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Strategic scenario analysis combining dynamic balanced scorecards and statistics

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STRATEGIC SCENARIO ANALYSIS

COMBINING DYNAMIC BALANCED SCORECARDS AND STATISTICS

Structured Abstract:

Purpose

This article aims to explore the way in which System Dynamics (SD) can enhance some key success factors of the Balanced Scorecard (BSC) model and support decision-makers, specifically in analyzing and evaluating the results of hypothetical scenarios. Moreover, the article aims to emphasize the role played by statistics not only in validating the SD-based BSC, but also in increasing managers' confidence in the model reliability.

Design/methodology/approach

The article presents a case study, developed according to an action research perspective, in which a three-step approach to the BSC implementation was followed. Specifically, the first step requires the development and implementation of a "traditional" BSC, which is refined and transformed into a simulation SD model in the second step. Last, the SD-based BSC is combined with statistics to develop policy making and scenario analysis.

Findings

The integration of BSC and SD modelling enables the development of a comprehensive approach to strategy formulation and implementation and, more importantly, provides a more reliable basis upon which to build and test sound cause-and-effect relationships, within a specific BSC. This article exemplifies how an SD-based BSC can be used – and perceived reliable - to evaluate different scenarios and mutually exclusive policy effects in a multidimensional approach. In particular, this study illustrates how to forecast and depict trends for financial and non-financial indicators over the simulation period, with reference to three different scenarios.

Originality/value

This article contributes to the ongoing debate on the BSC by exploring whether a combination of SD and statistics may enhance the BSC system's advantages and facilitate its implementation process and use for decision-making and scenario analysis.

Keywords: Balanced Scorecard, System Dynamics, Scenario analysis, Strategic decision-making.

Article Classification: Research paper

1. Introduction and research aims

The background to this research takes into consideration over 25 years of publications and applications related to performance measurement systems (PMSs). In general, the literature reveals common advocacy and effort among management accounting scholars towards the development and implementation of multidimensional, integrated and dynamic PMSs and strategic management systems (Neely, 1998; Epstein and Manzoni, 1998; Dyson and O'Brien, 1998; Otley 1999; Bititci *et al.*, 2000; Epstein and Manzoni, 2004; Marr *et al.*, 2004; Kaplan and Norton, 2008b; Micheli and Manzoni, 2010; Eccles and Krzus, 2010; Yadav and Sagar, 2013; Wieland *et al.*, 2015; Busco and Quattrone, 2017). As a consequence of this proliferation of studies, a vast array of widely adopted best practices and management accounting innovations (Busco *et al.*, 2013) currently populate the business world. Management practices such as Just in Time, Activity Based Costing, Six-Sigma, Business Process Reengineering, Enterprise Resource Planning systems and Integrated Reporting, to name a few, all have substantive success in terms of adopters and are heavily marketed by consultancy firms which help their popularization across the globe (Bititci *et al.*, 1997; Al-Mashari *et al.*, 2001; Jones and Dugdale, 2002; George, 2002; Quattrone and Hopper, 2006; Eccles and Saltzman, 2011). In this context, however, one of the most cited and suggested models is certainly the Balanced Scorecard (hereafter BSC) (Kaplan and Norton, 1992, 1996a, 1996b, 2001).

It is more than 25 years that the BSC is applied worldwide and across industries as well as in private, public and non-profit organizations to support strategic management decisions and facilitate knowledge sharing and sense-making in management teams. Regarded as one of the major innovations in the recent history of accounting management (Atkinson *et al.*, 1997; Ittner and Larcker, 2001; Busco and Quattrone, 2015), or even as one of the most influential ideas of the 20th century (Bible *et al.*, 2006), the BSC is still widely used.

As we will better explain below, part of the success of the BSC is certainly due to its great malleability, ability to change and evolve, particularly if complemented with other tools and techniques, thus generating a comprehensive and reliable integrated performance management system able to enhance organizational performance, and sustain decision-making. However, in the literature how to combine fruitfully the BSC model with other management tools represents a still open debate due to some inevitable challenges deriving from the implementation process of the combination advocated.

In this context, this article specifically aims to investigate the development and implementation of a BSC in accordance with the System Dynamics (SD) modelling principles, and subsequently to validate the emerging SD-based BSC by relying on the use of statistical tools. More in detail, the article extensively presents and discusses the empirical data and results of an action research case study, pursuing a threefold aim (Eisenhardt, 1989; Yin, 1994).

First, by building on a review of the relevant literature and discussion of the insights emerging from the case study, this article primarily aims to explore the way in which the SD principles can reinforce and enhance some key success factors of the BSC model, contemporarily facing some limits of its adoption.

Second, this work aims to investigate how a combined use of an SD-based BSC and statistics may support decision-makers in exploring the effects of strategic decisions in terms of future performance, specifically by analyzing hypothetical scenarios.

Third, the article aims to emphasize the role played by statistics in increasing managers' confidence in the reliability of the SD-based BSC.

The article is structured as follows. Section 2 briefly presents the literature review on the debate on the BSC adoption and the main advantages of the SD methodology, in order to introduce the threefold aim of the study basing on the advocated combination of the BSC model with SD and statistics. The third section presents the research design while the following one focuses on the case study, reporting data and results arising from the development of the SD-based BSC and the statistical analysis implemented. The last two sections respectively discuss the results according to the stated threefold aim and emphasize the limitations to the study in order to stimulate ideas for further research.

2. Literature review

The BSC model: an open debate

Starting from the well-known article published in 1992 by Kaplan and Norton, it is noteworthy that the BSC system has been presented, discussed and implemented in a variety of fields, consistently meeting considerable consensus. A wide literature (e.g., Hepworth, 1998; Hoque and James, 2000; Rigby, 2001; Davis and Albright, 2004; Akkermans and Van Oorschot, 2005; Busco *et al.*, 2007; Hoque, 2014; Busco and Quattrone, 2015) has pointed out the relevance, strengths and potentialities of this system, starting from identifying the cause-and-effect logic as the heart of the BSC-framework (Nørreklit, 2000, p. 70; Hoque and James, 2000, p. 2) and the very “essence” of the approach (Atkinson *et al.*, 1997, p. 26). Additionally, Lipe and Salterio (2000) have noted that the selection of a limited number of Key Performance Indicators (KPIs) along with the four BSC perspectives (Internal Business Processes; Learning & Growth, Customer Satisfaction, and Financial) supports managers in overcoming cognitive limitations in using large numbers of KPIs; Malmi (2001) and Wiersma (2009) have referred to the BSC as a managerial solution which can favor coordination and self-monitoring; Busco and Quattrone (2015) have analyzed the BSC as a method for ordering and innovation, as well as an instrument utilized for generating organizational action, when observed in practice. Moreover, as illustrated by Hansen and Mouritsen (2005), the BSC may play a creative role in the emergence of new strategic imperatives compared to the reasons that originally prompted its adoption, and may support strategy implementation, increase performance, and improve strategic decision making (Kaplan and Norton, 1992, 1996a and 1996b).

