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AN AXIOMATIC DESIGN STANDPOINT OF SOCIO-POLITICAL MODELS FOR SUSTAINABLE GOVERNANCE

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ABSTRACT

The most widely accepted definition of sustainability is the one of the World Commission on Environment and Development (WCED), a. k. a. the Brundtland Commission, which states that the "sustainable development is the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". Accordingly, sustainable development takes into account the population, the economic and the environmental dimensions. Axiomatic Design (AD) allows expressing the many interactions between the aforementioned three concerns that yield to coupled design equations, which may have a higher or a lower degree of complexity depending on the number and on the nature of the requirements. Using the first two dimensions, *i.e.*, the population and the economic ones, we can accomplish design equations that reflect the traditional socio-political shape of the Western civilization. Thereafter, one introduces the third dimension, the environmental one, expanding the design equation by adding the so-called eco-requirements and the related parameters. Doing so, it expresses, or will to express, the shifting from the former socio-political ideas about the role of engineering design to the new concept of sustainable design, giving rise to the discussion about different models for the future development of the mankind. One of the objectives of the application of AD to the sustainability problem is to help choosing design solutions with as low complexity as possible. In order to achieve it, one could change the design range of the extant requirements or try different sets of design parameters, as well as freeze some specific elements of the design equation or try redundant design solutions. Different solutions for sustainability may reflect diverse socio-political models of governance, which are also briefly discussed in the paper.

Keywords: sustainable design, axiomatic design, governance, socio-political models.

1 INTRODUCTION

During the last decades of the 20th century, the international community became increasingly aware of the need to act over the continuous aggression that is being done to the natural conditions of the Earth.

The formal international discussion about sustainability may have been launched in Stockholm, Sweden, during the United Nations Conference on Human Environment, in 1972. This conference issued a 26-principle declaration on the relationship between the human activities and the environment [*Declaration of the United Nations Conference on the Human Environment*]. Principle five is particularly important and states, "the non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by all mankind". The conference also initiated an "action plan for the human environment" involving education, exchange of information, social and cultural issues, and human settlements. It has not explicitly mentioned the role of the economy, although it made important references about the role of financial help to the developing economies.

About one decade later, in 1983, Secretary-General Pérez de Cuéllar appointed the former Norwegian prime minister Gro Harlem Brundtland to chair the World Commission on Environment and Development under the aegis of the United Nations. This commission, latter known as the Brundtland Commission, first introduced the notion of sustainable development through the well known statement: "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [*Report of the World Commission on Environment and Development - Our Common Future*]. Some have criticized this definition, as "meeting the needs of future generations" does not explicitly comprise the future human requests, as well as the future technologies.

Furthermore, the commission declared that "areas of population, food security, the loss of species and genetic resources, energy, industry, and human settlements" are all interconnected, giving the basis for the rising of the United Nations Conference on Environment and Development in Rio de Janeiro, 1992, also known as the Earth Summit or the Rio Conference.

The main results of the Rio Conference are summarized in the 27 principles of the Rio Declaration on Environment and Development, the Agenda 21 and the Forest Principles. It is especially meaningful the fourth principle of the Rio Declaration, which states that "in order to achieve sustainable development, environmental protection shall constitute an integral part of the development process chain and cannot be considered in isolation from it" [*Rio Declaration on Environment and Development*]. New developments of the Rio Declaration came in 1997, 2002 and 2012 and the main milestone that came after Rio was most likely the 1997's Kyoto Protocol. This protocol supported by the United Nations Framework Convention on Climate Change (UNFCCC), aims at reducing the emissions of anthropogenic greenhouse gases (GHG), namely CO_2, in order to stabilize it "at a level that would stop dangerous anthropogenic interference with the climate system."

