A Multi-criteria Methodology for the Identification & Ranking of Critical Infrastructures

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Abstract

The increasing incidence of natural or terrorist events in recent decades, especially after the September 11 (2001) in United States, have alerted the global society for the need to study and develop models to identify and rank those assets ("critical infrastructures") that its destruction or disruption consequences may put in danger the well-being of a state. In order to protect these critical infrastructures and the social and economical well-being, many countries and international organizations are studying and working this problematic. In two available models, from Canada (multi-criteria based model) and Portugal (mono-criteria based model), were found conceptual inconsistencies that can directly affect their purpose and results and, therefore, the social and economical well-being of these nations. Based on multi-criteria based model, this study proposes a multi-criteria approach to correct the problems presented in the Canadian model, using their original assumptions, in order to restructure and rebuild it, according to the multi-criteria decision analysis tool - MACBETH.

Keywords: critical infrastructure, multi-criteria model, MACBETH, identification of critical infrastructures, interdependency.

Introduction

The increasing number of catastrophic events and their implications, over the last decade, brought to the international community a new challenge concerning the critical infrastructures protection (CIP), that is, those vital assets that, in case of destruction or disruption, may put in danger the well-being of a nation. Currently, there are international organizations (such as NATO and EU) and countries that are working in progress in developing and studying an analytical model to identify and rank those vital infrastructures. In two nations, Canada and Portugal, the available models were, respectively, implemented and tested (still in study) but, after a deep description and analysis, both suffer from structural problems that may affect their results and the well-being of these nations.

Thus, it is important to study and analyze what were their analytical processes and what could be a good solution to solve these problems, according to the multi-criteria decision analysis subject, best practices and tools. So, the aim of this article is to study the CI (Critical Infrastructure) models and bring a new methodological approach (*MACBETH - Measuring Attractiveness by a Categorical Based Evaluation Technique*), based on the multi-criteria decision analysis subject, to the problematic in question. This article is structured as follows. In the first section is presented the theoretical framework that supports this study, focusing on the CI concept, historical context and their need of protection. The second part of this article describes and analyses the Portuguese and Canadian CI Models, concerning the value model structure and methodological problems. The third part is presented a new methodology. The last section presents the final considerations.

1. Critical Infrastructure Protection

The Concept, the historical context and Need of Protection

1.1. What is a CI?

The definition of CI is not universal and formal. According to Gordon *and* Dion (2008:4), in spite of some similarities, the definition of CI differs from each country, because each one has it on specifications and socio-cultural characteristics. Moteff *and* Parfomak (2003) argue also that the definition of CI changed over the time, due to the world and society evolution. The author states that "*Critical infrastructures were originally considered to be those whose prolonged disruptions could cause significant military and economic dislocation. Critical infrastructures now include national monuments (e.g. Washington Monument), where an attack might cause a large loss of life or adversely affect the nation's morale. They also include the chemical industry. While there may be some debate about why the chemical industry was not on earlier lists that considered only military and economic security, it seems to be included now primarily because individual chemical plants could be sources of materials that could be used for a weapon of mass destruction, or whose operations could be disrupted in a way that would significantly threaten the safety of surrounding communities.*" Moteff *et al.* (2003:2)

The Gordon *and* Dion (2008:4) study for the OCDE presents six definitions of CI, including the Canadian concept of CI: *"Canada's critical infrastructure consists of those physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of Canadians or the effective functioning of governments in Canada."* The Portuguese definition states that a *"Critical Infrastructure is a facility or an element whose destruction, disruption or misuse would directly or indirectly affect permanently or for a large period of time: the functioning of the sector it belongs to or of other sectors, the continuity of government, national security, collective values and symbols, thus seriously affecting the well being of the population. Its criticality will be evaluated by the impact caused by its destruction, disruption or misuse in the above-mentioned criteria"* (Mota de Sá, 2005).