Overall, the success of the BSC model is witnessed by the numerous publications that have reported and discussed effective implementations in private, public and non-profit sectors (e.g., Olve *et al.*, 1999; Niven, 2003 and 2011; Manville, 2007; Hoque and Adams, 2011; Moullin, 2017), in small, medium and large organizations (e.g., Andersen *et al.*, 2001; Landry *et al.*, 2002), in specific geographical territories (e.g., Malmi, 2001; Speckbacher *et al.*, 2003; Ax and Biørnenak, 2005; Greiling, 2010; Zeng and Luo, 2013; Antonsen, 2014) or production and organizational contexts (e.g., Gosselin, 2005; Bhagwat and Sharma, 2007). In brief, the BSC – as well as the managerial models and innovations mentioned above – is believed to have substantially contributed to integrating “strategic perspectives with PMS, leading to the fulfillment of long-term objectives and the vision of the enterprise” (Yadav and Sagar, 2013: 956).

However, the linearity of the relationship between the adoption of the BSC and the benefits it is supposed to bring has been also questioned on at least two grounds.

Firstly, research has shown that this correlation is often quite weak if not absent. Part of the literature has criticized the model for not generating the desired effects (see Ittner, 2008) or not increasing firms’ performances (Davis and Albright, 2004). Also, the BSC model has been criticized

on the basis of other issues, including: providing poor guidance on causality (Nørreklit, 2000 and 2003; Nørreklit *et al.*, 2012), being characterized by ambiguity when considering the scorecard performance indicators (Busco and Quattrone, 2017), not adopting a resource-based perspective (Bourguignon *et al.*, 2004, p. 118), and being developed according to a top-down, linear and too internally focused process (Mooraj *et al.*, 1999; Nørreklit, 2003; Speckbacher *et al.*, 2003; Nørreklit *et al.*, 2012).

Secondly, implementations usually are time-consuming, painful and costly (Newing, 1994) and there is often a marked difference between the smooth and effective adoption and overall organizational alignment (Akkermans and Van Oorschot, 2005) which is promised by operative manuals and consulting teams, and the actual reality, which can be marked by a long series of stops and gos (Nørreklit *et al.*, 2012), or even implementation failures (Dinesh and Palmer, 1998; Neely and Bourne, 2000). When such techniques finally become working practices they do so at a considerable financial and organizational cost. In this regard, as an example, Antonsen (2014) found out that the use of the BSC within a Norwegian bank eventually strengthened formal control and reduced employees' scope for contributing to new ideas.

In summary, the literature on BSC has been characterized by a number of heterogeneous accounts. Yet, despite criticism offered by some of these contributions, this body of research (see Hoque, 2014 for an extensive review of BSC-related publications) confirms that the more the process of BSC diffusion and implementation is studied, the more rationale for its adoption and endured use are discovered (Busco and Quattrone, 2015).

It is noteworthy that while the BSC may not entirely deliver what it promises, it is certainly characterized by a certain degree of malleability which has facilitated its continuous evolution and adaptation over the last two decades (Lawrie and Cobbold, 2004; Cooper *et al.*, 2017). In this direction, Kaplan and Norton have been constantly innovating the BSC system not only by introducing new tools (e.g., the strategy maps - Kaplan and Norton, 2000 and 2004) but also by advocating, capturing and creating opportunities for its integration with new management ideas, techniques and principles (Kaplan and Norton, 2001, 2006, 2008a, 2012), in this way generating and feeding an overall integrated strategic management system (Kaplan and Norton, 2008b).

Overall, this situation opens an avenue to combine and blend fruitfully a number of qualitative and quantitative tools and techniques within the unique BSC system. Examples of integrations related to the BSC system include other techniques/methodologies, such as Data Envelopment Analysis (Eilat *et al.*, 2008; Amado *et al.*, 2012), fuzzy logic (Wu *et al.*, 2009; Tseng, 2010; Chytas *et al.*, 2011), Lean Thinking (Baroma *et al.*, 2013), and Interpretive Structural Modeling (Thakkar *et al.*, 2006). Very often, such integrations were suggested to address one of the key issues related to the BSC system, i.e., its development and implementation process within the organization, and subsequently its capacity to operate as a proactive PMS able to support decision-makers in exploring possible future pathways of value creation and hypothetical managerial scenarios, therefore also facilitating mental models enhancement, users' engagement and strategic innovation (e.g., see Bititci, 1994; Malina and Selto, 2001; Nørreklit, 2000 and 2003; Malina *et al.*, 2007; Othman, 2008; Nørreklit *et al.*, 2012; Humphreys *et al.*, 2016; Busco and Quattrone, 2017). Within this research agenda, this article contributes to the ongoing debate on the BSC (and PMS) usefulness for decision-making by exploring the potentialities of combining the BSC model with System Dynamics and statistics.

Over the last decades, computer-aided simulations have acquired increasing relevance in the business domain due to technological improvements and an increased need for a more developed support for decision-making and policy analysis of complex and dynamic situations (Morecroft, 2007; Qudrat-Ullah *et al.*, 2007). Briefly, computer simulation methods allow experimentation on a computer model of a real-world system (Pidd, 2004), and are consequently used for understanding and improving the real world (Maani and Cavana, 2000; Robinson, 2004; Morecroft, 2015).

Among the most widespread computer simulation techniques (Greasley, 2004; Morecroft, 2007; Tako and Robinson, 2010), *System Dynamics* (SD) (Forrester, 1961 and 1968; Richardson and Pugh, 1981; Sterman, 2000) has gained an increasing interest within the academic community, being based on a core set of methodological principles and tools (Forrester, 1968) able to support decision-makers in analyzing complex business domains, and developing and implementing long-term strategies. As described by Morecroft (2000, p. 15), “System Dynamics is a framework for thinking about how operating policies of a company and its customers, competitors, and suppliers interact to shape the company’s performance over time”. Furthermore, “System Dynamics is also a rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations. Together, these tools allow us to create management flight simulators - ‘microworlds’, where space and time can be compressed and slowed, so that we can experience the long-term side effects of decisions, speed up learning, develop our understanding of complex systems, and design structures and strategies for greater success” (Sterman, 2000, p. vii).

Initially developed by Jay Forrester (1961) as “industrial dynamics”, SD is now an approach to policy analysis and design that is suitable for any dynamic problem arising in any kind of system, including business, ecological, managerial and social systems (Ford, 1999; Sterman, 2000; Morecroft and Sterman, 2000; Morecroft, 2007; Warren, 2002 and 2008).

From a methodological point of view, SD relies on a few key concepts.

1) Any systemic structure can be represented in terms of the resources within that specific system, their rates and the causal linkages connecting such variables.

Usually referred to as stocks or levels, *resources* are the building blocks of any system since they represent the actual level at the managers’ disposal (Warren, 2008), characterize the state of the system, provide systems with inertia and memory, are the source of delays and decouple rates of flow (i.e., their inflows and outflows) thus creating disequilibrium dynamics (Richardson, 1991, Sterman, 2000, Warren, 2008).

