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The Dynamic Adaptive Sustainability Balanced Scorecard: A new framework for a sustainability-driven strategy

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Abstract

The Sustainability Balanced Scorecard (SBSC) has been widely recognized as a valuable decision aid approach in the management of sustainability. Controversy is nevertheless still prevalent on which SBSC architecture is most suitable for which organizational context. Moreover, the literature unveils some structural flaws in SBSC design methodologies that remain up till now fundamentally based on intuitionist mental models and subjective judgment. Building upon existing critical evaluations and the gaps to be addressed, we propose in this paper a new sustainability decision aid framework based on a novel combination of Multi-Criteria Decision Making methods (MCDM), Fuzzy logic, and System Dynamics modeling. The resulting framework, denoted as the Dynamic Adaptive SBSC (D-ASBSC), offers the advantage of high adaptability, comprehensiveness, and unbiased methodical cause-effect relationship construction. In addition, thanks to a systematic rule-based generation of the causal loop diagram and the stock-flow chart, the D-ASBSC permits to effectively remedy to the infamous *mental models* restriction that has long been raised in System Dynamics modeling.

Keywords: Sustainability Balanced Scorecard, SBSC architectures, sustainability decision making, MCDM, System Dynamics.

INTRODUCTION

To cope with the global sustainability challenges lying ahead, managers need to be equipped with reliable information systems and sound decision making processes. Sustainability management has spurred wide interest from researchers and practitioners over the past two decades. Research in this field covers a variety of decision aid frameworks and models across different sustainability areas including energy (Strantzali & Aravossis, 2016), green technology (Ibáñez-Forés, Bovea, & Pérez-Belis, 2014), green supply chain management (Tajbakhsh & Hassini, 2015), forestry management (Ananda & Herath, 2009; Diaz-Balteiro & Romero, 2008), water management (Aivazidou, Tsolakis, Iakovou, & Vlachos, 2016)...etc.

Sustainability management decision aid methods can be classified in two categories: operational methods and systemic approaches (Chaker, Janati Idrissi, & El Manouar, 2017). Despite the importance of adopting a systemic lens in addressing sustainability management issues given the prevalent interconnectedness that exists between various sustainability areas, few studies adopt system thinking decision aid approaches (Williams, Kennedy, Philipp, & Whiteman, 2017). In contrast, the largest literature coverage concerns operational techniques such as analytical decision making methods (eg. Govindan, Rajendran, Sarkis, and Murugesan (2013); Diaz-Balteiro and Romero (2008); Huang, Keisler, and Linkov (2011)) or performance measurement techniques (Dočekalová & Kocmanová, 2016; Hubbard, 2009), to mention a few.

The Sustainability Balanced Scorecard (SBSC) has been widely recognized as a systemic approach for helping to create and execute the sustainability strategy (Dias-Sardinha & Reijnders, 2005; Figge, Hahn, Schaltegger, & Wagner, 2002; Hansen, Sextl, & Reichwald, 2010; Nikolaou & Tsalis, 2013). In a systematic review of the literature, Hansen and Schaltegger (2014) describe the various types of SBSC architectures and related corporate value systems. Chaker et al. (2017) conducted a critical evaluation of those architectures and associated construction methodologies, and unveiled some important areas of improvement that can make a positive contribution to this field of research. These areas concern three characteristics −orientation, confinement, and cause-effect relationships− and two structural improvements related to the dimensions of ethics, governance, and time.

Based on this critical evaluation and the gaps to be addressed, we propose a novel design methodology employing analytical decision aid techniques and system dynamics simulation. The resulting framework is denoted as the Dynamic Adaptive Sustainability Balanced Scorecard (D-ASBSC).

This paper is organized as follows: In section 2, we describe the construction methodology of the ASBSC, the adaptive part of the proposed framework. Then, in section 3, we augment the ASBSC with a conceptual method for constructing the System Dynamics model so as to result in the Dynamic-ASBSC (D-ASBSC). In section 4, we discuss the benefits and limitations of our proposed framework, and make concluding remarks in section 5.

THE ADAPTIVE SUSTAINABILITY BALANCED SCORECARD (ASBSC): A NOVEL AND SYSTEMATIC FRAMEWORK

The ASBSC: Why and How?

In a critical evaluation of SBSC architecture design, Chaker et al. (2017) depict *orientation* and *confinement* as key features to be addressed by future research works. The authors argue that the construction of the SBSC should be adaptive, reflecting the varying organizational priorities based on industry, activity, and context. Authors argue, in addition, that the liaisons between perspectives should also be dynamic and not necessarily reflective of a predefined hierarchical order as stated in some earlier studies (Akkermans & Van Oorschot, 2005; Barnabè, 2011; Norreklit, 2000; Nørreklit, 2003).

