paper to define "*how cognitively able plants are as intelligent agents*" (quoting Legg & Hutter 2007) where intelligence is assumed to be used by many authors in the same way as cognition in the context of the semantic war that scientists and botanists wage over metaphorical language or borrowed from neuroscience (e.g. emotions vs. sensitivity, consciousness vs. awareness, etc.). However, the Sterelny method makes it possible to get out of this impasse by qualifying the heterogeneity and the complexity of the environment as well as the conditional nature of the adaptive responses or of the phenotypic plasticity of plants. Msimang gives the example of the Venus flytrap of *Dionea M.* as a robust animal-like tracking system indicating that the sophistication of some of the behaviors of plants can be achieved with relatively simple modes of cognition. He also deduces that the fact that plants do not have a type 4 cognitive control, that is to say representational, disqualifies them as having consciousness or awareness.

These criteria clearly delimit the behaviors we are dealing with, by differentiating for example the functional criteria from the causal criteria–the definition of an intelligent system depends on it! – or by examining the contingency levels of discrimination systems (often adaptive) and by relating them to behaviors strictly qualified as functional. Plant behaviors using chemical, metabolic or electrical pathways, proprioception, stored information that can be recalled or learning, clearly display cognitive processes that can be graded and differentiated from machines or AI. Msimang analysis notes that strictly following Sterelny's classification, the two last criteria are not necessary conditions compared to detection systems). However, it doesn't mean that plant does not have intelligent behaviors but that "*... particular kinds of controls are outside their purview*". He argues that some of the plants have minimal cognitive systems using simple detection operating on cues and not on memory (like autonomous machines) whereas others present robust tracking systems depending on the integration of several parameters, and more generally that "plant display an array of adaptive responses, but only a subset of these responses can be classified as behavior" [39].

Numerous examples of cooperation, mutualism or mychorizial (and bacterial) symbiosis leading to interconnections with the root network and intra- or interspecific exchanges developed over huge areas are also widely described in the literature (Simard, 2012) [56]. They allow a wide communication between plants and trees of the same species or different species. As a recent example of mutually beneficial relationships, *Conospermum*, a plant that has developed a way to use ants to its advantage, like the pollinators overcoming their antimicrobial defenses, a mechanism as effective as the action of native bees! (Stock et al, 2020) [57]. This is the first finding of such a cooperation mechanism, even if "it would be risky, in an evolutionary sense, for the plant to rely only on the native bee for pollination" say the authors. To these considerations could be added Margulis'involutive hypotheses (endosymbiosis and...) regarding cooperation and mutualism as a sufficiently frequent mechanism in inter-species relations to oppose the classic evolutionary thesis based on a preponderant and generalized competition (Margulis et al.) [58, 59]. Finally, the incessant discoveries of unknown taxa, such as the *Langsdorffia* holoparasite recently indicate that each plant-environment pair corresponds to a form of sensitiveness and direct cognition between the organism and its environment (Thoroggod & Santos, 2020) [60].

This ecosystemic cognition calls, as for many species (fungi, insects, marine animals...): 1/ to self-organization and reciprocity or biofeedback mechanisms characteristic of living systems (Maturana, 1980) [48]; 2/ to a perception-action loop and emerging behaviors specific to non-neural organisms such as plants, fungi or physarum polycephalum, or neural and having a complexity inversely proportional to their functionality as in the case of the Octopus; 3/ to forms of minimal (tropisms, information-processing systems, epiphenomenal (Calvo, Garzón) [45, 61], embodied [43], distributed (swarm or colony) or extended cognition when it comes to communicating on a large scale and over a long distance (via root networks and mycorrhiza) and even to cognizing agents constituted by action-oriented feedback mechanisms like those supported by the skin-brain thesis (Keijzer, Milkowski 2017) [62, 63]. Developed by Keijzer in opposition to the classical reflex arc of pain described by Descartes, this approach shows that it represents probably a secondary adaptation and that biological information processing can occur without CNS in early organisms. Consequently, he describes the myoepithelium or an excitable epithelia using chemical signaling as a primitive conductive element able to transmit information through neuromuscular junctions and motor coordination before the evolution of nervous systems (Keijzer, Wiljes et al. 2015) [64, 65].

This thesis supported by Parkers' phylogenetic work about elementary nervous systems (1919) [66] is important because it admits two consequences corresponding to our pioneering discovery on plant spontaneous Kalanchoë electrophytograms (Debono & Bouteau, 1992) [5]: 1/ the presence of a spontaneous activity capable of supporting self-organized whole body organization; 2/ the generation, at the same level of description of animal protomyocytes or neuromuscular processes (Mckie, 1990) [67] and of plant dynamic protoneural networks (Debono, 2013) [6] forming coordinated patterns of activities (illustrated by Wiljes for the tube-shaped animal model) [65].

Milkowsky (2017) also quote the recent hypothesis of Arendt (2015) [68] suggesting an apical (controlling the whole body physiology) and a blastoporal nervous system (feeding movements and locomotion) nervous system, differentiating external (reflex) from internal coordinated multicellular activities, specifying that "*the claim is not about the current organization of the nervous system; it's about its evolution*", which means that: "*early stages (that could be related to property detection)... need no sensory contact with reality to produce minimal cognition*". This minimal cognition often presupposes a receptor-effector link and a reflex arc architecture that was able to evolve towards an internal motor coordination. However, different sensory modalities can drive to different reactions depending the nature and the plasticity of the substrata (brain, plant or bacteria). For instance, the phenotypic plasticity of plants is highly significative for their growth and development in a hostile environment while the sensorimotor coordination of animals is essential for their survival. Another consideration linked to our previous description of the mesological plasticity of plants and the sensory flows they need to constantly treat on line (Debono, 2018) [17] is the Gibsonian contextualization of sensory organs vs receptors where the firsts are described as active parts of perceptive systems (including proprioception recently developed by Moulia et al. [54]) while the seconds are fixed informational and/or recording systems (Gibson, 1966) [69].