During the 1990s, it became clear that one should slow down the consumption of the finite natural resources and minimise the pollution generated by the human activity as a means to achieve sustainability. It was also acknowledged that the current generations should ensure the future fittingness to life of Earth, as well as the welfare of the next generations. This awareness is transversal to all the human activities, including engineering design, which must therefore concern with society, environment and economy along the whole life cycle of the design objects, in a simple scheme usually abbreviated through the PPP acronym, which means people, planet and profit, as shown in Figure 1.

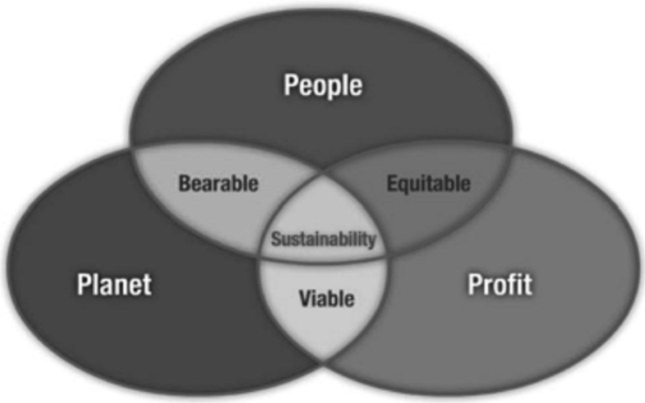

Figure 1. The triple bottom line of sustainability [Chiu and Chu, 2012]

Hence, sustainable design refers to the development of socially acceptable products that carry out their functions and generate profit to the stakeholders, while using minimum material and power resources, as well as generating minimum scrap.

The success of sustainable design depends on decisions that are usually made in a circumstance of scarce knowledge and sizeable uncertainty.

2 MODELS OF SUSTAINABILITY

Any book of economy describes the basic economic model as a permanent cycle between the enterprises, or production organizations, and the households, or more generally the population, as shown in Figure 2. The enterprises pay wages to the population that provide the working force to the enterprises; on the other hand, households buy products for which they pay to the enterprises and these ones provide the households the required goods or services.

It is out of the context of this paper to discuss the role of the families and the individuals in the society and we will use the term "population" to aggregate the concepts of individual and household. Among other meanings, the term "society" may express the different relationships between the population and the public and private production entities, which will be here jointly designated as "enterprises". Some anthropologists define "society" as a group of individuals with common aspirations, possibly forming a whole country. Others, however, say that countries have populations and not societies. Lady Thatcher, a renowned follower of this current of opinion, once said about the obligations of the government to the people, "there is no such thing as society. There are individual men and women, and there are families."

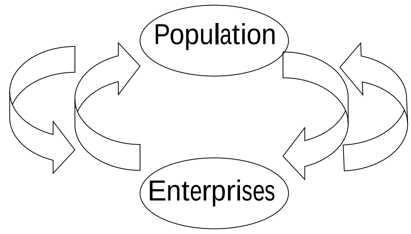

Figure 2. Economic cycles between population and enterprises.

The basic social interactions depicted by arrows in Figure 2 are difficult to address, as there are multiple feedback loops that tend to increase in number with the advancement of the economy. Models of equilibrium between production and consumption started in the 19th century with Jean-Baptiste Say. Keynes published in 1936, in the end of the Great Depression, The General Theory of Employment, Interest and Money, which although assuming states of equilibrium in the economy, argued about the need of government interventions in periods of recession. Processes in economy are in reality dynamic, making it possible to define feedbacks along the time between the major entities of an industry [Forrester, 1961-2013]. The dynamics of the US economy was well explained by Forrester using the System Dynamics National Model, and since the 60s there has been a continuous effort to simulate the dynamic behaviour of the society. As a result, it is now possible to address the activities of organizations and enterprises, clusters, and even the human behaviour and decision-making, taking into account instability and oscillations [Sterman, 2000].

Alongside with the known growing mechanisms of enterprises and population, there are loops of energy and materials that affect the economy in the long term. The increase in the productivity of the enterprises allows lowering the unit price of the goods they produce while increasing the wages of their workforce. This stimulates the population to invest and to spend more money in goods, yielding to a positive result to the enterprises. Yet, this cycle is depleting the reserves of raw materials as well as changing the climate.