In this work, we propose a SBSC design methodology that allows overcoming the above mentioned limitations. Practically, we ask three comprehensive questions:

- Which sustainability dimensions are most important to, and impact most, a business?
- How do these dimensions rationally relate to one another? and in which hierarchy order?
- Which performance measurements are most meaningful within each dimension?

In order to answer these questions, our model should not only help to rationally define dynamic hierarchies amongst perspectives, but also prioritize KPIs within each perspective.

For this aim, we combine two multi-criteria decision making methods: Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Hierarchy Process (AHP). In addition, since the sustainability balanced scorecard's construction relies heavily on subjective assessment of decision makers who cannot precisely translate their evaluations into crisp data, fuzzy logic seems a good candidate to support decision making in this particular setting.

First, we derive cause-effect relationships and priority levels amongst the balanced scorecard's perspectives using fuzzy DEMATEL. Impact weights are derived through the total impact matrix, and a resulting network relation map (NRM) is constructed. In addition, a novel graphical representation is proposed to help prioritize dimensions by importance and by total impact produced or received in the system (Chaker, Janati Idrissi, & El Manouar, 2015). The result of this first step is an automatically prioritized and constructed network of relationships among the SBSC's dimensions, or what is referred to as the Sustainability Strategy Map (SSM).

Second, we generate priority graphs for criteria within each dimension. To do so, a set of key performance indicators (KPIs) are defined for each dimension of the scorecard, then AHP is used to rank these KPIs and arrange them by priority levels to help focus managerial attention on the most salient information.

Thanks to its automatic generation process and highly adaptive characteristics, the resulting SBSC is denoted as the Adaptive Sustainability Balanced Scorecard (ASBSC) (Fig.1.)

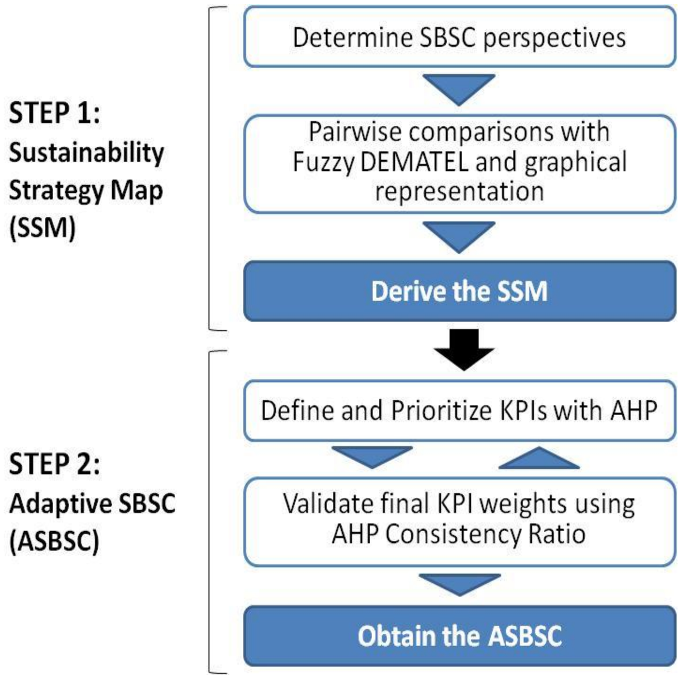

Figure 1: Proposed methodology for constructing the ASBSC

Deriving the Sustainability Strategy Map (SSM)

Determine the ASBSC's perspectives

In our proposed framework, we introduce the dimensions of Ethics and Governance as two distinct perspectives of the SBSC. The non systematic inclusion of ethics and governance as separate SBSC perspectives is viewed as one of the major conceptual flaws depicted in the literature (Chaker et al., 2017). Historical evidence from both the 1997-1998 Asian financial crisis and the 2008-2009 global economic meltdown demonstrates how weak governance and loose ethics procedures can lead to drastic financial and economic results at planetary scales.

Pairwise comparison and graphical representation

We deal with interdependencies existing among perspectives using fuzzy DEMATEL method. This consists of collecting the pairwise impact evaluations between each two dimensions taken separately from a group of experts, resulting in a set of pairwise comparison matrices with linguistic values. The pairwise comparison matrices are used as inputs for Fuzzy DEMATEL method. The total defuzzified relation matrix is obtained highlighting the total effects produced and received by each perspective.