1.2. Historical Context

According to Pais *and* Mota de Sá (2005), since the beginning of the "90 that some countries and international organizations (NATO and UN) are working in progress in their studies about CI protection (CIP) by the fact that this is a crucial matter for the economical and social development and stability of nations. The study about CI in EU started in 2005 with the elaboration of a common strategy for CIP through the creation of the "Critical Infrastructure Protection European Plan" (EPCIP), primarily to fight the terrorist events. Later on, the EU adopted the EPCIP in order to promote further support measures for the CIP, to increase the level of protection and to help to reduce the vulnerabilities, threats and risks these assets in European zone (CEU, 2008).

Concerning the two countries in study, in Portugal, the problematic of CIP started in 2003 with a creation of the CNPCE, the working group in charge of study and develops the CIP project - PNPIC (Pais *and* Mota de Sá, 2005). According to the same source, in 2004, this project has 3 stages; 1st) creation of a conceptual CI definition; 2nd) development of a CI identification and priorization model; 3th) creation of a geographical database to aggregated to the CI model. Pais *et al.* (2007) state that the results, to 12000 evaluated assets, were the followed; i) more than 65% National CI can be seriously affected by a seismic event or related; ii) more than 300 have a potential to be affected through terrorist events; iii) some of these CI are located in high risk zones such as burning areas or related; iv) extreme need of implementing security policies measures. According to Marcelino (2011), in 2007, was made a provisional assessment by CNPCE, where 60% of these facilities were considered "vulnerable" to terrorism (analyzed only 89 critical facilities, not all sectors of activity). An updated list, in 2011, made by the same organism, set 270 of evaluated Critical Infrastructure (missing only those relating to the financial sector), it appears that, in relation to seismic risk, 60% of installations are in areas high risk (55.1% belong to the NSS).In Canada, the CIP program (NCIPS), presented in April 2004, have two objectives; to reduce vulnerabilities, threats and risk, and improve response and recovery efforts and timing (OCIPEP, 2004a). On contrary to the Portuguese case, the Canadian working group didn't provide any results.

1.3. CI: Need and Challenges for its Protection

According to Pais *and* Mota de Sá (2005) there are 3 prime reasons to be considered the protection of these types of assets: i) the high level of investment in economic development contrasting to the low level of security investment; ii) the increasing incidence, in number and dimension, of natural or man-made events; iii) the continuous appearance of new treats such as the transnational terrorism. Apostolakis *and* Lemon (2005) consider the extreme importance to protect this kind of infrastructures, from terrorist and natural events, due to their complexity and interdependencies. Fritzon *et al.* (2007), O'Rourke (2007), Moteff *and* Parfomak (2003) and Gordon *and* Dion (2008) consider even the interdependency phenomenon and the cascading effect as the major challenge to be considered in CIP problem. Regarding this, Pais *et al.* (2007) argue that the lack of clear and strong knowledge and the difficulty in measuring their impacts are important challenge to be worked on into this problematic of CIP. On the other side, Kunreuther *and* Heal (2002) state the interdependent security (security investment equilibrium between the public and the private sector and their incentives to invest in security) as an important issue to be considered in latter stage on this problem. Regarding the two countries models in analysis, Portugal and Canada identify the cascading effect and interdependency as the most important and problematic issues to be accomplished. Both CI models are presented and analyzed in the next section.

2. Portuguese and Canadian CI Models

Description and Analysis

2.1. Portuguese Model

The Portuguese methodology is based on a study developed by Mota de Sá (2005), entitled "*Ranking Critical Infrastructures – The Portuguese Methodology*". The paper announces that the main objective of a nation consists in the guarantee of the well-being of a nation, supported by four indispensable dimensions; Security, Governance, Economy and Values and Symbols.