This model, which has been considered sound since the industrial revolution, gives a negligible importance to the environment as it takes the geosphere as an infinite source of materials and energy, as well as an infinite sink for the waste that results from their use. The model is no longer acceptable, as the environment is proving to have a decisive role in the current and in the future economy.

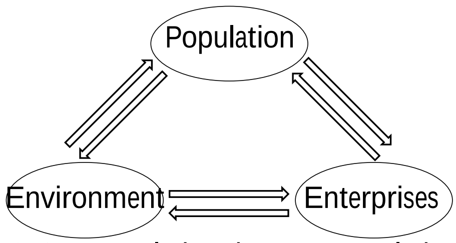

Figure 3. Current relations between population, enterprises and environment

Figure 3 depicts the present day relations between the population, the enterprises and the environment, showing the cycles between any pair of entities by pairs of arrows. Most models of sustainability aim at solving important but specific problems, focussing on one of the aforesaid relations. The most common ones centre their attention on the relation between environment and population, or in a corporate viewpoint, between enterprises and environment.

Other approaches to sustainability than the triple bottom-line are the natural step, the ecological footprint and the 50 years time scale of Graedel and Klee. All these methods focus on the scarcity of natural resources, including energy, as the present rate of consumption is impossible to sustain in a large timescale or at a global geographical scale.

Assuming a human centred approach, the hierarchy of values that should be used to choose the actions leading to sustainability depends firstly on the consequences they cause to the mankind and secondly on their impact on the environment. Thereafter, the highest level that require immediate action is the one “that, if continued at the current or forecasted rate, endanger the survival of humans” [Marshall and Toffel, 2005]. Human actions depend, or will depend, on the limits that the original functions of the ecosystem diverge from an acceptable range when subjected to a disturbance, as well as according to the extent the ecosystem is able to regain the original functionality in an acceptable time frame.

Some well-known methodologies, such as the EIA (environmental impact assessment) and the SEA (strategic environmental assessment), are used to solve problems of people in areas affected by environmental strains. EIA applies to the context of individual projects or events and aims at identifying environmental problems that should be mitigated by appropriate decisions and the corresponding implementation processes. On the other hand, SEA seeks the integration of community plans to the related geographical context *i.e.*, local, regional, national or international.

Moreover, enterprises are paying attention to the decisions related to the environment, due the economic impact they may have. Several studies carried out in the context of enterprises have shown that internal environmental programs impact the social and the economic areas. However, when sustainability programs are focussed on social issues, usually there is an impact in the environmental conscience of the populations, but with small financial benefits [Gimenez et al., 2012].

As expected, any sustainable program should have in mind the sustainability issue from the early stages of the design process. When one considers different alternatives, it is important to take into account the total amount of energy and raw materials that should be employed in the whole life cycle of the design object. It is also necessary to check and take into account the resulting economic and environmental impacts of our decisions [Eddy et al., 2013].

With larger productions, one could standardize and specialize labour and production, so that producing the same amount of goods would require less people and capital. In order to foster this cycle, enterprises use several marketing and innovation techniques, so that they can reach more customers at increasingly lower prices. As a result, the economy trend is to dematerialize through continuous renovation and remanufacturing, reusing and recycling, consuming less raw materials while focussing on final services [Ayres and Bergh, 2005].

The strategies for sustainability of the energy-intensive industries also have a strong economic impact, as their most common behaviours are the increasing utilization of scrap and the recovery of energy. Currently, industries are searching for alternative fuels and raw materials, due to the increasing price and scarcity of the traditional ones. Most likely, industry will soon develop symbiotic actions between different companies and between companies and customers in order to reduce waste and cost.

More and more there is a claim for global models leading to new economic and social models that require a smaller contribution from the environment.