At this stage, we modify the standard DEMATEL graphical representation in order to improve the decision making process. While the traditional DEMATEL's IRM graphical representation is useful in plotting factors in terms of importance and function (dispatching vs. receiving), it does not readily inform of the factors which represent the highest intensity of impact, and which deserve, consequently, the closest attention from managers and decision makers. Therefore, we rely on a framework exhibiting factors with respect not only to their importance but also to the intensity of impact they produce or receive (Chaker, Janati Idrissi, et al., 2015). In this layout, factors are plotted on a three-dimensional plan representing *importance*, *total impact produced*, *total impact received*. Consequently, authors classify factors as First Impact Factors (FIF), Second Impact Factors (SIF) and Third Impact Factors (TIF) (0).

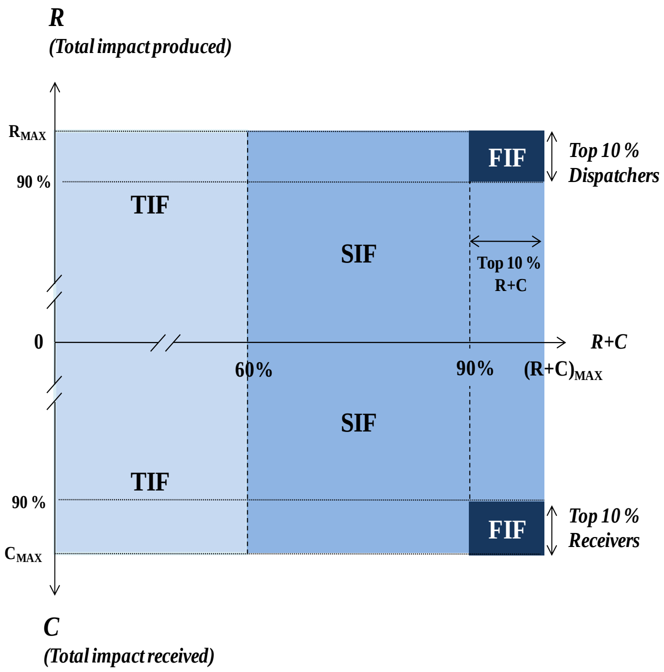

Figure 2: The proposed graphical layout (Chaker et al., 2015)

In addition, we enlarge the scope of SIFs to include extreme factors with exclusive dispatching or exclusive receiving characteristics but with low relative overall importance. These factors lay roughly within the ranges of top 10% dispatching intensity and top 10% receiving intensity regardless of overall importance. This amendment allows taking into account those factors which are either exclusively dispatching or exclusively receiving, and which are therefore susceptible of seriously impacting the system's components. The range of Third Impact Factors (TIF) is subsequently changed based on this extension (0).

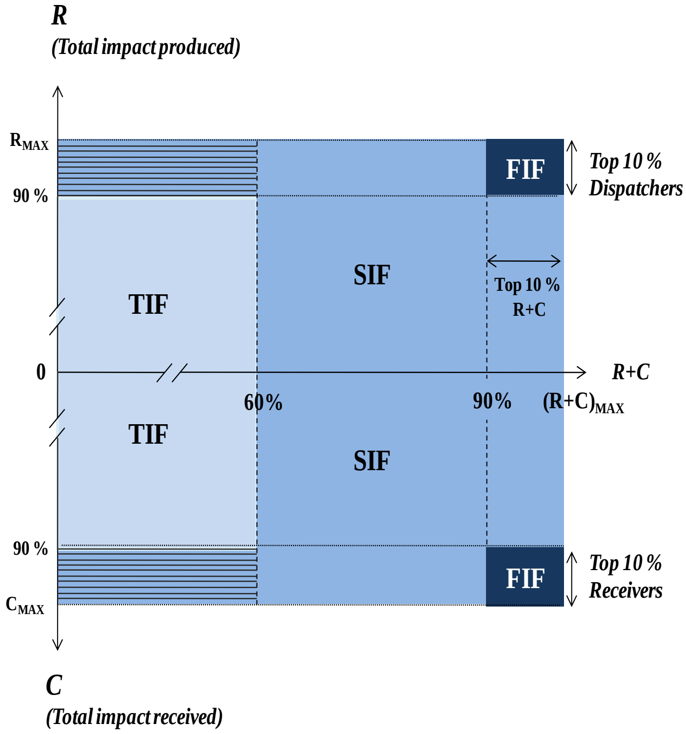

Figure 3: Framework extension

Derive the Sustainability Strategy Map (SSM)

Based on the graphical layout above (Fig.3), we derive the SSM in a systematic manner**.** The most important and impactful perspectives are readily recognizable, namely the dispatching FIFs. These perspectives contribute most to the system's overall influence and retain the highest overall importance. Therefore, they are placed at the bottom layer of the SSM as impact generators. In contrast, the receiving FIFs are the most importantly influenced perspectives with the highest overall importance as well. They are, hence, placed at the top layer of the SSM as impact receivers. In between, SIFs are placed according to whether they are dispatching (below) or receiving (above). TIFs, being the least important elements of the system (with the least total impact produced and received), are discarded and are not incorporated in the resulting arborescence. The influence relationships exerted are represented by directed arrows linking perspectives with one another (Fig.4). These links are derived from DEMATEL's α-cut total influence matrix.