The Portuguese CI model was developed on basis of a robustness and functional methodology, reflected on a mathematical modulation that includes the construction of an algorithm (ADPA algorithm) that allows the evaluation of the cascading effects and interdependencies between sectors and its infrastructures. The ADPA algorithm (Dijkstra algorithm modification) of developed in order to measure the infrastructure's potential in expanding its functional dysfunctions, through subjective probabilities asked to the participants with the supported by MABETH to convert those qualitative performance in quantitative values (Pais *et al.*, 2007). Through this, the next step involves the creation of a Dependence Matrix that represents the Probability of each Node in a Complex System of Interconnected or Interdependent Sub-Systems (or Nodes) of being Seriously Disrupted, Directly or Indirectly by Propagation Effects due to the Disruption of another Node (Mota de Sá, 2005).

$$P_{i,j} = P\begin{pmatrix} Sector\ "i"\ be\ seriously\ affected \\ if\ Sector\ "j"\ was\ disrupted \end{pmatrix}$$

$$P_{i,j} = P("i" = Fail|"j" = Fail)$$

$$P_{i,j} = P("i" = Fail) \times P("j" = Fail)$$

$$P("i" = Fail)$$

$$Probability\ of\ Sector\ "i"\ be\ seriously\ damaged$$

$$P("j" = Fail)$$

$$Probability\ of\ Sector\ "j"\ be\ significantly\ disrupted$$

Thus, an infrastructure is more critical (vital) than others if presents a high evidence of vulnerability that may affect significantly the well-being of a State. The reason to use probabilities consists in the fact that the critical concept includes an open wide of variables (risk, vulnerabilities, threats and consequences) impossible to accurate with precision (Mota de Sá, 2005).

2.2. Canadian Model

The development of the Canadian CI model is presented in OCIPEP (2004b) document. The aims of the Canadian model consists in providing *"a national framework for action and to build a resilient national critical infrastructure"* (OCIPEP, 2004a:4) and to capture the critical level of the infrastructure, based on a *score* methodology. The methodology applied and developed by the Canadian working group consists in a mathematical formula in which an infrastructure "I" is classified as "CI" based on the obtained value ***Ci***, that is, the sum of impacts ***Vi,j*** of each assessment criteria (***j=1,…,N***) described below (**Figure 1**);

$$C_i = \sum_{j=1}^{N} V_{i,j}$$

The group of criteria selected to evaluate the infrastructures, in order to capture their level of impact in the well-being of a nation (in specific case, the Canadian Nation) is composed by six fundamental points of view; **Concentration of people and assets (CPA)**, **Economy Impact (EI)**, **Critical infrastructure sector (CISI)**, **Interdependency (ITI)**, **Service Delivery (SI)** and **Public Confidence (PCI)** (OCIPEP, 2004b). The final part of the presents some improvements that can be done in order to accurate and precise its results. The Canadian CI model states that *"if an asset is not critical, as it has a negligible consequence, a score of "0" should be used. Estimates can be further refined by having experts examining other variables such as potential impact on people, the environment, and confidence in government, etc, either through models or through Business Impact Assessment Studies"* (OCIPEP, 2004b).

CI Priority Assessment Screening Model - Consequence Criteria				
Impact Factor	**Severe**	**High**	**Medium**	**Low**
Score	15	5	3	1
Concentration of People and Assets Impact (potential for catastrophic effects)	Greater than 10,000 people	Between 1,000 and 10,000 people	Between 100 and 1000 people	Less than 100 people
Economic Impact / Direct cost of restoration including critical information and information technology (service relies on or asset contains critical information and I.T.)	Direct damage and restoration > $1 billion	Direct damage and restoration $100 million to $1 billion	Direct damage and restoration $10 to $100 million	Direct damage and restoration under $10 million
Critical Infrastructure Sector Impact (service or asset relates to a critical infrastructure sector)	Sector may shut down or international	National	Provincial or regional	Local
Interdependency Impact	Debilitating impact on other sectors	Significant impact or disruption of other sectors	Moderate impact on important missions of other sectors	Minor impact on important missions of other sectors
Service Impact -- Potential for immediate significant impacts	High cross-sectoral cost, recovery time longer than one year (years)	High cost, long recovery time (months -- year)	Medium cost, significant recovery time (days -- weeks)	Low cost, brief recovery time (hours -- days)
Public Confidence Impact	High national risk & ability to control in doubt	Public perceives high national risk & low ability to control risk	Public perceives moderate risk & moderate ability to control risk	Public perceives low risk & high ability to control risk

Figure 1: Canadian CI Model (OCIPEP, 2004b).