During the 70s, it became very clear the detrimental consequences that a damaged environment could cause to people. In the 90s the society set new regulations about the environment. As it is more and more evident, the economy impacts the society and the environmental preservation impacts the economy [Schönsleben et al., 2010].

A recent global model proposed by Tim Jackson [Jackson, p. 228, 2009] includes a picture similar to the one of Figure 3, and argues that it is possible to achieve sustainability increasing the eco-entrepreneurship. Accordingly, some eco-enterprises will focus on social activities while others will try to increase the productivity of raw materials. In such relations, the participation of persons in the eco-enterprises will raise the human abilities. Hence, any high level action towards sustainability should have in mind that sustainable development leads to coupled designs with various economic and environmental loops that affect the population.

3 SOME NOTES ON AXIOMATIC DESIGN

Axiomatic Design (AD) aims at finding the best design solution for a certain set of functional requirements (FR) by using the most appropriate design parameters (DP). According to AD, every design solution can be represented by a design equation of the type $\{FR\}=[A]\{DP\}$, where $[A]$ is the design matrix. The shape of the design matrix allows perceiving “good” and “poor” design solutions. Ideally, design solutions might be uncoupled, or at least decoupled. Therefore, the main goal of AD is to help choosing the best design from a set of alternative solutions.

Anyway, sometimes it is not possible to change the design solution due to intrinsic relations, as it occurs when addressing the problem of sustainability.

Therefore, a new line of research is to establish from the set of corollaries and theorems of AD [Suh, 1990] the way to handle with coupled designs. The following list of guidelines, derived from the stated corollaries and theorems, summarizes the actions to employ in order to help solving a coupled design.

G1: Try to change the design in order to get a decoupled or an uncoupled design (from Corollary 1 of AD);

G2: Try to use the largest possible acceptable range for the FRs, so that the cross interference of DPs is as low as possible (from Corollary 6 of AD);

G3: Try freezing some DPs by assuming acceptable values for them [Fradinho, 2013];

G4: If the extant coupling depends on some interactions between DPs and FRs, try to store or deliver the result of such interaction into sinks or sources (from Theorem 24 of AD);

G5: Use a redundant solution in order to get rid of the extant couplings (from Theorem R1 of Coelho et al.) [Coelho et al., 2012]

In the following sections, Guidelines 4 and 5 will be used to solve the coupled designs that characterize the sustainable solutions.

4 THE PEOPLE AND PRODUCTION MODEL

From more than a century ago, the damages that were caused by the industry to the environment did not take part on the general development equation. The main requirements of those times were to ensure the production of agricultural and industrial goods in order to satisfy the needs of the population.

The Western paradigm of the 20th century has been to provide welfare to the population, based on the creation of a strong public service, and on development warranted by public and private enterprises. During all the 20th century century the paradigm remained the same, even though the increasing needs of the population and the overwhelming evolution of the means of production.

In a AD point of view, one may define consistently the FRs and DPs [Thompson, 2013] as follows:

FR_1: Provide welfare to the population;

FR_2: Produce / provide goods and services;:

DP_1: Public service;

DP_2: Enterprises.

Public service is a set of facilities provided by the government through the public sector or through non-governmental entities financed by the government. Beside security, military and law administration, the Western public services also provide free healthcare and education to a large extent. Moreover, the public services may include facilities that depend on the city council, as for example gas, electricity or water supply and a myriad of other commodities. Some of those commodities are enterprises directly dependent of the public services, other are private organizations that report to regulators.

Enterprises are typically business economic bodies, aiming at producing tradable goods and services, in order to get a profit. Furthermore, enterprises produce wealth to the country or community providing welfare to the population, by paying wages, taxes or providing other direct means of welfare.

The aforementioned relationships may have an AD translation in the following design equation:

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & X \\ X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix} \quad (1)$$

The design matrix of Equation 1 shows that at the highest design level the design equation for the society is a coupled design. One may imagine how difficult it may be to tune such a coupled design at the lower levels of the design decomposition! Moreover, tuning all the elements of such an equation with all the cycles and feedbacks defined trough governmental policies would give rise to dictatorships.