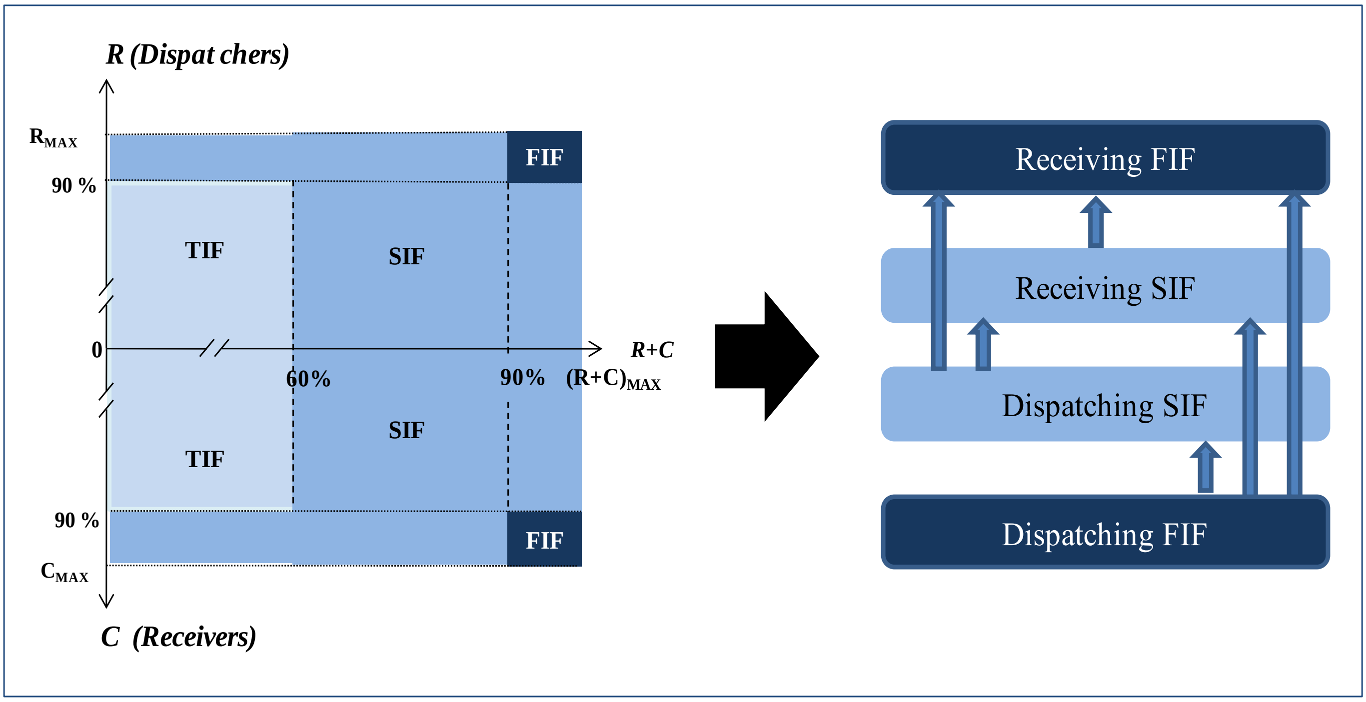

Figure 4: Deriving the adaptive SSM from the graphical layout

Obtaining the ASBSC

For each perspective, a set of performance indicators (KPIs) is defined by an expert. A comparison matrix is constructed for each perspective to allow pairwise importance comparison amongst indicators. Following AHP method, importance weights are derived in the Eigen vector, and a corresponding Eigen value is calculated. To check for model consistency, a consistency index is calculated along with the consistency ratio (CR).

The consistency ratio helps gauge the model's consistency. If the calculated CR is below a certain threshold, the weights are accepted as priority levels, otherwise, the model presents inconsistencies that need to be corrected by revisiting the pairwise comparisons entered in the initial comparison matrix such that more logical sequences are respected.