Milkowski (2017) rightly underlines in his paper that the "organism may stand in a non-informational interaction with the environment without any sensory reception, or more, without any information detection", and that we can differentiate information-based-causation (like DNA machinery) from other transactions. Amebas are cited as unicellular examples having no dedicated sensory receptors but coordinated behaviors, contrarily to skin-brain models having no discriminative abilities, so no sensory detection, regarding their external environment. His main conclusion are that in that case "there is no ecological meaning of the internal signals, and the proximal signals do not seem to carry any distal information event about the Innenwelt of the skin-brain animal", which matches our argumentation about ecoplastic plant interfaces and their dynamic and trajective character, in the mesological sense of these terms [11] (Table 1-2). More generally, the author assumes that the function of the central nervous system (CNS) itself has changed over time in most organisms and that "*the sensory experience, or even any reliance to the senses, is not required to make a piece of information knowledge for a cognitive agent*". It means that unlike the CNS which evolved for motor control in animals and humans, minimally cognitive processing linked to evolutionary earlier nervous systems like bacteria or plants may have evolved without any senses. More accurately, the author defines the "epistemic primacy of sensation" as related to meaning or knowledge (based on sense experience or conceptualized from it and not linked to conscious experiences) and explains that minimal cognition can occur without sensory experience. Knowledge is here possible without sensation, whereas sensory reception is a necessary step to reach knowledge.

Anyway, for us, the question to be addressed is how the dynamic coupling of plant and the environment permits a cognitive access to the experience of reality? And what kind of cognitive abilities or behaviors is put into play? To answer these questions about the cognitive nature of plants, we suggest the study of the ternary link 'plant-environment-world', excluding to separate the body, not from the mind, since the question does not arise here, but from its cognitive and terrestrial matter (or habitat). Overall, it is a question of taking into account the different levels of organization, sensitivity and reactivity with which living systems evolve according to their specific ecoplastic interfaces, and of redefining the frontiers of cognition as regards non-neural organisms and plant cognition in particular.

The protoneural dynamics of plants that we have previously described with regard to the EPGs recorded in Kalanchoë D. [6] does not indicate at all the development of a "neuronal plant", but the establishment during evolution of common biochemical and genetic cellular mechanisms to all living systems (like bacteria's ion channels) which would gradually differentiate to lead to synaptic plasticity of the brain in animals and humans. All in all, the prototypal character of plant cells that appeared before the emergence of the nervous system of invertebrates, vertebrates, and then primates, explains their indissoluble links, as well as their fundamental differences linked to the divergence of kingdoms during evolution. Among these essential differences, the modularity and the pluricentrality of divisible, iterative, autotrophic and almost immortal plants in front of the uniqueness, centralization, indivisibility and heterotrophy of the animal kingdom. Both kingdoms show indeed to far degrees, sensitiveness, movements and forms of cognition ranging from access to experience to sentience in plants and from immediate consciousness to introspection and self-awareness in primates or man. We therefore find ourselves today logically having to explain the gap between perception and integration of brainless systems that have evolved differently and that demonstrate complex, sensitive behaviors according to certain intelligent criteria.

In order to calibrate the nature of plant cognition, understood as a process of knowledge of the environment with semiotic value or knowledge accumulating systems [11] compared to that specific to animal species such as birds or insects whose delta between the size of the brain and the cognitive complexity noted is very large but can be explained in other words (density vs extensiveness: see 5.2), we refer to the three classic cognition categories. This is namely: 1/ the distributed cognition where it is the multiplication which creates a form of collective intelligence typical of colonies of ants or other insects and animal or human societies; 2/ the situated or embodied cognition, linked to the preponderance of a peripheral part of the body (octopus tentacles etc.) and in humans the non-prevalence of the brain on the body, 3/ the extended cognition that goes beyond the body (spider web, AI in humans, etc.). Other forms of cognition can be brought into play depending on the species and the categories (Table 3).

14.5.2 Small Brains, Great Cognition

Comparative approaches between plants and animals consists in detailing the differences between the cognitive modes of small vertebrate species compared to biggest animals or man. Indeed, a recent study of the brains of 28 species of bird brains (parrot, magpie, crow, wren, jay ..) published in PNAS (Olkowitcz et al. 2019) [28] presents the high cognitive capacities and similar to the primates of many birds (construction of tools, decision-making, complex learning and language, self-awareness) despite their small size. This study shows that this would be due to the density of their neurons, 2 to 4 times higher than in certain mammals. The researchers' hypotheses on the cognitive performances and the levels of intelligence observed lean for different evolutionary strategies depending on the species: long-distance connection in the brain of mammals vs increased density of neurons in birds, which would make them win in weight/brain mass ratio (advantage for flight). In insects, tiny brains are not only dense but thrifty, allowing them to process a large amount of information in real time (although it is much less efficient than that of higher animals in terms of memorization or abstraction) and in a minimum of space despite their limited number of neurons (hence lower energy expenditure unlike mammals and humans: 20% energy expenditure) [28].