The solution implemented in the Western countries, at least since the World War II, is to alternate the government action along the time changing the relative importance of the enterprises and of the public services. Therefore, according to AD, this is a way of solving the coupling by changing the design model into an uncoupled or a decoupled design, depending on the social conditions.

As a consequence, it is important to notice that:

- The following design equations show a governance attitude, and not the existent relational flows that model the behaviour of the society;
- The DPs vary according to the approach. In other words, DP_1 and DP_2 are formed by different sets of entities depending on the approach.

Moreover, the range of each FR, especially in what concerns to the welfare of the populations, may vary along the time, making an acceptable range to be unacceptable years later. Especially in periods of austerity, persons may accept a wider range of variation of the FRs, recovering latter to the initial state, a feature that is called “resiliency”.

If the initial situation is attainable anymore, persons may adjust to the new situation in a process called “adaptability”.

In what concerns to naming the approaches, we will call a rightist approach to the one that focus on the role of the enterprises to produce goods and services and a leftist approach to the one that gives a more important role to the public services. Thus, under the rightist trend, most of the economic bodies responsible for the services and other commodities are enterprises.

In this system, the role of the public services is providing welfare to the population without interfering on wages and other benefits that enterprises may give to their employees. Even though, different rightist approaches may locate health care, education and even housing under the public services. Anyway, one can believe that the market establishes the relations between welfare and enterprises, with small government interference. On the other hand, the public services have a small direct impact on the production, although may influence it deeply through contracted work with enterprises.

Equation 2 shows the design equation for such a kind of governance denotes an uncoupled design.

As for a better readability, one uses a blank element in the matrix instead of a small x to express low dependency between DPs and FRs. Thus, all blank elements in the following equation, as well as in all further equations, express in reality week governance attitudes.

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & \\ & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix} \tag{2}$$

If the system cannot fulfil FR_1, one or more buffers may be added in order to provide the necessary welfare to the population, as expressed in Equation 3.

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & & X \\ & X & \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ B \end{Bmatrix} \tag{3}$$

These buffers may be inter-social help, usage of domestic savings, loans from the banks, or increasing the deficit at the country size. These solutions allow keeping a resilient FR_1, avoiding the need for variation of its range to some extent.

Notice that using the buffer turned the design into a redundant one, which remains uncoupled.

On the other hand, the leftist approach gives a larger role to the public services, which include sectors with a production objective. As such, DP_1 may now include most of the commodities and other state owned enterprises, which give a stronger help in the fulfilment of FR_1.

In this system, after defining the public sector, the enterprises play the role of tuning the system in order to achieve the production objective.

Equation 4 represents a decoupled design, indicating that DP_1, the public services, might be the first to set followed by the setting of the enterprises (DP_2).

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & \\ X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix} \tag{4}$$

Some approaches to this societal model may force the enterprises to play an important social role, causing the system to turn into a coupled design.

It is possible to help fulfilling FR1 by using buffer systems similar to the ones described in Equation 3, as shown in Equation 5.

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & & X \\ X & X & \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ B \end{Bmatrix} \tag{5}$$

The buffer in Equation 5 may be any one of the aforementioned, but historically the public deficit is the most typical in the European Union (EU) zone. This has been a very successful policy that allowed the system to be resilient, until the deficit turned out to be a problem for most countries.

In reality, after the World War II, Europe felt a great development being able to provide a progressive welfare to their populations. This welfare allowed the populations to easily adapt to better conditions of living. Since the 90s, the need to maintain the welfare regarding the smaller increase of production, made the EU to solve Equation 1 by introducing borrowed money as a buffer in the equation. This new DP, DP_D, helps solving Equation 1 turning the design into a decoupled redundant design, as shown in Equation 6.