The method presented above leads to the systematic generation of the ASBSC such that the resulting scorecard is adapted to various organizational contexts and industries. Yet, as powerful as the resulting scorecard could be, it represents a static picture of the current state of the organization. Balanced Scorecard protagonist David Norton wrote “dynamic systems simulation would be the ultimate expression of an organization’s strategy and the perfect foundation for a Balanced Scorecard” (Norton, 2000) (pp 14-15). In the next section, we present a systematic method for constructing the Dynamic Adaptive SBSC.

THE DYNAMIC ASBSC (D-ASBSC): CONCEPTUAL METHODOLOGY

Critical evaluation of existing works

The visible limitations of the BSC approach has led researchers to explore ways of overcoming some of them. Barnabè (2011), for instance, explicates the strengths and shortcomings of the BSC, and outlines the necessity to incorporate the BSC approach with System Dynamics thinking. This combination had already been explored in earlier works mainly via case studies (Akkermans & Van Oorschot, 2005; Rydzak, Magnuszewski, Pietruszewski, Sendzimir, & Chlebus, 2004; Zhang & Gao, 2008) where authors explain by example the benefits accrued from applying system dynamics tools to the BSC approach. The resulting decision aid system is denoted the Dynamic Balanced Scorecard (DBSC).

Despite the extensively addressed advantages of the DBSC, some strategic limitations are encountered. Few studies investigated these conceptual limitations which relate mainly to design and implementation of the DBSC. In fact, many approaches fail to involve bidirectional or multidirectional relationships among indicators. In addition, the causal loop diagram is not necessarily derived using methodological steps with little subjectivity bias (TABLE 1). The main features of the DBSC and how they are addressed by existing literature works are summarized below (TABLE 1).

TABLE 1. MAJOR FEATURES ASSOCIATED WITH THE DBSC CONSTRUCTION METHODOLOGY

Major research works	***Features of DBSC construction***						
	Dynamic scorecard with a simulation case study	Methodological construction of the Strategy Map	CLD generated using intuitionist mental models	CLD generated using objective methodology	Multi-directional relations	Quantitative resolution of ambiguous relationships	Overcoming Systemic mental models
Rydzak et al. (2004)	√		√		√		
Akkermans and Van Oorschot (2005)	√	√ (from CLD)	√		√		
Bianchi and Montemaggiore (2008)	√		√ (from strategy map)				
Zhang and Gao (2008)	√	√	√ (from strategy map)		√		
Capelo and Dias (2009)	√		√		√		√ (partially via strategy map review)
Barnabè (2011)	√		√		√		

More generally, the following shortcomings are noteworthy:

- Most studies rely on the classical SD construction process which is fundamentally based on managers' mental models and perception of reality. Therefore, as Akkermans and Van Oorschot (2005) rightfully noted, the main limitation of such studies lies in the "*modelling of 'mental models', not of the 'real world'*" (p.939), which highlights the importance of the modeling methodology proposed in this paper.
- All previous studies used the predefined BSC architecture as described by Kaplan and Norton (2000). Besides the structural limitation that this confinement entails, building the dynamic simulation model around the predefined rigid architecture puts higher weighting on the cause factors in the lower layers than those in the upper layers of the scorecard as the simulation unfolds, which might lead to an over estimation of the role such factors can play in the system.
- None of the research works combining SD and the BSC, to our knowledge, has addressed the sustainability aspect of the scorecard by systematically integrating the environmental, social, ethics and governance dimensions in the model.

The D-ASBSC: A robust framework

The D-ASBSC is constructed in two major steps. First, the Causal Loop Diagram (CLD) is technically derived from the ASBSC using systematic analytical methods. Second, the stock-flow chart is constructed on a System Dynamics tool where the whole model is checked, simulated and calibrated (Fig. 5).

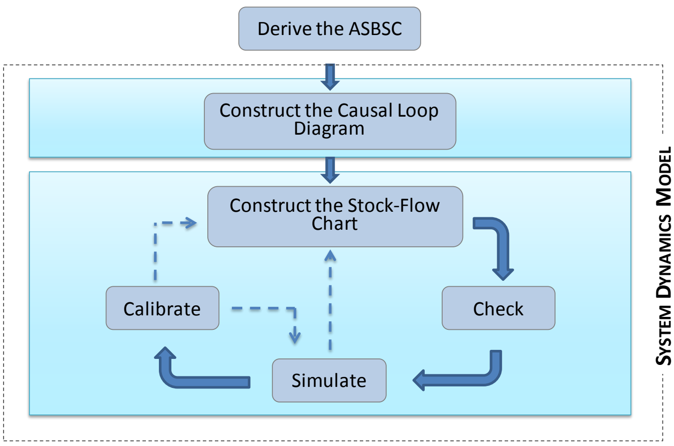

Figure 5: ADSBSC construction methodology

The Causal Loop Diagram

In an earlier work, Chaker, El Manouar, and Janati Idrissi (2015) present a System Dynamics (SD) modeling method based on DEMATEL. In the paper, the authors argue that existing SD conceptualization methods rely mostly on intuitionist mental model based assessment as opposed to rigorous objective analysis. It is proposed thus to base the SD's Causal Loop Diagram (CLD) construction on DEMATEL's impact relation maps. As a result, the model enjoys both conceptualization robustness and dynamic time-bound simulation.