The next section presents the analysis of both CI models (Portugal and Canada), that is, the problems that each one of them have in their model's structure as well as in their formulation (concepts, suitability to the matter in question, purpose and assumptions).

2.3. CI Models: Detected Problems

As it was mentioned in the beginning of this article, both models suffer from inconsistencies and structure problems that influence their results (**Figure 2**). In the Portuguese definition, a CI is defined as an active/infrastructure that, in case of destruction or disruption, can affect the "well-being" of the nation. However, the Portuguese definition does not fit with the CI model because it is not clear what the impacts are and because they are not present on it. The second identified problem is the absence of such impacts in the methodology. The only criteria followed for the measurement of criticality is the level of interdependence ("indicator of interdependence" through the conditional probabilities product between sectors). But this result does not include neither the number nor the impact this may have. Because of these detected problems the Portuguese model also presents an inconsistency between the definition of IC and its purpose, which also has consequences in the model's structure. Bana e Costa and Beinat (2005) argues that the difficulty of decision making depends

Identified Problems in both Portuguese and Canadian CI Models		
Problems	Portugal	Canada
Suitability between CI definition and the model	Inconsistent	
Weighting of the Assessment Criteria	Absence of the identified criteria in the model's evaluation	Inconsistency in the criteria's definition
Theoretical Support	Lack of theoretical support due to the development of untested analytical processes	
Structuring Errors	Absence of criteria and impact descriptors definition	Incorrect value function and criteria's construction
Suitability to the CI Problem	Inconsistent due to the errors observed in the model's development	

Figure 2: Identified Problems in both Portuguese and Canadian CI Models

on the complexity of the problem and on the uncertainty of decision-makers.

The Canadian model follows a multi-criteria methodology to six criteria. Nevertheless, there's a lack of weights in the assessment model. For example, the weight of the **Concentration of people and assets** criteria is equal to the weight of the **Interdependence impact** criteria. Another methodological problem is the adoption of quantitative techniques without a theoretical basis - lack of theoretical foundation. The impact score (1, 3, 5, 15) are also problematic because it's not clear how they were achieved in terms of value function construction. The absence of weighting coefficients in the criteria's group is another detected problem (Bana e Costa *and* Beinat, 2005). The problem lies in assessing the relative importance of one objective against another. When this happens, it leads to a poor decision in that it is produced misinformation about values, without which the scenarios are taken into account (Keeney, 1994). Another identified problem is that all six criteria are linked, directly or indirectly, to each other. According to Bana e Costa and Beinat (2005), the group of assessment criteria should be comprehensive, non-redundant, concise and consensual. Each should be described in a clear (unambiguous), and preferably independent to each other. So, in order to overcome these difficulties, this CI model will be used as case study on the basis of a theoretical methodology approach in their correcting and structuring process, as it is present in the next section.

3. Case Study: Canadian Model with MACBETH approach

General Overview, Structuring and Evaluation

The aim of this study is to propose a methodological approach (MACBETH) to the CI identification and ranking problem, applied to the Canadian CI model, in order to correct its problems identified in the previous section. The proposed methodological approach takes into account the existence of a multi-criteria problem, with complex objectives, uncertainties, risks and different perspectives, so that the usage of multi-criteria decision analysis methods fits the matter in question. The methodology that is going to be used in the corrected Canadian model (CCM) is the MACBEHT method and its software M-MACBETH. The choice of this method is because it has a socio-technical approach in the problems development and also because it works with qualitative judgment (instead of quantitative), which is better and easier for the decision makers (Bana e Costa *and* Beinat, 2005).

3.1. Problem's Definition

The original purposes and assumptions of the Canadian CI model will remain the same. According to the definition of CI created by the Canadian working group, the main objectives of the CCM are to;

- Identify, through a "*Critical Index*", how much "Critical" the Infrastructure/Asset is for the social and economical nation's well-being.
- Rank these assets, based on urgency categories (urgency in protective measures and safety policies take placed to protect those assets) established according to a restructure of the original Canadian model (OCM) impact's scale; Absolute (Severe), High, Medium and Low.