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & X & X \\ X & X & \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_D \end{Bmatrix} \tag{6}$$

Whatever will be the performance of the public services and enterprises, it is possible to fulfil the requirement of providing welfare to the population. This new design had as side effect to allow smoothing the differences between rightist or leftist approaches to the society. However, it had the cost of increasing the public deficit to more than 90% of the GDP of the EU-18 countries [Eurostat Compact Guides]. Because of this, a new era is now coming to the Euro zone that makes the governments to ask the populations to adapt to lower levels of welfare.

Making the argument of a rightist or leftist policy dependent of the social and economic context maybe is not the best solution for Equation 1. The governments need to balance between Equation 2 and Equation 4, or most probably between Equation 3 and 5, changing from one to the other whenever the corresponding buffers are no longer able to fulfil the expected FR_1.

5 THE ENVIRONMENT REQUIREMENT

A new requirement is arising nowadays, FR_3, because one needs to limit the impact of the human activities in the environment. The need of this new FR in the design equation of the society is becoming increasingly recognized by the population and governments.

The impact of the environment on the living of individuals and on the economy is no longer an academic hypothesis claimed by scientists, but turns into reality. Katrina hurricane (2005) in Louisiana, USA; the 2009 bushfires in Victoria, Australia; or the floods in Rio Grande do Sul, Brazil, in 2013, all are examples of how the nature may have a decisive importance in the welfare of populations and on the production needs.

Another example, the Fukushima disaster, illustrates very well the various dependencies between people, economy and the environment: starting with and earthquake, the nuclear power plant of Fukushima had electrical and mechanical interactions that caused the leakage of radioactive material [Nakao et al., 2013]. Next, this leakage caused a new environment problem that affected a large city area where it is no longer possible to live. In the end, the Fukushima power station was forced to close.

From the aforesaid, societies realized that the need of living in a healthy environment became a key asset of the modern life. Therefore, the new FR_3 might state as:

"reduce the environmental impact of human activities";

and the corresponding DP_3 as:

"environment-friendly technologies."

In the 70s, people start acquiring an environment consciousness that forced governments to issue regulations on the polluting activities of the economy. Usually, these regulations epitomize restrictions on enterprises or people activities, in order to allow maintaining the general society Equation 1. Examples of the former are the imposition of reductions on the usage of old cars in certain areas of a city; incentives for changing from a more polluting fuel, such as coal, to a less polluting one, such as natural gas; or stressing for use a more efficient equipment corresponding to the desired level of emissions.

Assuming that there is a solution for Equation 1 apart from the environmental restrictions, setting a solution inside the boundaries imposed by the environment may be possible by adding a new DP, DP_R. The goal of DP_R is to remove the pollutants that are emitted above a prescribed level that the existent systems needed to produce in order to fulfil the production of the goods and services. Therefore, the design turns into a decoupled redundant design (Equation 7).

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} X & X & \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_R \end{Bmatrix} \tag{7}$$

Examples of DP_R at a global scale could be the carbon sequestration in saline caves or in aging oil fields, the bio-energy with carbon capture and storage, and the technologies for carbon dioxide removal. At a smaller scale, the smoke filters installed at the thermoelectric power plants, the systems for industrial water treatment and the automobile catalytic converters are examples of systems that allow reducing the impact on the environment without changing the exiting producing systems.

The nowadays challenge is to change from a driven system with environmental restrictions to a new society that incorporates the environmental as a new functional requirement.

5.1 THE NEW DESIGN EQUATION

The society challenge of the present and of the next generations is to achieve a solution for the coupled design shown in Equation 8.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & X & X \\ X & X & X \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{8}$$

The reader might be aware of how difficult it has been to govern a country which design equation at the highest level is a (2x2) as stated by Equation 1. Now, imagine how hard it will be the governance expressed by the new equation!

Notice that according to the AD's Theorem 5, adding a new FR to the design equation does not mean that solving the problem is just a matter of adding an extra DP. In fact, it is necessary to look for a complete new design and check in what extent the new added DP interfere with the existent FRs.