2) Structure produces behavior.

As Richardson and Pugh (1981, p. 15) state, “the System Dynamics approach to complex problems focuses on feedback processes. It takes the philosophical position that feedback structures are responsible for the changes we experience over time”. As clarified by Sterman (2000, p. 28 and 107) “the structure consists of the feedback loops, stocks and flows, and nonlinearities created by the interaction of the physical and institutional structure of the system with the decision-making processes of the agents acting within it”. All of these variables are connected by causal links which may be assigned a polarity to denote the kind of influence of the cause on the effect: a positive polarity (a “+”) for a direct influence and a negative polarity (a “-”) for an indirect effect.

A variety of tools, both *qualitative* (e.g., maps named Causal Loop Diagrams - CLDs - and Stock and Flow Diagrams - S&FDs) and *quantitative* (e.g., mathematical computer models and management flight simulators), are used in SD to represent and investigate both the structure of the system under analysis (i.e., the whole chain of causality between stocks and flows) and the behavior generated

within that system by the policies being developed and implemented (Senge, 1990; Wolstenholme, 1999).

3) Feedback loops, non-linearity and delays are building blocks for generating and understanding dynamic behavior.

Feedback loops are fundamental in order to understand system behavior. As clearly explained by Richardson (1991, p. 1), “the essence of the concept (...) is a circle of interaction, a closed loop of action and information. The patterns of behaviour of any two variables in such a closed loop are linked, each influencing, and in turn responding to the behaviour of the other”. Therefore, a feedback loop consists of a circular relationship between a set of concepts (or parts of a system), e.g. X affects Y, then Y affects Z and ultimately Z affects X determining a circular relationship between X-Y-Z. It is essential to note that there are just two typologies of feedback (Coyle, 1996; Sterman, 2000): positive (or reinforcing – “R”) feedback loops amplify the dynamics arising within a system; negative (or balancing – “B”) loops counteract the dynamics within a system, seeking equilibrium and stasis. All dynamics arise from the interaction of these two kinds of loops, in which exponential growth, goal seeking and oscillation are the fundamental modes of behaviour. Each one is generated by a single feedback structure: exponential growth arises from positive (reinforcing) feedback; goal seeking is generated by negative (balancing) feedback; oscillation is determined by negative feedback with *delays* (considered as the timing between actions and results). More complex modes of behavior arise from the *non-linear* interaction of the fundamental feedback structures.

In broad terms, any SD modelling intervention is based on five stages (Sterman, 2000):

- a. articulate the problem that needs to be addressed;
- b. formulate a dynamic hypothesis or theory about the causes of the problem;
- c. build the simulation model to test the dynamic hypothesis;
- d. test and validate the model;
- e. formulate and evaluate policies.

The modelling process eventually leads to a mathematical model, representing the real system under investigation and fitting with historical data, which will be subsequently used as a future-oriented tool to explore an entire range of feasible options, thus supporting policy analysis and scenario planning. In sum, the mathematical model reproduces the behavior of the system under investigation in light of specific policies being implemented. Notably, to be effective the modelling process should be focused on clients’ needs (Sterman, 2000), be designed to solve problems and gain insights (Lane, 2012 and 2017), and help managers and entrepreneurs in piloting their organizations better (Kunc and Morecroft, 2010), supporting decision-making (Warren, 2008; Morecroft, 2015), sustaining organizational redesign and fostering processes of individual and organizational learning (Senge 1990, Vennix 1996; Kim, 2001).

As revealed in advance, however, within the various possibilities of using SD in the business domain this article specifically suggests of applying the SD technique (in combination with statistics) to the BSC model in order to generate a sound “dynamic scorecard”. As underlined by Sterman (2000: 80), “System Dynamics does not stand alone. Use other tools and methods as appropriate. (...) Modeling works best as a complement to other tools, not as a substitute”. SD is here subsequently combined with BSC, since it is considered able of contributing to the development of dynamic performance management systems and, specifically, of “dynamic scorecards”.

So far, a growing yet still limited literature have highlighted the role played by SD in projects aimed at developing “dynamic” BSCs (Akkermans and Van Oorschot, 2005; Bianchi and

Montemaggiore, 2008; Capelo and Ferreira Dias, 2009; Barnabè, 2011; Barnabè and Busco, 2012; Nielsen and Nielsen, 2015), with some articles primarily aimed at presenting single SD-related tool/methodological principles able to contribute to the BSC framework (e.g., Kunc, 2008; Nielsen and Nielsen, 2012; Khakbaz and Hajiheydari, 2015). However, this literature is very specific in its purpose and does not offer a comprehensive vision of the potentialities provided by the whole SD methodology when used in a real-world organization to tackle dynamic domains and enhance BSCs potentialities. Moreover, the use of statistics in this context particularly requires a specific in-depth analysis because, even if not entirely new in the field of BSC (e.g., Valmohammadi and Servati, 2011, applied statistical methods to select strategic objectives and measures to be included in the BSC), it is original if considered throughout the phases of validation and testing and for the specific purpose of increasing managers' confidence in the reliability of the BSC system.

Notably, calls for more research, case studies and empirical evidence in all of the aforementioned streams of research have been explicitly advocated by several scholars (Kaplan and Norton, 1996a; Warren, 2008; Kaplan, 2009 and 2012; Barnabè and Busco, 2012; Yadav and Sadar, 2013; Hoque 2014).

In this study, the idea underlying the development of an SD-based BSC and the combined use of statistics is to represent formally and analyze deeply the specific business domain under investigation, specifically aiming (as stated) to verify the positive effects of this combination in terms of:

- enhancement of some success factors of BSC;
- support to the decision-making process;
- improvement of managers' confidence in the reliability of the BSC modelling.

3. Research design

The achievement of the threefold aim aforementioned builds on the development of an "exploratory case study" (Yin, 1994) that, generally carried out "to explore the reasons for particular accounting practices" (Ryan *et al.*, 2002, p. 144), is here mainly used to evaluate the utility of implementing an SD-based BSC adopting the action research perspective (Lewin, 1946). Notably, the potentials of relying on case studies (Eisenhardt, 1989; Yin, 1994) to explore and explain how management accounting in practice works are widely recognized and accepted in literature (e.g., Ryan, Scapens, & Theobald, 2002), and the action research perspective - based on an explicitly political, socially engaged, and democratic practice (Brydon-Miller *et al.*, 2003) - is particularly powerful in favoring co-operation, participation, interaction and dialogue between researchers and practitioners (Wicks and Reason, 2009), thus facilitating the development of practical knowing (Reason and Bradbury, 2001) and stakeholder empowerment (Bradbury-Huang, 2010).