3.2. Construction and Assessment

The CCM is restructured on basis of an addictive model, where's a "bad" performance can be compensated with a "good" performance in other criteria (Bana e Costa, *et al.*, 2003), (Bana e Costa, *et al.*, 2005). The purpose is to evaluate each asset according to the assumption that, the more critical an asset is, worst will be for the infrastructure and, consequently, for the nation's well-being. The addictive model formulation is:

$$V(a) = \sum_{j=1}^{n} k_j \times v_j(a)$$

with $\sum_{j=1}^{n} k_j = 1$ e $(k_j > 0 - j = 1, \dots, n)$, and

$$\begin{cases} v_j(\text{"}NEUTRAL\text{"}_j) = 100, \ \forall_j \\ v_j(\text{"}GOOD\text{"}_j) = 0, \ \forall_j \end{cases}$$

Where ***a*** is the asset performance, ***n*** the total number of assessment criteria ***j***, ***kj*** the weight of criteria ***j***, ***vj(a)*** the "local" value of ***a*** according the criteria ***j*** and ***V(a)*** the global value (*Critical Index*) of the evaluated asset. The "local" value ***vj("GOOD"j)*** correspond to a fixed value of a reference level in each criteria (scored with 0 points) in which an asset is in the border line to be considered as a "non-critical" infrastructure (which is "good" for the infrastructure), that is, it destruction or disruption consequences are not enough to put in danger the well-being of a nation. The "local" value ***vj("NEUTRAL"j)*** correspond to a fixed value of a reference level in each criteria (scored with 100 points) in which an asset is in the border line to be considered as a "critical" infrastructure, that is, it destruction or disruption consequences are enough to put in danger the well-being of a nation.

3.2.1. Assessment Criteria and Impact Descriptors

Knowing that the assessment criteria are identified, the first step will be to identify the concern areas, that is, the "families" on which the criteria are associated. Due to the main objective of the model, it is possible to identify two concern areas; the social well-being (CPA, PCI, SI) and the economical well-being (EI, ITI, CISI). The next step is to use the MACBETH software for its integration and structure (Value Tree), in order to begin the multi-criteria model construction (**Figure 3**).

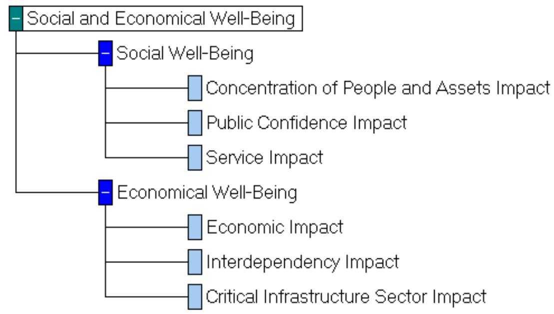

Figure 3: Value Tree

Following the MACBETH methodology, the next step will be the attribution of a group of impact descriptor to each one of the assessment criteria. These impact descriptors must reflect all the possible considered impacts in each criteria (N1, N2, N3, N4, ...). In each group of impact descriptors are set two fixed reference levels – "GOOD" (blue) and "NEUTRAL" (green) – according to which the performances of the assets are evaluated (**Figure 4**). The establishment of these two reference levels is important for the next steps, in order to obtain the value function and weights.