As previously evoked for lemurs, primate brain size does not predict their intelligence. Although we are discussing cerebral species here, the consequences of this weight/energy ratio on the degree of cognition involved are interesting to be taken into account in our context, because they indicate the crucial importance of phenotypic and epigenetic plasticity in evolution. Related to affordant systems and mesological niches, signs make indeed possible to interpret the relationships between the perceived signal and its response in terms of efficiency and biosemiotics. For instance, there is no doubt that a bird interprets a horizontal branch on its way as a natural perch, which will not be the case with other species such as small rodents, insects, or even climbing plants or roots that will have to avoid or bypass it. In another context, the bird, to make its nest, will use the twig.

Let us return now to plant cognition, Parise et al. [70] show with regard to extended cognition, that when the spider weaves its web, it is all its body that becomes an extension of the environment and that external physical objects are part of the cognitive system of the animal or that it can handle them. This is also the case with bird nests to a lesser extent, and tools made and used by certain animals, notably primates with tools and humans with the development of writing and now AI. Each time, cognition goes beyond the apparent limits of the organism in its own environment. The authors go further than this observation, specifying the need to establish criteria for mutual manipulation in order to eliminate false positives (temperature, blood oxygen, physiological constants, etc.) and to consider the cognitive system spider + web. In fact, the responses of the spider are totally conditioned by the tension of its web and the vibrations perceived by its CNS. The spider therefore developed an increased sense allowing it to discriminate the vibrations associated with various stimuli like the wind or the presence of insects. If you artificially change them, you completely change its understanding of the world. The authors hypothesize that plants could offload part of their stains by extending their cognition and the areas of influence of the roots far beyond their body thanks to the mycorrhizal network and the rhizosphere, especially during the perception of obstacles linked to the accumulation of allelopathic exudates between the two elements: the roots and the physical obstacles detected. This leads to inhibition of root growth in the direction in which these exudates are accumulated and therefore a mean to bypass them. Same observation at the level of bacterial exchanges where we find this manipulative behavior benefiting plants with respect to the microbiome of the rhizosphere: example of triterpenes of specific Arabidopsis bacteria, of the amplification of the perception of mychorrize fungi to favor the exchanges or the uptake of water, and nutrients and phosphorus photo-assimilated elements of plants. This indicates that the fungal network extends the perception of the environment by plants and facilitates their cognitive processes such as memory.

The criterion of mutual manipulation is therefore a good model of cognition via an organism rather than a physical object and can be extended to another organism of a different kingdom [70]. It supports our model of the plant as ecoplastic interface and considering the dynamic coupling of the plant and its environment (milieu) as inseparable from its cognitive valence, in part thanks to the electrome that highly contributes to the development of sensitiveness and communicative functions of plants [2, 11]. Other advanced forms of cognition in organisms without a brain, even tiny ones like in the insects or birds that we mentioned earlier, have been described in a protist, the *Physarum polycephalum*, single-celled organism of the myxomycetes family, which is able of learning and memorizing. A recent work shows that not only does the Physarum learn from its experiences, but that it can transmit them to a congener by fusing with it thanks to a contractile venous system (Actin-Myosin) filled with cytoplasm which allows it to move and grow to record sizes (around $10m^2$) by absorbing food (especially mushrooms) (Vogel and Dussutour, 2016) [71]. The fusion of venous networks and its ability to absorb/deploy at high speed and over large areas make the "Blob" an almost eternal organism. What interest us here are its high cognitive capacities: solving maze-like problems, creating complex networks (Nakagaki et al. 2000, Tero et al., 2010) [72, 73] and anticipating stimuli (Saigusa et al., 2008) [74]. Some protagonists associate these learnings and the memorization of information with processes inducing epigenetic modifications (Schaaps et al, 2015) rather than with a form of intelligence [75]. However, the long-term memorization of aversive substances after periods of dormancy recently described by Broussard et al. (2019) would imply here a conservation of this habitation and therefore a form of inceptive memory [76].

More generally, the observation of cognitive abilities is far from only concerning rare species of plants. The behavior of many ordinary plants such as the "*Ladies' Arabette*" exhibiting proprioception (Moulia and Fournier, 2009) [53], the aspen showing mechanoperceptive behaviors following stress (rapid triggering of a specific gene when a branch is bent by the wind remaining memorized for at least a week; Martin,

2010) [77], maize roots exhibiting responses to specific sound frequencies (220Hz) (Gagliano, 2012) [78], volatile mediators like the B-phellandrene or A-Pinene of the tomatoes (Mescher, 2006) [79] and all responses provided by plants facing biotic or abiotic stimuli. Whether they are purely defensive or reactive to new situations, they require complex sensory perception modes and a great plasticity not only adaptive, but minimally developmental, inducing metabolic, genetic modifications and specific bioelectrical mechanisms.

14.5.3 Plasticity of the Plant Body and Hypersensitiveness to the Environment

On another scale, the inter- and intra-species communication developed via the root networks (the Wood Wide Web) and the mycorrhiza of all plants in varying degrees depending on their size and age can reach considerable areas (thousands of km^2 for a tree of consequent size) and lead to extremely fine readjustments of the metabolism and the feeding of the terminals as well as to elaborate transmissible defense strategies. The same applies to the displacement of the treetops depending on the light projected and the poplar plantation concerned in the canopy, the complex plant-animal interactions during pollination or the use of second-degree species lures by orchids. Is it a purely adaptive phenomenon, a hypersensitivity to the environment or traces of intelligence? In any case, this justifies questioning the concept of intelligence of the living, even if this term remains subject to questioning and bring nothing in itself, while posing that it would undoubtedly be more relevant to focus on the sensitive and cognitive qualities of plants, more able to reveal their deep nature [16].