Specifically, the case study is a longitudinal one (Scapens, 1990), developed over a period of three years in order to carry out and complete the cyclical process of the action research perspective, which typically includes four steps, i.e., data analysis, planning, action, and evaluation (Lewin, 1946; Adams *et al.*, 2006). The organization under analysis is an Italian SME operating in the tire industry, with a yearly average turnover of € 3.8 million. The business case is a peculiar one since this industry has experienced sharp increases in the demand due to several factors, among which new central and local government ordinances requiring to buy snow tires, and a spread financial crisis at the macroeconomic level that pushed people to keep their old car for longer, subsequently stimulating the tire industry. We adopted multiple data collection methods in order to increase the study validity and reliability through triangulation (Patton, 1987). Specifically, prior to the data collection process

and the modelling project, the researchers paid particular attention to explaining clearly and extensively the main aims of the action research intervention, in order to avoid any possible bias and “observer-caused effects” (McKinnon, 1988), and the data were collected through written documents, interviews, and informal discussions.

In detail, the research project started with the collection and analysis of the organization’s historical data, followed by a four-round semi-structured interview of the CEO, the sales manager and the production manager of the organization. Each round typically lasted around an hour and the last one was scheduled at the end of the research project in order to collect a final feedback from the practitioners on the results achieved. Throughout the three years of the research project, a few informal discussions were also conducted in order to favor dialogue and co-operation between researchers and practitioners throughout the whole process (Coughlan and Coughlan, 2002). Basing on all of the data collected, the modelling project was carried out subsequently.

At first, a classic BSC implementation was introduced adopting the powerful tool suggested by Kaplan and Norton (2000, 2001 and 2004) building on the relevant literature related to causal mapping, and labeled by the authors as *strategy map*. Strategy maps may be regarded as a precondition for an effective implementation of the BSC, being specifically designed to highlight graphically the overall relationships of cause and effect between the determinants of individual perspectives that are included in the strategy document. From a practical point of view, a strategy map is a diagram that represents the organization’s strategy, pointing out the primary strategic goals pursued and providing a holistic visualization of the alignment between the organization’s intangibles and strategy. Then, appropriate (multidimensional, according to the four perspectives of the BSC framework) KPIs follow from the defined goals and measures of performance. For this case study, the organization’s strategy map was designed through an interactive and cooperative form of group model building (Vennix, 1996), and included the desired goals, the feasible policies and the relevant KPIs of the firm over the next three years period.

Subsequently, we adopted the SD approach to build a Stock and Flow Diagram in the Vensim environment (Ventana Systems Inc., 2006) on the basis of the original strategy map and the data collected through the interviews and the informal discussions with the organization’s managers that were particularly useful to identify the causal linkages between relevant variables.

The successive steps of the research design respectively entailed the adoption of the mathematical SD model to produce three different possible scenarios for the set KPIs, and the analysis of the simulation data to evaluate the organization’s policies in view of the defined scenarios (Schoemaker, 1993 and 1995). Statistical analysis and tests were performed using R (R Core Team, 2016). At the end of the three years of the research project, a feedback on the perceived utility of the SD model and the scenario analysis was gathered.

4. The case study

The project meant to combine computer-aided modelling techniques and statistics in order to obtain a more reliable and effective BSC to be used to support scenario analysis. The following sections will present the key actions and results of our case study.

The strategy map

According to the research design, the first stage of the modelling project, aimed at a classic BSC implementation, led to the development of the organization’s strategy map shown in Figure 1.

Perspective	Goals	KPIs
Financial	Shareholder value With reference to shareholder objectives, on the one hand the firm must evaluate profitability deriving from the implemented strategy, and the financial risk derived from it on the other.	
Customer	Market share In order to measure whether the firm produces value for customers, two different approaches must be used. First of all end customer satisfaction has to be measured (directly) using a questionnaire. In a roundabout way end customer satisfaction can be measured by the market share.	
Internal business processes	Timeliness Timeliness is a key factor for end customer satisfaction. All efforts must be focused on assuring timely service, eliminating delays, and reducing the number of daily end customers waiting for the tire services provided.	
Learning and growth	Seasonal work, e-commerce In order to create value for customers and shareholders, the firm must optimize recourse to seasonal work (when demand is exceptionally high) and implement B2C e-commerce through a new, updated website.	

Figure 1 – The Strategy map developed in the first stage of the project

For each one of the four perspectives of a BSC, Figure 1 shows the strategic goals of the organization (on the left) and the KPIs for performance management evaluation (on the right). The main objective of the organization is to maximize the shareholder value (financial goal). In order to achieve this goal (more specifically referring to end customers), the organization relies on launching B2C (e-commerce implementation project) and achieving the timeliness of deliveries, which is a key driver for the end customer satisfaction. To increase the turnover of end customers, the organization could invest in the development of its website (already in operation for B2C). The website, properly designed, could become an effective informative tool, enabling end customers to buy tires online, which would be mounted by the firm or another tire service provider with whom there is an agreement. The design of a proper strategy map and the classic BSC implementation allow the definition of the organization's goals and KPIs and a description of the policies pursued by the managers.

The stock and flow diagram

The second phase of the project entailed adopting the strategy map to develop a *Stock and Flow Diagram (S&FD)* aimed to represent the organization's accumulations (stocks) and the elements generating their changes over time (inflows and outflows) (Figure 2). The graphical elements adopted to make up the S&FD are listed below:

- elements of the system identified by brief descriptions;
- arrows connecting the elements of the systems in pairs (in the model in Figure 2 the solid lines represent delayed relationships);
- rectangles identifying stocks;
- pipes pointing into (adding to) the stocks (inflows);

- pipes pointing out of (subtracting from) the stocks (outflows);
- valves controlling the flows;
- clouds (sources and sinks for the flow).

In detail, to form the S&FD, we used the KPIs on the right-hand side of Figure 1, thus depicting the system structure from a quantitative point of view in order to obtain an SD-based BSC.

Overall, we remind that an S&FD aims to identify the processes of accumulation and dispersal of the resources of a complex system, representing, by means of a graph and the fundamental system structure (*loop*), the feedback processes related to the impact of any action on the situation to face in the future (Sterman, 2001). So, for instance, in Figure 2 *market share* fixes the *demand* and (depending on the inventory size) it generates the sales (*deliveries*). The volume of sales influences *daily end customers waiting, on the average* and subsequently, the *average daily end customer wait* (in days). Timeliness of deliveries represents a primary driver for *end user satisfaction* which, in turn, increases the *market share*.

Notably, for the business domain under investigation, monitoring customer satisfaction means keeping the market share, which could increase even further by B2C selling.