CI Priority Assessment Screening Model - Consequence Criteria

Descriptor of Impact / Assessment Criteria	N1	N2	N3	N4
Concentration of People and Assets Impact (potential for catastrophic effects) Affected People	10,000	1,000	100	0
Economic Impact / Direct cost of restoration including critical information and information technology (service relies on or asset contains critical information and I.T.) $Million	1,000	100	10	0
Critical Infrastructure Sector Impact (service or asset relates to a critical infrastructure sector)	National	regional	Distric	Local
Interdependency Impact	Debilitating impact on other sectors	Significant impact or disruption of other sectors	Moderate impact on important missions of other sectors	Minor impact on important missions of other sectors
Service Impact -- Potential for immediate significant impacts	High cross-sectoral cost, recovery time longer than one year (years)	High cost, long recovery time (months -- year)	Medium cost, significant recovery time (days -- weeks)	Low cost, brief recovery time (hours -- days)
Public Confidence Impact	High national risk & ability to control in doubt	Public perceives high national risk & low ability to control risk	Public perceives moderate risk & moderate ability to control risk	Public perceives low risk & high ability to control risk
		NEUTRAL		GOOD

Figure 4: Assigning Corrections on the OCM.

In the **Figure 4** (in red), the first three assessment criteria were changed, regarding to the OCM, because all of them where not well defined, according to the problems identified in the section **2.3.**. The first two criteria (**Concentration of people and assets**, **Economic Impact**) are quantitative impact descriptors (respectively, "*Affected People*" and "*$Million*") so that, their value function must be continuous. In the "Critical Infrastructure Sector Impact" criteria, it was need to include and remove a performance level (respectively, *District* – N3, "*Sector May Shut down or International*" – N1) in order to avoid any confusion with the "interdependency Impact", but also to increase and clarify the levels in judgment (*National* – e.g.: country; *Regional* - e.g.: Alentejo Region; *District* – e.g.: city; *Local* – e.g.: Village). The others impact descriptors of the three others criteria are qualitative and will remain the same. All these assumptions are integrated in the MACBETH's software as it presents.

3.2.2 MACBETH: Value Functions and Weights

In order to obtain the value functions (quantitative impact descriptor) and/or thermometric scale (quantitative impact descriptor), the MACBETH procedure consists in evaluating the attractiveness between pair wise of levels of impact in each assessment criteria. It is asked to the participants to judge (qualitatively) theses attractiveness according to six semantic categories - extreme, very strong, strong, moderate, very weak and very weak (Bana e Costa *et al.*, 2005) – such as; "*What it the difference of attractiveness between an asset be in the level N3 or in the level N4 in the Public Confidence Impact?*".
Each one of these semantic categories is represented (quantitatively) by intervals delimited by thresholds (1 to 6). These intervals are the value functions of MACBETH and are obtained for each judgment matrix, after a qualitative evaluation to each impact descriptor in it respective criteria (**Figure 5**). After the matrix is completed and validated, the MACBETH procedure converts the qualitative judgments into quantitative values (Bana e Costa *et al.*, 2003).

After that, the next step consists in determining the weights . These weights reflect the relative importance of each criteria *j* (Bana e Costa, *et al.*, 2005) to the group of participants. In this stage, the decision makers (e.g.: stakeholders, experts) start to order the assessment criteria in terms of their global attractiveness of the performance scale of the impact descriptors, taken into account the existing "swing" between the reference levels "GOOD" and "NEUTRAL". After that, the decision makers will evaluate, qualitatively, the attractiveness of which "swing", starting to compare the one that is considered