As it was shown at the introduction to this paper, the fourth principle of the Rio's declaration expresses a similar idea as the one of Theorem 5, making the introduction of the environment requirement a huge task.

Many simplifications of Equation 8 are possible according to the policy followed by the governments, which will depend on the extent of the environment degradation, the production volume and the expected welfare of the populations. Anyway, Equation 8 generally represents a more complex design than Equation 1.

The next sections of the paper will focus on some possible approaches to this problem, without having the leaning to decide what is the right solution.

5.2 A PROSPERITY PARADIGM

To help solving Equation 8, one may assume that at a Western working mode of the new economy, and out of any catastrophic situation, the relation between the environment-friendly technologies, DP_3, and the welfare of the population, FR_1, has a weak relation.

On the other hand, the "public services", DP_1, have a greater or lesser influence on the reduction of the environmental impact of the human activities, FR_3, depending on the economic bodies it includes.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & X & \\ X & X & X \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{9}$$

Equation 9 shows that the system is a coupled design. However, Equation 10 better expresses the situation of Equation 9, because it includes the benefits of the environmental buffer, B_E.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & X & & \\ X & X & X & \\ X & X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ B_E \end{Bmatrix} \tag{10}$$

Equation 10 represents a decoupled redundant design, which makes a less attentive reader to presume that it has an easy solution. Nonetheless, the environmental buffer (B_E) just gives some time to help solving the real problem.

To solve Equation 9, a government might choose to reinforce some interactions, while decreasing the importance of others. The choosing of the interactions to decrease is a policy decision depending on ideology, the society situation and the economic resources.

Thus, a government might choose a greater or a lesser influence of the enterprises in providing the welfare to the population and to choose the role of the environmental-friendly technologies (eco-tech).

Now, let us suppose that the choice is a rightist policy focused on the role of enterprises, which pay a special attention to the eco-technologies. In this instance, the welfare of the populations depends on the public services, while the enterprises aim at producing the necessary tradable goods. Moreover, one may suppose that the economic bodies of the public services have a weak interference in the environment. Additionally, the eco-techs may have an important role in the production of goods and services.

Equation 11 expresses the picture of this societal approach, which the authors call a rightist-eco-tech policy for sustainability.

This equation shows a decoupled design, and allows choosing an appropriate sequence to tune the equation in order to fulfil the FRs. In this design, the eco-tech (DP_3) is the first DP to adjust. Moreover, the eco-DP also has a role to play in the production of goods and services. Subsequently, the government will choose independently the other two parameters, DP_2 and DP_1, respectively the enterprises and the public services.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & & \\ & X & X \\ & & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{11}$$

One can read Equation 11 in two different ways, a theoretical and a pragmatic one. In the former the eco-technologies need to be developed to solve the environmental problem and foster for eco solutions in the production field; in the latter one uses directly the existent technologies trying to have a similar approach.

Equation 12 shows a rightist-enterprise driven solution. The sequence for tuning the DPs begins with choosing the enterprises, and afterwards the public services or the eco-technologies.

In this approach, the government gives priority to the role of the enterprises, because DP_2 have not only a production role but also an environmental one. After choosing DP_2, the public service and the eco-technologies are mutually independent.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & & \\ & X & \\ & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{12}$$

Coming back to the leftist approach already shown on Equation 4, two alike but different approaches emerge, a leftist-eco-tech economy and a leftist enterprise-driven one. In both the leftist solutions, there is an important role of the economic bodies of the public services over the environment.

Equation 13 shows the leftist-eco-tech solution, which is a decoupled design.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & & \\ X & X & X \\ X & & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{13}$$

In this approach, a government should first tune the public services, noticing the interference they have on the environment and on the production. Next, depending on the impact on the environment, it chooses the usage of the eco-technologies, which play the role of fostering the production requirement. At last, the role of the enterprises is to tune the remaining production of tradable goods in order to achieve the prescribed FR_2.