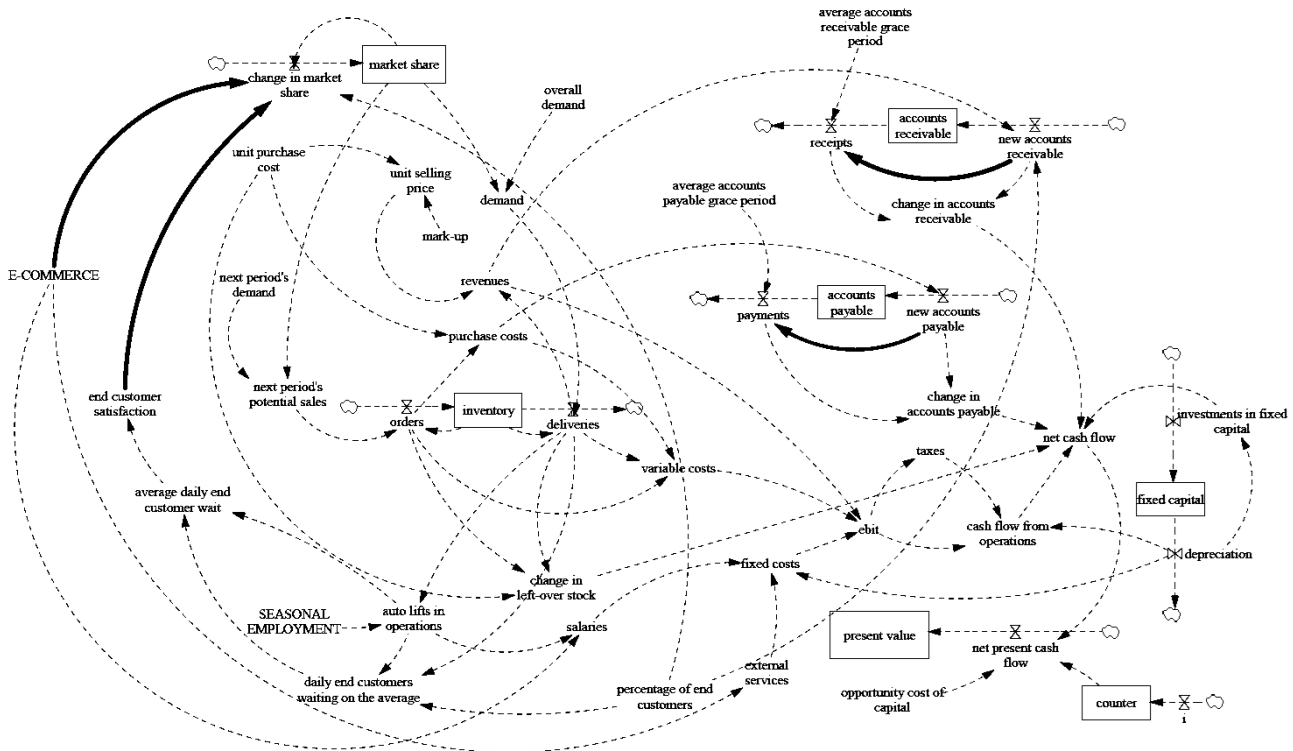


Figure 2 – Comprehensive stock and flow diagram

Moreover, in representing the S&FD in Figure 2, we used two additional conventions in order to improve its intelligibility: we showed the connections between the elements of the system by dash lines, and the names of the variables representing strategic choices are in capital letters (e.g., *E-COMMERCE*, which is technically a switch generating the value 0 if the organization decides not to use the Internet to sell its products and services, and 1 otherwise). Only a few relations are depicted by bold continuous lines in order to highlight that there is a delay between the occurrence of two different system elements (e.g., *changes in end customer satisfaction* do not produce immediate changes in the *market share* of the organization). Notably, in this SD-based BSC, start time is 0, end time is 36 and the time step is a month.

Scenario analysis

The third phase of the project entailed using the SD-based BSC to support scenario analysis.

With reference to this study three different scenarios were developed, analyzed and compared:

- Scenario A: only half of the productive capacity of the organization is used, B2C e-commerce is not implemented;
- Scenario B: all the productive capacity of the organization is used if required, B2C e-commerce is not implemented;
- Scenario C: all the productive capacity of the organization is used if required, B2C e-commerce is implemented.

At the beginning, only three of the six available auto lifts are in operation and during several months of the year, the demand generates some delays in the supply of services and some reduction in the variable *end customer satisfaction*, as measured by the managers' esteem on a 5-point rating (Figure 3).

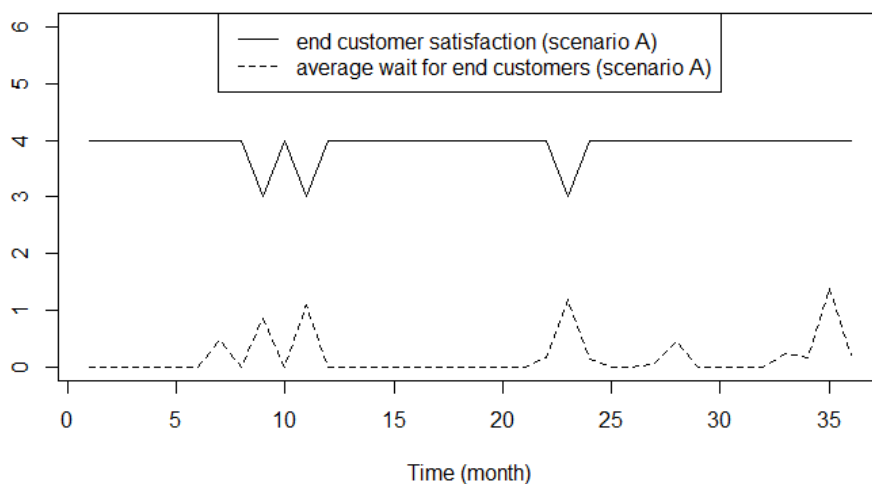


Figure 3 – Simulated data (Scenario A)

Seasonal employment during periods in which demand is very high reduces delays in the supply of services and keeps end customer satisfaction high. In practice, the variable seasonal employment could be seen as a switch enabling the opportunity for seasonal work when demand is higher than half of productive capacity. When this switch is turned on, delays in the supply of services decrease, and the *end customer satisfaction* remains unchanged (Figure 4).

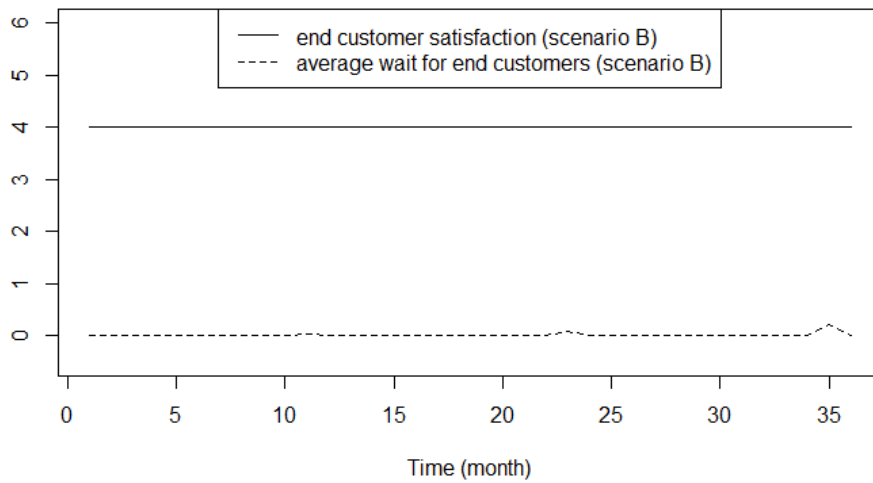


Figure 4 – Simulated data (Scenario B)

Figure 3 and Figure 4 describe only one of the possible trends for the two considered variables because the model in Figure 2 depends on several random variables (*market share, unit purchase cost, average accounts receivable grace period, average accounts payable grace period, percentage of end customers*). It is not correct to consider only one simulation in order to analyze the trends of variables along the same scenario and/or to compare the trends of variables referring to different scenarios; in that case, it could be useful to consider the frequency distribution of selected variables with reference to each month. In Figure 5 all simulation results on the *average daily end customer wait, end customer satisfaction and percentage change in market share* are shown.