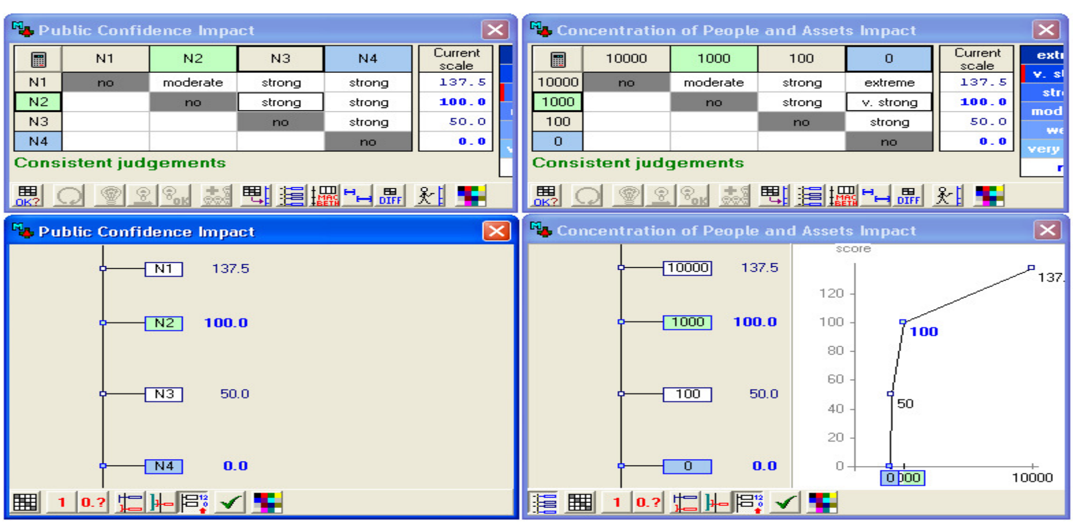

Figure 5: Judgment Matrixes of the Public Confidence and Concentration of People & Assets impact descriptors and, respectively, the Thermometric Scale and Value Function.

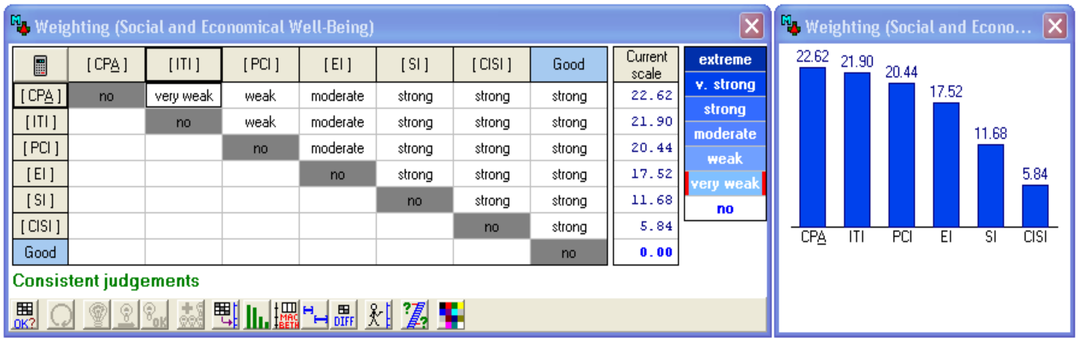

Figure 6: Judgment Matrix and Weights Histogram of all the assessment criteria.

the most important, and then the second, until the considered last one (Bana e Costa, *et al.*, 2005); "*What is the difference of attractiveness between the "swing" to NEUTRAL level from the GOOD level in the **Concentration of people and assets** criteria and the "swing" to NEUTRAL level from the GOOD level in the **Economic Impact** criteria?*" The Matrix of Judgment is completed according to the answer obtained through this kind of questions.

In the final of the process the MACBETH scale, obtained through the qualitative judgements introduced in the matrix, is presented and discussed, if need, to all the decision makers. This scale represents the weights of each assessment criteria. Furthermore, according to the MACBETH software, it is possible to do different sensibility analysis (to verify if others preferences or weights affect the chosen order) and robustness analysis to verify the consistency of the final results (Bana e Costa *et al.*, 2003). After all the steps done so far, the 1st aim set out for the CCM is complete and it is ready to be used (**Figure 6**).

3.2.3. Urgency Categories & Assignment Rules

The 2nd objective of the CCM consists in ranking these assets according to their obtained Critical Index. The aim is to categorize those assets in terms of their level of "criticality" and level of urgency, in implementing preventive measures and safety policies, in order to assure the well-being of Canada. Based on the impact scale observed in the OCM, four categories were defined (**Figure 7**):

- *Absolute* - the asset is "absolutely" critical to the well-being and its protection is unquestionable and urgent;
- *High* - the asset's destruction/disruption has unpredictable consequences that may put in danger the national well-being and its protection is need and urgent;
- *Medium* - the asset's destruction/disruption has potential consequences that may put in danger the national well-being and its protection most be monitored;
- *Low* - the asset's destruction/disruption hasn't consequences to the national well-being and its protection adequate to its purpose;