The Stock-Flow Chart

Drawing on the combination between DEMATEL and System Dynamics in the CLD, the stock-flow chart is constructed. Equations are based on both the organization's internal data and factor weights derived from DEMATEL.

Each dimension is represented by a *Dimension Index* which reflects the dimension's score in the model. We distinguish between the *dispatching dimensions* and the *receiving dimensions* based on the SSM.

In dispatching dimensions, the *Index* is calculated as a weighted average of the dimension's indicators that were prioritized using AHP method. AHP priority weights are used as the weighted average weights (eg. Equation 1). Dimensions' indices are used as the connecting points between dimensions (Fig. 6).

$$Environment\ Index = (\alpha \times Waste\_recycling) + (\beta \times Water\_recycling) + (\gamma \times Energy\_efficiency) \quad (1)$$

α, β, and γ being the respective AHP priority weights corresponding to *Waste_recycling*, *Water_recycling*, and *Energy_efficiency* indicators.

Nonetheless, given the complex interactions existing in real-life organizational contexts, it is sometimes necessary to assess the evolution of a perspective of the SBSC in more detail. In this case, one aggregated index is not sufficient to highlight some important interactions taking place within the system dimensions. In this case, we propose to use Fuzzy DEMATEL as an effective technique to determine the relationships amongst indicators of the same dimension. We refer to this dimension as the *complex dimension*. The causal linkages construction thus changes slightly as shown on Fig. 7