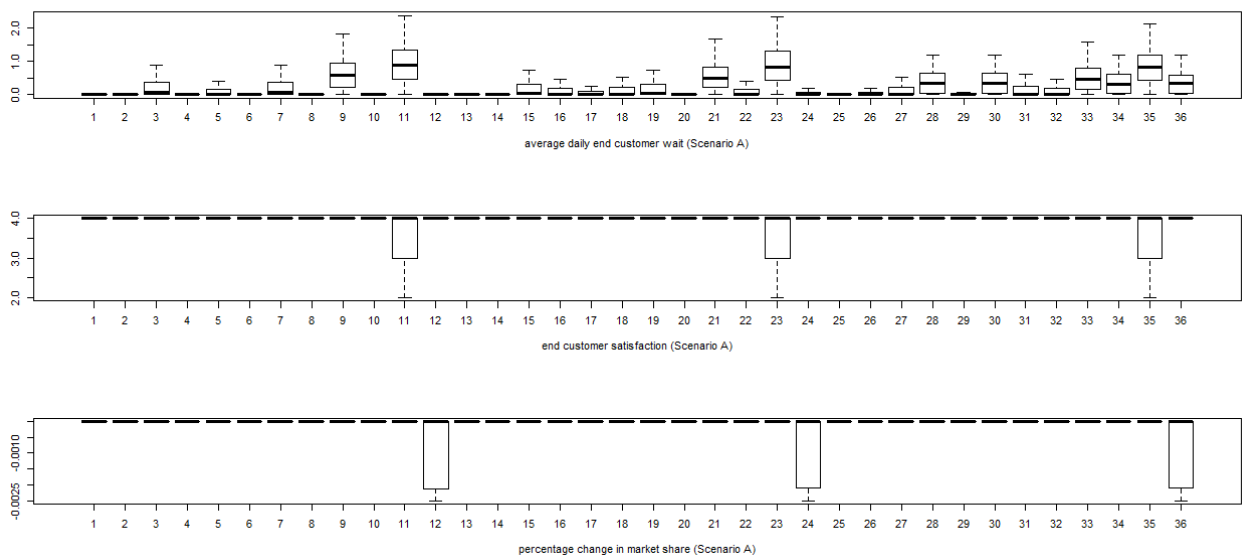


Figure 5 – Simulated data on lead and lag indicators (Scenario A)

The greatest variance of the monthly performance (in terms of *average daily end customer wait*) in the three-year period considered is in November of each year (upper part of Figure 5) and it causes

a high variability (and an obvious decrease) in the *end customer satisfaction* (middle part of Figure 5). The changes in the variables *average wait for end customer* and *end customer satisfaction* reduce the *market share* (*percentage change in market share* is negative). It is important to note that while *average daily end customer wait* and *end customer satisfaction* are concomitant, *percentage change in market share* is late for one month. The negative changes in the first two variables in November generate a decrease in the third variable in December. *Average daily end customer wait* and *end customer satisfaction* are lead indicators while *percentage change in market share* is a lag indicator. These causal effects are depicted in Figure 6 which represents a detail of the S&FD in Figure 2 and shows the polarities of the relations connecting the system elements and the loop involving them.

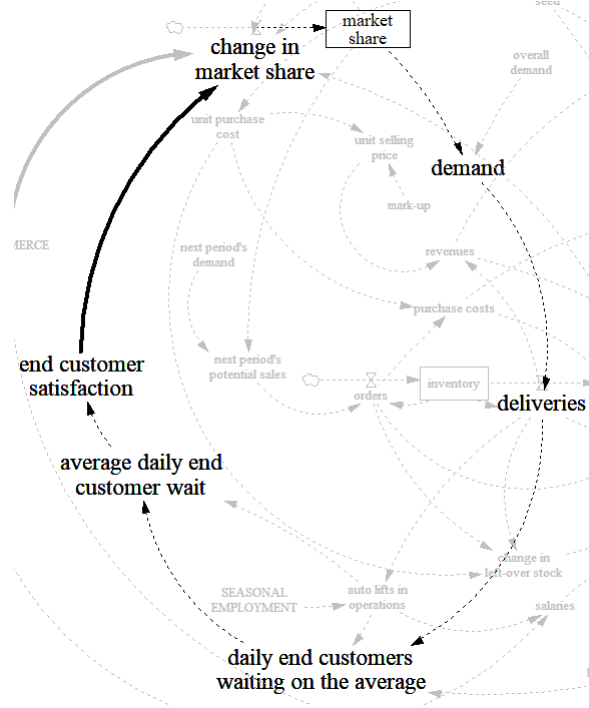


Figure 6 – Example of a negative loop (detail from the S&F diagram)

Figure 7 shows the impact of the changes in *average daily end customer wait*, *end customer satisfaction*, and *percentage change in market share* on the financial perspective.