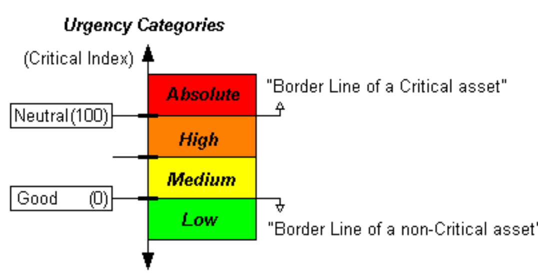

Figure 7: Urgency Categories

These categories are associated to an interval of the Critical Index, determined through the same index calculated to the reference profile of two hypothetical assets carried on. The followed method to build and distribute these categories is based on the paper developed by Bana e Costa *and* Oliveira (2002) for the Lisbon Municipal Office, in assigning priorities for maintenance, repair and refurbishment in managing a municipal housing stock.

For assigning categories to the evaluated infrastructures, it is necessary to establish thresholds (“Critical Index”) in order to separate the different categories and define the assigning rules. Thus, those infrastructures that present "critical" performances (more than a score of 100) in, at least, one of the following listed criteria (PCI, ITI, CPA), are immediately assigned to the category "Absolute" urgency. As it was mentioned, this method takes into account the identification of reference profiles (fictitious infrastructure). The actors are called to classify each of these assets to a certain category of value, through bottom-up and/or top-down procedures. In the bottom-up procedure (the top-down is the opposite one) the actors start with a fictional infrastructure characterized by the level "good" performance in all criteria. Then, at each stage of evaluation, they choose new criteria to raise the impact level corresponding to their "neutral" level of performance. This procedure continues until the players hesitate about which category must be assigned to the infrastructure profile, resulting from the rise in the level of impact in the last added evaluated criteria (Bana and Costa and Oliveira, 2002).

In the end, these thresholds are obtained in the multi-criteria model, evaluating the profiles of the infrastructure that resulted after this procedure. The construction of the two procedures is intended to validate the values of thresholds (protection index), as if the model is well built, the values have to be equal in both situations. If the identification of these reference profiles does not lead to identification of these thresholds, a discussion and reflection are needed among stakeholders on possible changes and reformulations of the model parameters of evaluation (Bana e Costa and Oliveira, 2002).

4. Final Considerations

The conception of a model to identify and rank the CI is a current problem of high importance and complexity for each nation. The lack of a formal and unique CI definition, the development of a compensatory or non-compensatory model in its basis, the selection of the fundamental points of view, infrastructures and the participants on the process are some of the identified problems, and still be working nowadays, regarding this issue. Regarding the development of a value model structure in the CCM, one of the greats limitations identified has to do with the lack of more available CI models, to compare with the Portuguese and Canadian models. In spite of, in part, this limitation does not prejudice the correcting process, the model could be more precise and objective through the incorporation of others fundamental points of view and impact descriptors in the OCM.

About the methodology used to correct the problems observed and studied in the OCM (MACBETH), it proved to be a good option, in solving and building this kind of CI identification and prioritization models. Considering all the conclusions achieved in this paper work, the objectives and aims established were achieved. Unfortunately it was not possible to test the CCM, in order to have a notion and a realistic idea of its suitability and operation level.

For future challenges and prospects, are made some suggestions and recommendations considered important: i) the usage of multi-criteria methodologies (e.g.: MACBETH), based on the decision analysis literature, on the resolution of a high level of complexity, variables and uncertainty; ii) the kind of socio-technical process that must be considered in projects of national interest; iii) the development of support models, complementary to the CI models, such as management and monitoring CI during their life cycle; iv) the need to investigate new approaches to the problem in questions, through the elaboration of CI models for each activity sector, under a multi-criteria basis (decomposition of the problems in small parts increase the precisions of the results as well as the accuracy of the model); v) the introduction of a new dimension in the interdependency studies – economic interdependency – as a result of a global society more economically dependent, that can affect as well the social well-being of a nation.

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