Finally, Equation 14 shows the leftist-enterprise driven approach, which is again a decoupled design. The setting sequence of the DPs in this system starts by fulfilling the needs of the population, followed by tuning the role of the enterprises and ends by choosing the eco-technologies.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & & \\ X & X & \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \tag{14}$$

Although it is difficult to give detailed examples of societies where Equations 11 to 14 hold, it is nevertheless possible to identify examples of enterprise-driven and eco-technological approaches to the environment.

LEED (Leadership in Energy and Environmental Design) is an example of the former, for it may give to the buildings owners an endorsement if they are environmental responsible and use resources efficiently. This program is enterprise-driven, but not compulsory, and aims at quantifying the design, construction, operation, and maintenance quality of a building all along its life cycle. It uses a system of ratings from the very early stage of the design, allowing different ways for attaining the qualification.

ISO 14001 is another enterprise-driven approach to sustainability. It helps creating an environmental management system that integrates the processes and the procedures of the enterprises to protect the environment. As a result, one could stress the high efficiency in energy and material usage that the large chemical and automotive enterprises have experienced in the last decades.

On the other hand, the eco-technology approaches to sustainability largely interfere in the society, and are usually developed or applied by governments or related institutions. As for example, the focus of the Portuguese government in the wind energy made it possible to install in the last decade wind turbines with a total power of about 4,500 MW. This currently represents about 20% of the installed electric power, and about 50% of the used renewable sources.

In this example, the choice was well known technology, so that it was just necessary to develop the application. Other potential approach could be to develop the technology from the very beginning, as it happened with the OLEV (Online Electrical Vehicle). OLEV was a brainchild of Professor Suh during his leadership of KAIST, and can significantly reduce the energy costs of public transportation.

Currently, EU is making an important effort in the development new renewable technologies from the outset, by making a huge investment in research and development until 2020.

5.3 Other Prosperity Paradigms

Other prosperity paradigms may arise from Equation 9, or from any of the derived societal descriptions, by introducing new DPs to turn them into redundant designs. Equation 15 shows the introduction of DP_D, the public deficit, and environmental buffer B_E.

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} X & X & & & \\ X & X & X & & \\ X & X & X & X & X \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_D \\ B_E \end{Bmatrix} \tag{15}$$

The public deficit invested on the accomplishment of the environment requirement, along with the natural ecologic buffer may give the society a smooth transition to a cleaner economy. In order to do it, it is necessary a strong investment in new technologies, changing the buildings and the design of the cities, as well as advancing in the research and development of new procedures and technologies.

6 DISCUSSION AND CONCLUSIONS

This paper briefly describes some current models of governance and points out some possible solutions to help solving the new sustainability problem. The big challenge for the present and future generations is the integration of environmental requirements in the societal equation.

The current models of governance need to fulfil two FRs, namely to "provide welfare to the population" and to "produce/provide goods and services". This may lead to a greater or a lesser interference of the government.

In the case of a lesser interference, the design is uncoupled and we called it a rightist approach; in the leftist approach, there are more relations defined by the government, making it a decoupled design.

Adding the environmental FR, "to reduce the environmental impact of the human activities", one forces the governments to look for a complete new design for the society. According to AD, the main conclusion is that the sustainable society will be more complex than the current one.

Both the rightist and the leftist models may focus on enterprises or on the eco-technologies, giving rise to the four possible environmental models that are discussed in this paper. All these models are decoupled, so that the tuning of the DPs must follow a definite sequence.

Therefore, as a second conclusion, the governments might be aware that there is an appropriate sequence to tune the DPs in the sustainable design equation.

Moreover, to change the society to a more environmental focussed one, it will be necessary huge investments to introduce new technologies that start at a domestic scale and end at least at a country scale.

The current deficit of EU might make hard to address these kinds of investments. Anyway, EU is making a big effort toward the search and implementation of new environmental technologies through the Horizon 2020 Program.

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