We can clearly see through all these exemplifications that the plasticity of living systems is the common denominator of all species, whatever their mode of exploration of the environment [23, 25], but that different *modus vivendi* emerge depending on each of them. However, it is each time the determination of the dynamics of the organism-environment couple that produces forms of interactions sometimes qualified as sensitive, sometimes cognitive and intelligent. Most of the discussions revolve around the delta between the nature of the observed behavior (for instance a form of learning) and its consequences in terms of classification in the cognitive scale, and further downstream, at the evolutionary one. Hence the generation of circular issues resulting in the two types of drifts (semantic and anthropo- or zoocentric) that we know about plants. We must therefore detach ourselves from this sterile problematic. Thus, the generalization of responses involving in certain species (whether animal, vegetal or other) loops of perception-action, cross-communication, recall and/or transfer of stored information and learning capacities is a flagrant marker of the existence of cognitive processes in biology, whether or not these attributes are qualified as intelligent (Abramson & Chicas-Mosier, 2016) [80]. We have also seen that it was possible to get around the problem of individuality and the macroscopic observation of the split behavior of divisible, decentralized and essentially modular plants, by appealing to the efficiency of complex biodynamic systems such as the bioelectrical continuum at the scale of their different tissues (phloem, xylem, symplasm, etc.). This process extended to a uniform somatotopic mapping - given that the functions are not separated but present in all plant cells - unlike the specialized structures of animals, can compensate for this non-individuation made up of minimal cognitive entities following the description of Calvo and Keijzer [45], because it allows rapid and long-distance information transfers between bioelectric networks via complex excitable structures (like interconnected bundles or vascular tissues including anastomoses;Volkov, 2012) [81] which can be synchronized (Masi et al. 2009, Debono 2013). It is therefore, like the physarum or other somatocentred organisms, the entire plant in connection with its environment, which constitutes a eco-sensible cognitive interface suitable for accumulating information and knowledge, memorizing it for a longer or shorter time and to restore it thanks to its mesological plasticity (active and coextensive binding of the ecoplastic interface, mediation of the plant body and trajection to the plant-environment interface; Debono and Souza, 2019, Debono 2021) [11, 82].

So, let's come back now to the three essential questions dealt with throughout this chapter: 1/ why is 'everything' (i.e. all these cognitive abilities) possible an aneural context? 2/ Where and in what way do the emerging behaviors and the cognitive nature of plants compensate for this lack which is not really one? 3/ What is the nature of the cognition brought into play between the plant and its immediate environment, regardless of the permanent changes to which it is subject? We have largely answered these questions, but at this stage of the description which wants to approach the world of sensitiveness (which is neither a sensitive, nor a sensible or emotive field), too often relegated to the background in human civilization for the benefit of profit or materiality, our answer will be that the links between the plant - to be considered as a subject - and the environment are by nature inseparable and that they determine an unconscious and 'unrepresented' access to experience, but which is very real. It is determined by its hypersensitiveness to the environment and a rich sensoriality, in other words what anthropologists like Morin have described as a 'self-eco-organized' structure [83], post-cognitivist phenomenologists like Thomson and Varela as embodied and/or enacted cognition [43] and ethologists like Watsuji and Uëxkull (see Berque 2019) [84] as a mediance or a dynamic coupling between the subject and his environment (Table 3). Our proposal takes these fundamentals into account, but goes further, in that they explain them: 1/ through a precise and operative scientific observation: the role of the electrome or the electrical dimension of plant life (Toledo et al., Debono and Souza, 2019) [2,11], 2/ using a transdisciplinary reading grid.

Indeed, we have shown that the behavioral unit observed in plants is largely made possible thanks to the emission of spontaneous surface variations (EPGs), which constitute, within the electrome, a monitoring system reflecting exchanges between the underlying bioelectric networks and a permanent discrimination of environmental stimuli. In other words, the electrical dimension of the plant life permits a fast and efficient propagation of the information, allowing them to communicate and have a form of cognition anchored in a body, an environment and a world [16] intrinsically linked to their hypersensitive dimension and their otherness. These two components constitute an electromic and eco-sensitive interface linking the whole plant to the plasticity of the world itself [11]. The finding of the operability of what I have called 'mesological plasticity' has direct implications on the interpretation that one gives to the terms of intelligence, sentience, cognition or subjectivity of plants by cutting short sterile semantic or tendentious discussions.