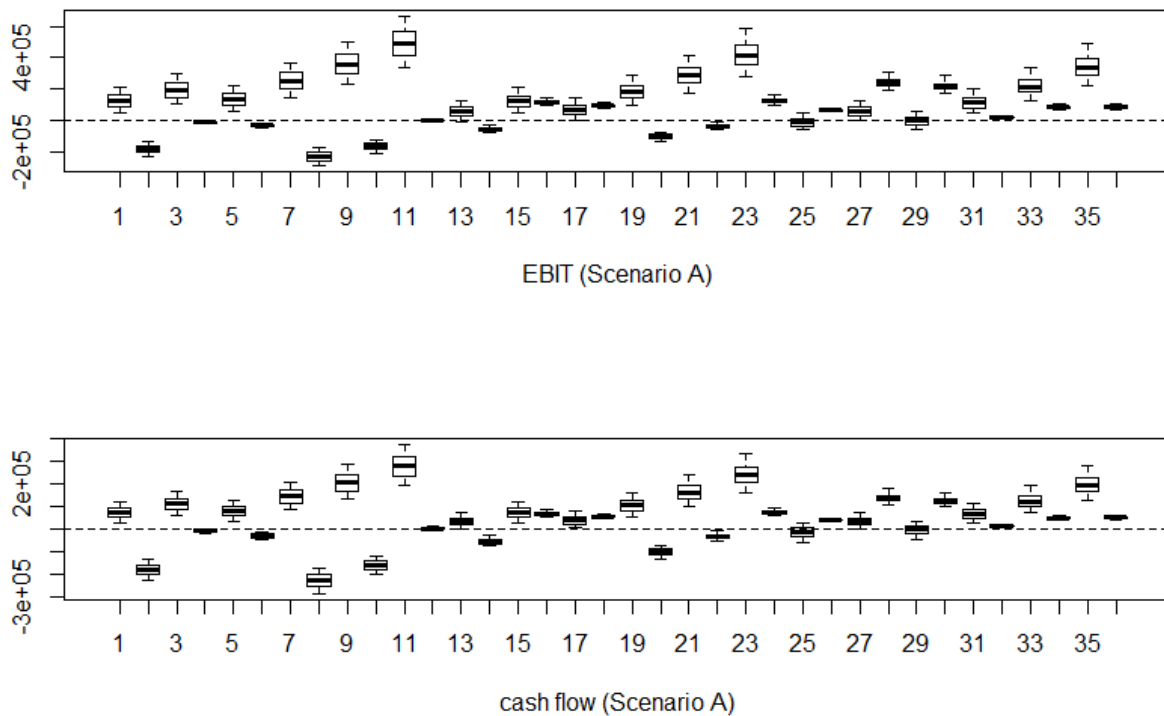


Figure 7 – Simulated data on EBIT and cash flow (Scenario A)

The boxplots in Figure 7 show the risk profiles for the financial indicators. The best income results will occur in November (of each year) but cash flows will probably decrease dangerously in periods 2, 8 and 10, exposing the organization to serious financial risk.

In order to evaluate the impact of the use of seasonal workforce on the firm performance, it is possible to turn on the switch labeled *seasonal work*. In the new scenario (Scenario B), characterized by a higher productivity and reduced waiting times, the situation seems to improve significantly. In fact, the recourse to seasonal workers decreases *average daily end customer wait*, leveling *end customer satisfaction* (at its highest value). Figure 8 shows these results.

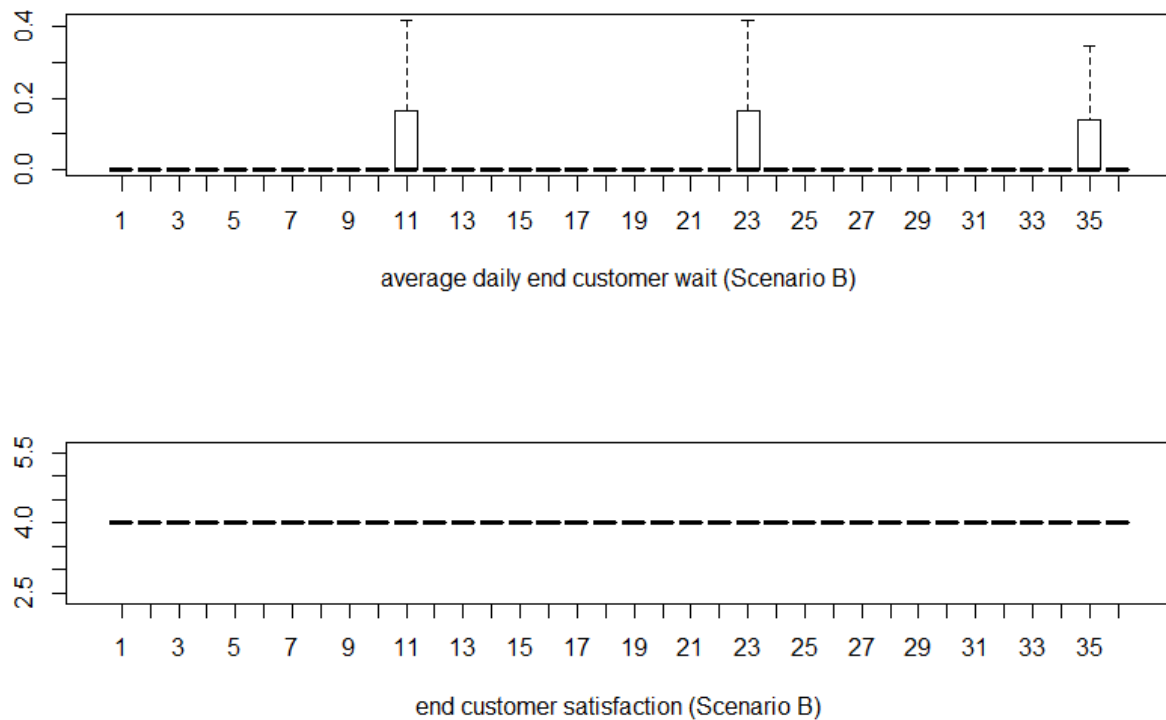


Figure 8 – Simulated data (Scenario B)

Until now SD modelling and data analysis have been used to show the impact of a certain policy on some selected KPIs. Moreover, it is possible to compare the results deriving from the implementation of different alternative policies and choose the most effective scenario. For this purpose, two examples of comparisons between alternatives are introduced and commented below. On a case-by-case basis, in order to choose the best options, simulation time series data related to specific KPIs in the model are analyzed using appropriate statistical tests.

The strategy evaluation

In order to assess which scenario is the most suitable to generate the best results for the organization, Scenario B and Scenario C were compared during the last phase of the project by verifying whether the Net Present Value (NPV) of cash flows related to Scenario C was greater than the NPV of cash flows generated without implementing B2C e-commerce (Scenario B). For this purpose, a paired *t-test* was used. This method is typically used for statistical inference analyses in which each value in one sample is *matched* (or *paired*) with another corresponding value in the other one. More profoundly, when comparing two treatments or groups in which the experimental units have important differences prior their assignments to the treatments or groups, the samples should be paired (Ott and Longnecker, 2015). In particular, we considered paired data referring to the simulation results for the final values (at the end of the three-year period) of the variable *present value* (for *scenario B* and *scenario C*). Once the differences in the 1,000 pairs of measurements ($d_i = npv_scenarioC_i - npv_scenarioB_i$) and the mean (μ_d) and standard deviation (s_d) in d_i s were computed, the proper t-test procedure could be developed:

$$\begin{aligned}
H_0: \mu_d &\leq 0 \\
H_a: \mu_d &> 0 \\
TS: t &= \frac{\bar{d}}{s_d/\sqrt{1000}}
\end{aligned}$$

RR: For a level $\alpha = 0.05$ Type I error rate and with $df = 999$, reject H_0 if $t \geq t_{0.05} = 1.65$

Before drawing conclusions, assumptions required to develop a t procedure must be checked. It can be verified that the sampling distribution of the d_i s can be assumed as a normal distribution. For this purpose, we used a quantile-quantile (Q-Q) plot which is a graphical method for comparing two distributions by plotting their quantiles against each other. The Normal Q-Q plot in Figure 9 highlights that the distribution of the d_i s can be actually assumed as a normal distribution because it is possible to observe an alignment of the points depicted with a line in the graph.