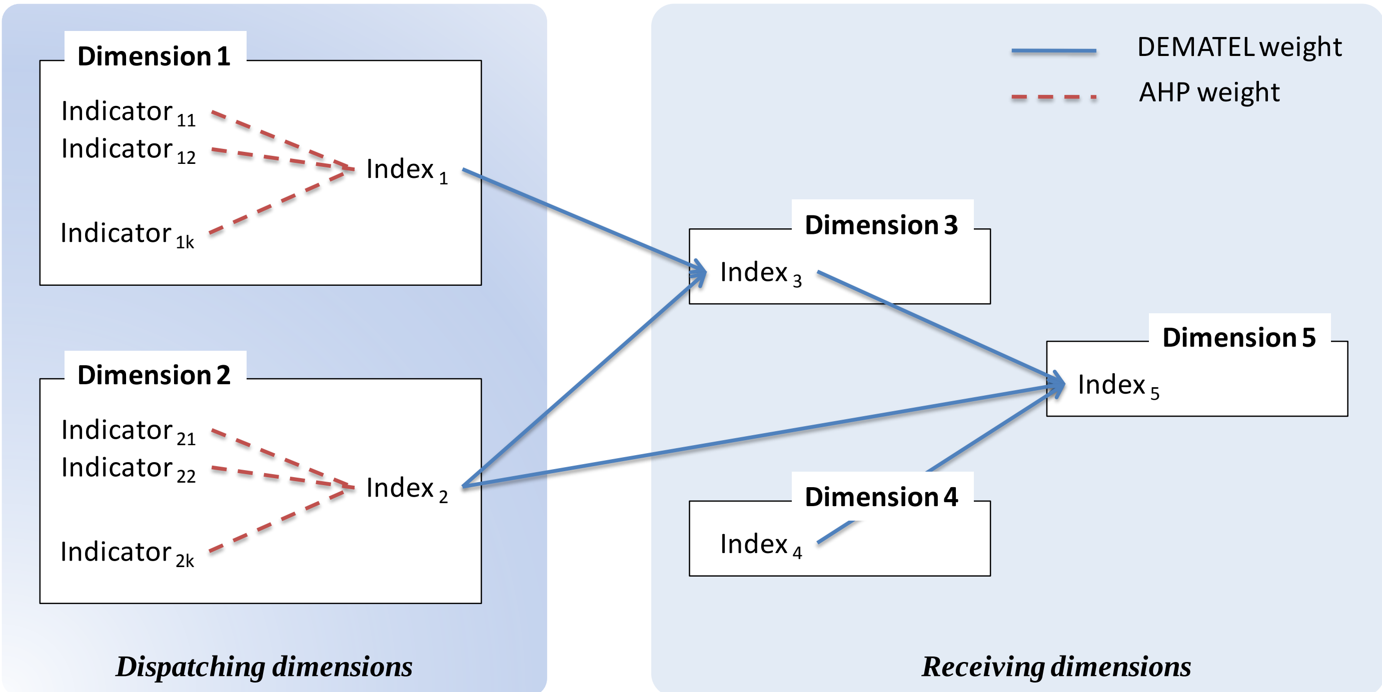

Figure 6: Causal linkages construction in the D-ASBSC

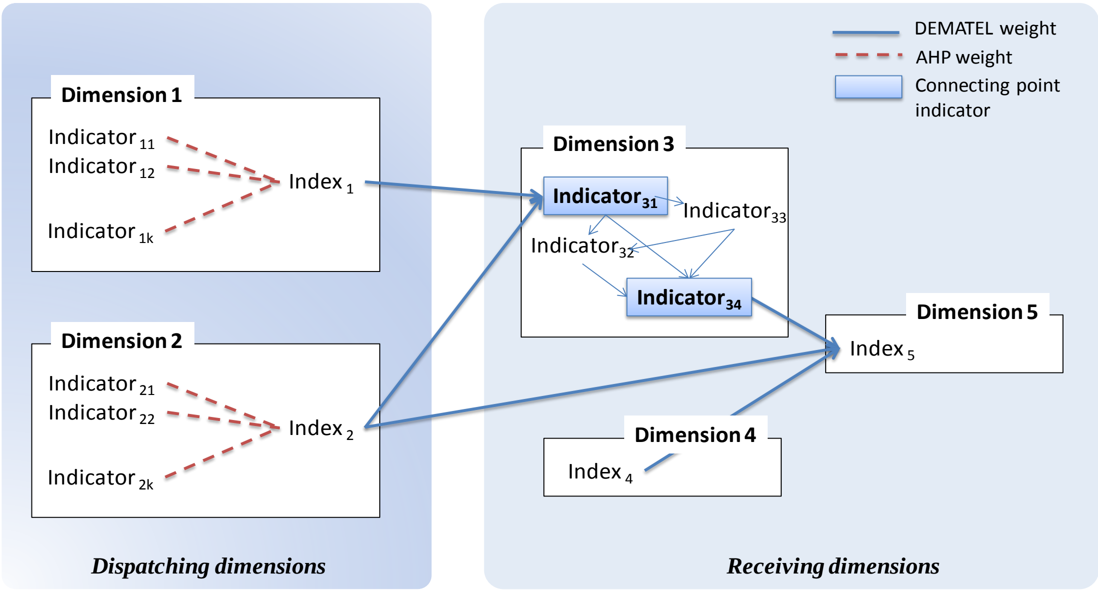

Figure 7: Causal linkages with complex interactions

In a *complex dimension*, the modeler is required to determine the indicators which will serve as connecting points with the related dispatching and receiving dimensions. To solve for this in a systematic manner, the source indicator which receives impact from the aggregated indices of dispatching dimensions is the FIF with the highest impact produced within the complex dimension. The result indicator, which dispatches impact towards subsequent receiving dimensions, is the FIF with the highest impact received in the *complex dimension*. To illustrate, in Fig. 7, $Indicator_{31}$ is the source indicator of *Dimension3* (which is a *complex dimension*). It serves as the impact receiver from *Dimensions 1* and *2,* while $Indicator_{34}$ is the result indicator which transfers impact to *Dimension 5*.

More practically, on the implementation side, each dimension of the ADSBSC corresponds to a stock with an inflow and an outflow. Generally, an arrow representing a cause-effect relationship translates into an outflow from the cause factor, which, combined with other variables, constitutes the inflow of the effect factor.

DISCUSSION OF THE D-ASBSC FRAMEWORK

Benefits

The proposed Adaptive SBSC framework brings some salient benefits:

1. ***The scorecard's construction is adaptive:*** the cause-effect arborescence of perspectives will not be the same across organizations, industries and sectors. This flexibility allows to more precisely capture the structural differences that exist between organizations and across industries, which results in various priorities in strategic decision making.
2. The ASBSC is constructed based on an ***unbiased mathematical decision making*** technique (DEMATEL) which involves a group of experts as input providers. The use of this systematic method helps to clear away much of the modeling restrictions pertaining to subjectivity bias and mental models limitations.
3. ***The SBSC is encompassing***: It clearly identifies the dimensions of *ethics* and *governance* as stand-alone perspectives given the paramount importance they play in shaping business performance. This particular characteristic could prove highly useful for firms and organizations that wish to be well prepared for the various CSR or sustainability certifications.
4. In addition to systematically-drawn cause-effect relationships, the constructed ASBSC is further enriched with ***KPI prioritization within each perspective***, which provides managers with an additional decision making tool.