Table 3: Comparison of cognition modes in plants.*

• **Cognition / Etymology**: " The word cognition dates back to the 15th century, where it meant "thinking and awareness. The term comes from the Latin noun cognitio ('examination,' 'learning,' or 'knowledge'), derived from the verb cognosco, a compound of con ('with') and gnōscō ('know'). The latter half, gnōscō, itself is a cognate of a Greek verb, gi(g)nósko (γι(γ)νώσκω, 'I know,' or 'perceive') "…. " It refers to the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" [WP]. Several conceptions of animal or human cognition exist since the development of cognitive sciences, mainly linked to psychology, cognitive neuroscience, social science, anthropology and the philosophy of mind considering the body as peripheral to understanding the nature of mind and cognition.
• **Plant cognition** is nowadays focalized on growth and the determination of the extent to which plants can use senses and cognition to respond to their environments. The Plant Neurobiology school of thought assumed in its first acceptation that plants have physical structures functioning as neurons, synapses or minimal brains (i.e. the "root-brain hypothesis" presented by Balūska in 2009 on the basis of earlier Darwin's work) but is today dedicated to plant signaling and behavior and the study of their cognitive abilities including perception, learning and memory processes. This behavioral/ecological approach has a high impact on animal or human/vs plant intelligent behavior comparisons being defined as an active adaptation and response to any stimuli presented to all living beings. - A study of Calvo & Keijzer about minimal and distributed cognition in plants (see below) admits 5 criteria to establish the kind of plant cognition: 1/ Basic metabolism (biochemical normativity established in ref. to a study of Barandiarian (2008); 2/ Spatiotemporal dispersal characteristics of this metabolic normativity; 3/ Spatiotemporal structure of the environment accessed by free and reversible bodily movement, 4/ Basic sensorimotor (SM) organization mainly operating online; 5/ SM-based cognitive organization considered as cohering unit and not a collection of individual stimulus–response relations.
• **Post-cognitivist theory**: "The embodied mind thesis challenges other theories, such as cognitivism, computationalism, and Cartesian dualism. It is closely related to the extended mind thesis, situated cognition, and enactivism. The modern version depends on insights drawn from recent research in psychology, linguistics, cognitive science, dynamical systems, artificial intelligence, robotics, animal cognition, plant cognition and neurobiology". [WP]
• **Agency**: " In very general terms, an agent is a being with the capacity to act, and 'agency' denotes the exercise or manifestation of this capacity. The philosophy of action provides us with a standard conception and a standard theory of action. The former construes action in terms of intentionality, the latter explains the intentionality of action in terms of causation by the agent's mental states and events…". • **Agency without mental representation**: "…there are beings that are capable of genuine agency and that do not possess representational mental states… It is, for instance, compatible with what Barandiaran et al. (2009) call "minimal agency"…. "This view departs from the standard conception and theory in its characterization of action ("doing something") in terms of the "adaptive regulation" of the agent's "coupling with the environment" and in terms of metabolic self-maintenance (inspired by Varela et al. 1974). They suggest that organisms as simple as bacteria exhibit this minimal kind of agency. The crucial point is that this provides an account of goal-directed behavior that does not appeal to the mental representation of goals…". [SEP] • **Situated cognition**: Agent vs environment.
• **Action-oriented feedback organisms** (Milkowski, 2017)

Table 3: (continued).

• **Active Binding, Access to Experience**: Active perception thresholds, direct and interactive link between plants and their immediate environment (Debono 2016)
• **Cognition as mechanism of controlling behavior**: Sterelny's taxonomy of sensory evolutive systems. Four different types of behavioral control are described by Sterelny (2003): 1 / detection systems; 2 / robust tracking systems 3/ Response breath 4 /Decoupled representation.
• **Minimal cognition** (MC): Sensorimotor-based (minimally) cognitive systems. This minimal form of cognition (or of a distributed MC) is adopted by Calvo & Keijzer (2011) for plants in a global ecological meaning including a performance index. It differentiates mainly adaptative behavior "in the wild" from laboratories studies and do not separate MC organisms from the natural habitat (its « the geometric layout of its environment) in which they take place.
• **Distributed cognition** (DC): Collective or Swarm intelligence, Colony. Dispersed sensing (VOC: Volatile organic compounds, WWW: Wood Wide Web).
• **Embodied Cognition** (EmC): Involvement of the whole vegetal body and related processes. "The features of cognition include high level mental constructs (such as concepts and categories) and performance on various cognitive tasks (such as reasoning or judgment). The aspects of the body include the motor system, the perceptual system, bodily interactions with the environment (situatedness) and the assumptions about the world that are built into the structure of the organism". [WP]. "Cognition is embodied when it is deeply dependent upon features of the physical body of an agent, that is, when aspects of the agent's body beyond the brain play a significant causal or physically constitutive role in cognitive processing ". [SEP]
• **Embedded Cognition** (EmbC): Functional link with en external environment.
• **Embodied embedded cognition** (EEC): Brain-body-world complex behavioral access to the reality, intelligent behaviors.
• **Enacted cognition** (EC): interplay between plants and their singular environment involving the sensory system and an additional part of its cognitive system (feedback mechanims, recall of information and potential awareness).
• **Extended Cognition** (Eco): Into the organism's environment or extending the body (spider web, wood wide web, AI). • "The Extended Mind" is a field of cognitive sciences proposed by A. Clark and D. Chalmers (1998) presenting the idea of "active externalism" (similar to semantic externalism) in which objects within the environment function as a part of the mind. They argue that the separation between the mind, the body and the environment is an unprincipled distinction.
• **Ecological psychology** (EP) is the scientific study of perception-action from a non-functionalism approach. Ecological psychology is a school of psychology that follows much of the writings of Roger Barker and James J. Gibson (1966, 1977). Those in the field of Ecological Psychology reject the mainstream explanations of perception laid out by cognitive psychology. The ecological psychology can be broken into a few sub categories, perception, action, and dynamical systems. As a clarification, many in this field would reject the separation of perception and action, stating that perception and action are inseparable.
• **Perceptual learning** (PL), **Direct perception/Affordances**: Gibson believed that the environment and animals are not separable items. He stated that without the environment, animals cannot survive and without animals, there is no environment. The environment is what we perceive at any given moment. All animals are able to perceive. Humans perceive the environment directly. This is why we are unable to perceive things in the environment that are too small to see, such as an atom. For Gibson, the noun affordance pertains to the environment providing the opportunity for action. Affordances require a relationship in which the environment and the animal can work together… They can be related to different areas of the habitat as well and have social impacts. [WP]

Table 3: (continued).

• **Associative learning & decision-making**: Recent researches of Gagliano (2016) demonstrated that plants are able of associative learning and anticipation (Pavlovian learning). If confirmed, these results could open a new measure of the cognitive capabilities of plants.
• **Information processing**: Following the *Plant Neurobiology* conferences (2005-2010), a lot of publications from Brenner, Trevawas, Mancuso, Balúska, Calvo, Keijzer, Souza, Gagliano, etc…were published about signalization and plant behavior (see *Plant Behavior and Intelligence,* Trewavas 2014). The idea of plant intelligence, cognition or consciousness is a source of debate (Alpi letter, see Taiz et al., 2019) and new discoveries show that if plants do not have neurons, they are able to feel, learn, memorize and communicate.
• **Primary Meaning-Making** (PM) / **Bio-semiotics**: It corresponds to a post-darwinian semiotic biology derived from the work of Jacob von Uexküll on animal ethology. Primary-meaning mechanisms create an Umwelt or a phenomenal world in which animals, but also other species like eukaryotes, unicellular organisms are actors. Plant-environment relationships have been little studied by Uexküll and are the object of our approach of plant mesology presented in Table 2. At the semiotic level, the concept of functional circle is assumed to be here a key component of agency and linked to subjective time and semiosis (Kalevi Kull, 2000). These bio-semiotic components have points in common with the work of Berque (2014, 2016) and the above-mentioned mesologists without having the same perspective.
• **Mesological plasticity** (MP): As presented in tables 1-2, following the Berquian presentation of the mesological relation, we have extended the description of the dynamic coupling to plants that are electromic ecoplastic interfaces and medial structures (Debono & Souza 2019) presenting a high sensitiveness to their singular habitat, active perceptions and a trajective access to experience and/or cognition.

* Sources of some definitions: Wikipedia [WP] & Stanford Encyclopedia of Philosophy [SEP]

14.5.4 Learning and Complex Behaviors

As we have shown, the best expression of these cognitive skills and of the richness and complexity of the plant life (or of tree interactions in the forest) can be obtained by continuous *in situ* electrophytographic (EPG) recordings in natural conditions (rather than in laboratories). They lead to the observation of complex emerging behaviors, according to the establishment of exhaustive criteria such as those previously described or still recently shown by Michmizos & Hilioti (2018) about learning capacities and plant memory [85]. These authors discuss in particular the presence or not of internal representations of the outside world and of encoding in the form of engrams that may involve actin networks and feedback of the information learned, qualified as intelligent, but who are undoubtedly endowed with sensitivity and a cognitive aptitude which does not call upon any intentionality or subjectivity. According to these authors, this type of observation does not only concern epigenetic plasticity, but could be linked to the identification of unlisted mnemonic systems, for lack of adopting the right angle of view, such as the stabilization of the coactivation of patterns recruiting certain groups of cells, remodeling of the cytoskeleton, the emission of feedbacks ± or molecular signals (like calcium waves) in plants. Another crucial demonstration in the advancement of our understanding in the field of plant learning is also linked to Gagliano's associative and non associative learning experiments, using either two groups of pea plants responding to differential conditioned responses or repeated shocks in *Mimosa pudica's* [86a, 86b].

Following the cognitive perspective of access to experience without representation of plants which are expressed, as for mammals, in terms of sensitiveness (and not only sensitivity, mainly sustained by signalisation and electrical networks), communication, memory or learning, we need to explore in deep the non-linear dynamic relationships between perception and integration. However, it is not so much their neural – or more precisely protoneural – ability that is the fruit of a common evolutionary process which has diverged, which is to be taken into account, but the moment when the dynamic coupling 'plant-milieu' and the cognitive apparatus as an emerging vector of this complex self-organized system become operational [6]. It involves, as in animals or humans, not only forms of phenotypic, onto- and epigenetic plasticity – essential for the survival of species and optimal organismic growth – but: 1/ an activation of perception-action loops linked to the plant-singular environment pair (plants are neither immobile, nor identical, nor passive) and 2/ an access to experience via a system of affordance (Gibson, 1966, 1977) [69, 87] or of mesological plasticity [11, 16].

We have already described the mesological link. The Gibson's term 'affordances' [87] describing the relationships between animals and the environment eliminates the mechanistic view of a "machine" animal and neutral environment. On the contrary it is active, in other words, the field of multiple possibilities of action that the animal chooses is easily transposed to plants in its sense of 'awakening sensitivity' to the surrounding world and processing information in interaction with the environment. This active plasticity has the potential to engender, in the first as in the other case and with different degrees of integration, a schema of interpretation of the outside world. This concept of opportunistic action in a bio- or even phytosemiotic environment (Kull, 2000) [88] and/or making action possible without causing it, is also totally transposable to plants following Calvo et al. (2011, 2017), provided that it do not limit it to direct perception and interaction with an environment considered unambiguous [40, 45]. Indeed, while vegetative semiotics is mainly aimed at morphogenesis and differentiation following the founding works of Uexküll taking into account the thresholds between species, the fact that it is subject to a changing environment and by ambiguous essence asks it to make 'choices' or at least to adopt complex dynamic behaviors where the conditions of survival, reactivity and growth are intimately linked to their interaction with the environment [26, 31].