In addition, the dynamic component of the scorecard, or the ADSBSC, makes an important addition to research:

5. The ***time dimension in the ASBSC*** confers the scorecard all the benefits of system dynamics modeling, feedback loops and emergent self-organization, which are crucial elements that managers need to grasp in real life decision making.
6. The ***methodological construction of the System Dynamics part*** of the framework using a structured combination of multi-criteria decision making techniques constitutes ***a leapfrog*** that reduces to a great extent −if not eliminates− the mental models bias in system dynamics modeling.
7. When a perspective is deemed complex enough to be further explored, the model offers the possibility to

structure causal linkages amongst indicators within that perspective, which enables ***better representativeness of reality*** and its complexities.

8. The overall proposed methodology offers ***simplicity of execution***: managers generally have little time and need efficient and easy-to-implement solutions in order to maximize the chance that the solution is adopted at all corporate levels and departments.

9. The proposed framework is ***stronger with technology***: the rule-based generation of the ASBSC, thanks to the novel graphical representation of DEMATEL outcomes, makes it possible to computerize this generation process, enabling thereby massive distribution and use of information technology while still respecting the particularities of each organizational context.

10. The proposed framework is ***a real instrument for decision making***: The combination of priority levels resulting from DEMATEL and simulation results permits to instantly detect the sustainability perspectives with the highest overall importance and influence on the business activity. For management, this translates into well-informed investment decisions and sound management practices at the business unit and corporate levels.

Limitations

While the proposed D-ASBSC construction method brings an important addition to sustainability management research, it raises, nevertheless, some questions that can translate into perceived limitations:

1. Ignoring TIFs in the ASBSC generation may lead to the omission of some useful information. At first glance, this rule might appear rather drastic. However, we respond to this question by the fact that the omitted dimensions are only those deemed least important for decision making (they have the lowest values of R+C). In addition, the ignored dimensions are the ones which are responsible for the least impact produced or received. Therefore, and for the sake of presenting to managers only the essential and most important information, the trade-off is made of removing TIFs from the scorecard even though this might come at a small cost.

2. The use of AHP method presupposes the absence of interrelations between KPIs. It is true that performance indicators can display, at times, some order of influence, thus suggesting the use of the Analytic Network Process (ANP), in which case comparison matrices would include both KPIs and their corresponding perspectives (Saaty, 2001). However, using ANP necessitates a large amount of evaluations to be made at the comparison matrix level, translating into a great amount of time to be spent by managers on the topic. Taking a simple illustration, with eight dimensions at hand, and assuming only three KPIs per dimension −which is quite conservative− ANP method would require a manager to make 552 pairwise comparisons each time she attempts to construct the scorecard. Coming from a managerial perspective, this solution seems unrealistic, and could therefore be quickly rejected by decision makers.

3. The formulae based cause-effect relationships in the System Dynamics model might overlook some additional variables that the modeler might feel compelled to add to the model, especially when there is particular need to further elaborate on a perspective of the scorecard. In such a case, the model might need to resort to a combination of decision-aid techniques (such as fuzzy DEMATEL/AHP) and her/his best judgment.

CONCLUSION

Creating effective sustainability strategies takes more than good will. Decision makers need reliable tools and frameworks to help them make informed decisions. In this paper, we propose a novel adaptive and dynamic decision aid framework that helps create and execute sustainability strategies in a systematic fashion. Our framework builds upon the existing limitations and critical evaluations that have been raised in the literature and published over the past twenty years.

In this work, we construct the Adaptive Sustainability Balanced Scorecard (ASBSC) employing a combination of two multi-criteria decision making techniques and fuzzy logic. Then, we propose a systematic construction methodology of the System Dynamics model representing the ASBSC in order to run dynamic simulations. The resulting framework is denoted as the Dynamic ASBSC (D-ASBSC).

The proposed framework brings the main benefits of adaptability, comprehensiveness, and unbiased structural relationships. In addition, the methodological design of the D-ASBSC helps to overcome the infamous restriction posed by *mental models* in System Dynamics modeling.

The D-ASBSC can be an effective decision aid tool in sustainability strategy design. As a future perspective, we suggest deploying the framework with multiple firms and organizations from various sectors and industries in order to analyze how the resulting SBSC differs across industries, organization types and cultures. The collected information can then constitute a powerful data warehouse for sustainability management and policy making that could be tapped into by firms, public institutions and governments.

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