14.6 Third Included, Subjectity and Coextensive Reality

The operative significance of biological cognition has been described further. Mesological theory, for its part, differentiates the subjectivity of the animal or man from the subjectity [50] of the subject included in an environment, which applies perfectly to plants. In fact, the observation of both autonomy and a mutual dependence between the living subject and his environment leads to the development of a perception-action loop, which is not neutral, but indicates, if not a "self", a presence to" others ", here determined by the environment. In other words, we need to take into consideration, not the objectification but subjectivity of the relation (at the biological scale), that is to say a reciprocal interdependence or subjection between the micro- and the macrocosm (cell vs organism) or the individual and the collective (organism vs society). The homeostasis of the living is preponderant and is always in a state of 'stable imbalance', therefore of interaction between the interior and exterior environment (as in transmembrane exchanges) or the passage from object to subject, but when there is proactive perception or attempt of knowledge of the other, this interpenetration of environments leads either to a dual state, object and subject at the same time, or to a ternary state (Table 1). This is the third point I would like to address, stemming both from mesological reflection (Uexkull, Berque) [27] and transdisciplinary studies (since the quantum revolution: Lupasco, Nicolescu) [89-92]. Here, the highlight of the notion of 'third included' which indicates since Antiquity (Plato, Proclus, Aristotle) and in several traditions (notably Far Eastern) with differences in interpretation around whether the Aristotelian terms A and non-A admit or not the inclusion of a third term and its meaning (the Chôra of Plato, the T state of Lupasco, the Indian Tetralemma).

If we put it back in our questioning with regard to the behavior of plants, it indicates in an illuminating way, not only the ternary subject-environment-world link and the formation of plastic complexes following the perceptual bonding operated by plants [17, 21, 23], but also a 'Metaxu' (or an intermediary in reference to Plato) between the intelligible and the sensible [100]. This third term would support the otherness specific to the plant world (described, among other philosophical assertions as 'plant thinking' by Marder in 2013) [93] insofar that it derives from a subjectivity in animals or humans and from a subjectity on the scale of plants, since there is internalization of the form that defines it. Now, it is precisely the definition of the concept of Plasticity (Debono, 1996, 2005, 2021) [22, 23] which first links form and matter before showing that this active binding (here perceptual and linked to evolutive processes: Debono 2004) [94] becomes irreversible when it forms plasticity complexes (CP) where plasticity is the included third [95].

We find an expression of it in the proprioceptive capacities of plants which clearly stand out from their phenotypic or epigenetic plasticity, in the sense that they call upon sensors of balance, gravity and positioning (verticality), but especially to a perception of their shape and of the deformation of their body, or even those of their congeners – like the canopy whose constrained plasticity optimizes the performance whatever the species (cooperative behavior which does not exclude competitiveness, moreover) – (Sack et al. 2006) [96]. These behaviors are widely described at the level of tree tops in the forest and of the deformation of trees subjected to intense stress such as strong wind (taking into account their sharing of light or their positioning and the presence of juveniles), which indicates an internalization or spatiotemporal elements of a decentralized representation, a perception of their presence in the world, even if it is not integrated in the cerebral sense of the term, and a capacity for association leading not only to reactions but to actions, and even feedback.

Are we not here describing a phenomenon of cognitive nature, whether it is located, distributed, embodied or extended as the interconnections in shared underground networks might suggest (Parise et al., 2019) [70]. Are we not here describing somatotopic phenomena at the scale of the entire plant, therefore delocalized and integrative but not involving any central unit? Phenomena using protoneural systems that transmit information at a distance, are able to control growth patterns in the case of circumnutation or responses encoding predictions of errors in perceptual learning processes? If we follow our reasoning, there is indeed no need to appeal to a brain and even less to a consciousness in plants (without need also to use the circular argument "no brain-no consciousness" recently argued by Taiz et al. 2019

[97], insofar as their hypersensitiveness to the environment and the cognitive capacities which result from it operate through nonlinear dynamic processes [6] spilling out across the entire plant body [6]. Perceptual and reactive processes requiring no supervision, which could explain, in the case of the physarum (but not in that of insects or birds with small brains), dazzling successes in the labyrinth test (root going to seek nitrogenous food in the case of plants) and a form of dispersed and non-localized cognition.

In this paper, we have given some empirical evidence, even we can discuss if empiricism is empirically false as Milkowski did it interestingly [63], several avenues that allow us to outline answers on access to experience and the cognitive nature of plants, understood as subjects capable of modifying their biodynamism and their behaviors, depending on the stimuli. It is now a question of moving forward on these avenues and in particular on the role of the electrome of plants, which a recent publication has shown, as was previously the case for osmotic stress [9], that an infection by pathogens affected the dynamics of the electrome, and that these alterations, which could be located far from the site of the infection (therefore involving the propagation of long-distance signals during plant-pathogen interactions), were detectable by EPG before the visible effects of infection on tomato plants (Simmi et al, 2020) [98]. This study recalls the interest of EPGs as early markers of activity and *in situ* diagnostic tools, but above all indicates the active role of this electrogenesis in the sensory sphere of the whole plant.

This pragmatic functional approach seems to us more able to scientifically advance the debate on plant intelligence, on condition of not compartmentalizing the plant-environment-world relationship, which according to our mesological approach, differentiates the singular environment or the Umvelt in which the plant evolves from the raw data of the environment to which it is subjected. As Tassin (2020) recently said: "The sensible is coextensive with the living as the environment is coextensive with the subject" [36]. It exists before perception and installs the presence of beings in the world. It is therefore a question of understanding how this dynamic coupling operates and what are the conditions for a mediation of the sensitiveness on the plant scale? For this, we have to think outside the box and consider the ternary plant-environment-world links and the perception-action loop as inherent in a form of knowledge of this world.

14.7 Conclusive Remarks: Rehabilitate the Ecosensitiveness of the World: A Transdisciplinary Challenge

To conclude, plants considered to be primordial biosensors on the evolutionary scale of the living and the ecosystems governing us, have acquired the status of sensible subjects, which is a considerable step forward in integrative biology and in our own perception of the plant world. Our position based on recent developments in cell signaling and on the consideration of the electrome as a major support for plant information processing is that we can not be satisfied with these assertions and that we support the hypothesis of a progressive establishment of proactive perception systems during evolution leading to eco-sensitive and cognitive behaviors. It therefore seems high time to reassess the frontiers of cognition in plants without taboos or over-reference to the neuronal or intelligent model.

Scientifically, we propose to do this through the implementation of *in situ* integrated electrophytographic models such as those we have described, i.e. permanent spontaneous EPG activities subject to self-organized criticality (SOC) showing different patterns and colored noises depending on the type of stimuli or pathologies to which plants are subject as well as temporal correlations on large scales. EPGs are highly relevant early markers of activity that can be monitored by EPG kits in their natural environment permitting a lot of TD studies (concerning health, agriculture, biology, plasticity, communication. . .). More generally, plants must then be definitively considered as complex biodynamic systems embedded in an ever-changing milieu (an ecoplastic and mesological interface) and their study field need a redefinition of the sensory sphere, of subjectivity and of otherness, in other words, of its proper agentivity, ethology and intercognition (potentially including self recognition and internalization) with insects, plants, humans etc. This should lead us to a better understanding of the specific vegetal behavior as a whole, its own ontology and at what level of autonomy we accept to grade it among all other species (including unicellular organisms).

"*Are plants cognitive?*" ask recently Segundo-Ortin and Calvo (2019) responding to a critical review of Adams [99]. Clearly yes, if we assume firstly that it is a non-metaphorical argument, and secondly that plants, as all living systems, are cognitive agents, as admitted by the post-cognitivist current joining enactive to eco-responsible considerations. It is therefore a question of putting into perspective the cognitive value of the access to experience of plants understood as biological embodied cognitive systems allowing them, not only to exploit their surrounding environment (which give them great benefits), but also to show active perception and reaction to it. This behavior that can be proactive –anticipating modifications of its environment –, that memorize and learn, could be assimilated to a biosemiotic process of knowledge of the environment facilitated by the electrome and the hypersensitiveness of plants in their singular milieu. It defines for us a dynamic couple showing medial ability and a trajective way of expression (mesological plasticity) [11] or more literary, an "anchored intelligence" (Debono, 2020) [16].

We define then plants as electromic plastic interfaces implying endogenous and exogenous control of information, perception-action loops and high communicative skills, i.e. cognitive entities, but not as 'neuronal plants' or structures containing phytoneurones, as previously described concerning their bioelectrical transmission [11]. Indeed, this causes semantic disorders or confusions which do not seem to me to bring crucial elements (we know that plants do not have a brain or neurons), or then we must speak of protoneural dynamics and place ourselves on the level of convergences or divergences of species during evolution [94], where the notions of plant sensitiveness and biological cognition support the comparison with the animal kingdom and indicate differentiated modes of cognition (Table 3).

Indeed, beyond the recognition of the sensitivity, the cognition or even the awareness of plants, it is the entire domain of the sensitiveness and of the nature-culture relationships that must be re-examined. This concerns directly the interspecific links, the evolutionary scales and the re-evaluation of value systems and/or notions seemingly acquired about cognition, intelligence, sensitiveness vs sensitivity or even socio-anthropological considerations. Debate which, on the scale of questioning "the intelligence of plants" [31] cannot be approached unilaterally by botanists, biologists, anthropologists or philosophers, but only by the opening of a cross-pollination and a field of transdisciplinary studies on this vast question [25]. We situate it precisely through a careful examination of interactive ecosystems, perceptual and cognitive modes of apprehension of the ecosensitiveness of the world (Debono, 2021) [82]. And among these TD approaches, we can consider that the singularity and otherness of the complex biodynamic units that plants represent are flouted by a socioeconomic system (the 'Capitalocene' described by Marder and Haraway) [93, 101] centered on the anthropocentric prerogatives of man which could have serious consequences on the planetary balance and the place of man in the future.

To conclude, confluent empirical, epistemological or scientifically demonstrated arguments (see Garzón, Calvo, Segundo-Ortin, Milkowski, Marder, Debono, Keijzer, Baluska, Gagliano, Souza etc.) show that plants, as most of living organisms, have clear cognitive abilities, whatever they are classified. The transdisciplinary challenge to which we must respond, as previously described by Debono [34, 95], a core-TD biosemiotic research area reevaluating the frontiers in cognitive sciences including phenomenological and mesological approaches of sensory and biodynamic complexes [20]. Only this crossed field open to the universal but also to diversified messages of complex non-linear dynamic systems, trans-subjectivity and the third included [92] could ultimately lead to a redefinition of decultured or too anthropized attributes and clarify the debate on the modes of cognition or learning of plants, fungi, protists and more generally of all living subjects. Our own human status, today more acutely perceptible in its fragility (Covid 19) depends on it, not to mention the global threats linked to the consequences of both the era of Anthropocene and the Capitalocene. It is therefore urgent to rediscover the frontiers of cognition and of the sensible world, taking into account the phylogenetic origins of biological cognition and of elementary learning processes (Van Duijn, 2017) [102] as well as their ontological significance.

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