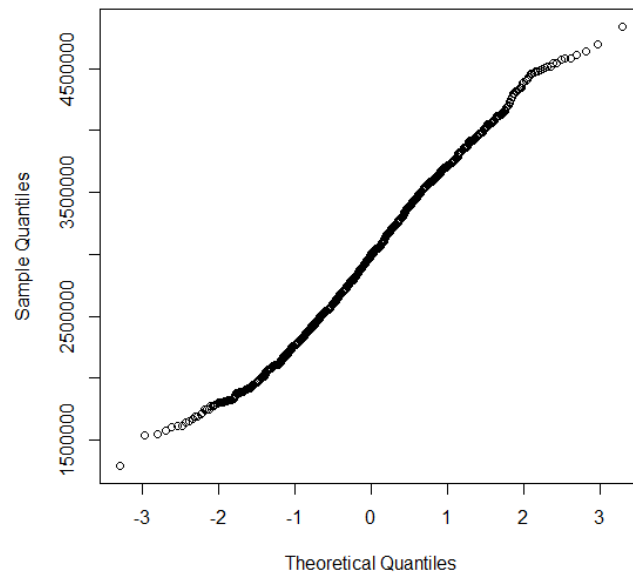


Figure 9 – Q-Q plot

Because t is about 140 (by far larger than 1.66), H_0 can be rejected and it can be considered that implementing B2C e-commerce means increasing the value of the organization (considering a three-year period). In fact, the NPV of the cash flows referred to in scenario C is greater than the value of the same variable referred to in scenario B. Generally, “nothing is gained without sacrifice” so what might happen is that increases in market share and sales generate negative impacts on the *end customer satisfaction*. The simulation data obtained can be used to validate, for example, that the change in the *end customer satisfaction* (considering simulation results referring to scenario B and scenario C), in each period, is negative (H_a), with respect to the change in the *end customer satisfaction* is zero or positive (H_0). The procedure used is the Wilcoxon Signed-Rank Test which considers the simulation results relating to all periods for the variable *end customer satisfaction*, referring to scenario B and scenario C. The Wilcoxon Signed-Rank Test is a nonparametric alternative to the paired t-test (Ott and Longnecker, 2015; Gibbons and Chakraborti, 2003). They are similar in aim, but the Wilcoxon Signed-Rank Test does not require that the population distribution of

differences be normal, although it requires that population distribution of differences be symmetric near the median (M). The proper Wilcoxon Signed-Rank Test procedure is resumed below:

$$\begin{aligned}
 H_0: M &\geq 0 \\
 H_a: M &< 0 \\
 T.S.: z &= \frac{T - \frac{1000 \cdot 1001}{4}}{\sqrt{\frac{1000 \cdot 1001 \cdot 2001}{24}}}
 \end{aligned}$$

R.R.: For a level $\alpha = 0.05$ Type I error rate, reject H_0 if $z < -z_{0.05} = -1.64$

H_0 can be rejected (B2C e-commerce would produce a negative impact on the *end customer satisfaction*) for over a half of the simulation period (19 out of 36 months) and concerns almost the whole third year of simulation (except for January), 7 out of 12 months of the second one and only the month of November of the first year.

5. Discussion

The results of the case study (including the final feedback received by the organization's managers at the end of the research project) may be now discussed accordingly to the threefold research aim of the article.

First, this study provides new evidence on the opportunity of combining the BSC model with other management tools and techniques, as advocated also by its developers (Kaplan and Norton, 2001, 2006, 2008a, 2012). Specifically, the introduction of the SD modelling principles (with the consequent development of an SD-based BSC) seems to be able of facing some critics opposed to the BSC adoption and contemporarily enhancing some key success factors of the model.

Indeed, as observed reviewing the relevant literature on the topic, several studies support Kaplan's (2012, p. 539) view when he claims that the BSC can be successfully implemented both in private and public organizations to assist in strategic planning, as it represents the "foundation of an entirely new system for strategy management and execution". However, other scholars have also advanced some doubts on the BSC capacity of supporting guidance on causality (Nørreklit, 2000 and 2003; Nørreklit *et al.*, 2012), and subsequently of facilitating the analysis of the functional relations between events, as advocated in any strategic planning. Indeed, although strategy maps show causal relationships between goals and policies, a number of misunderstandings may occur due to a lack of knowledge ascribable to their modelling and construction, mainly considering that strategy maps - centered on the four perspectives of the BSC framework - have necessarily to be selective and contain a reduced number of indicators.

The evidence offered by our case study demonstrates how combining the BSC model with SD principles may face this limitation and enhance the BSC effectiveness in supporting guidance on causality. Indeed, comparing the strategy map of our case study with the related S&FD, further useful insights on the organization and its processes may be gained. In the S&FD, stocks (e.g., *inventory*), flows (e.g., *deliveries*), and auxiliary variables are marked, each in a different way, in order to differentiate variables which are substantially and deeply dissimilar. Moreover, emphasizing the stocks in a system means giving attention to what provides systems with inertia and memory, and is the source of the delays which are responsible for oscillatory trends (in historic/conjectural time series data used to construct the reference modes). Basing on these principles, the SD-based BSC is then

able to describe the business domain under analysis adopting a holistic point of view, representing all of the connections among elements accordingly to the *systems thinking* approach and the assumption that “everything is connected to everything else” (Sterman, 2001, p. 10). Moreover, the structure of the SD-based BSC, consisting of stocks, flows, and feedback loops, supports the understanding of how causality actually operates within the business domain under analysis, subsequently supporting managers to make sense of the effects of the actions carried out through the identification of the underlying causes. At the same time, this process also enables the managers to anticipate the consequences of their strategic decisions. In the end, the integration of BSC and SD modelling enables the development of a comprehensive approach to strategy formulation and implementation and, more importantly, provides a more reliable basis upon which identifying, testing and exploiting sound *cause-and-effect* relationships, within a specific BSC. The final feedback obtained by the three managers involved in this case study confirmed the SD capacity to enhance this key success factor of the BSC model, specifically emphasizing its potentials in describing the causal relationships between the components of a strategy map, as well as in providing several graphical and numerical tools to depict strategy maps from a systemic point of view. Specifically, the managers particularly appreciated the support provided by the SD-based BSC in representing and discovering the mechanisms of how their business domain concretely worked, thus confirming the increased potentialities of the BSC modelling in favoring coordination and self-monitoring (Malmi, 2001; Wiersma, 2009).

Second, this article exemplifies how an SD-based BSC can be used in combination with statistics to evaluate different scenarios and mutually exclusive policies. Indeed, an S&FD allows implementing simulation processes to evaluate the risk profile of estimated variables. When faced with a stochastic system (a structure containing at least one random variable) there are many possible predictions. Every time new random values are drawn, the model generates different results, so it becomes very useful to know the frequency distributions of the variables, in order to estimate the probability (for the desired value ranges) and to test hypotheses about their trends. To implement the simulation process, this study specifically adopted statistical hypothesis testing to compare the financial and non-financial performance of the organization in the three defined scenarios over the simulation period. Financial and non-financial indicators were produced running the SD-based BSC according to the amount of the stock resources, the typology of the defined loops and the equations inserted in the model.

In the end, the combined use of the SD-based BSC with statistics allowed identifying which scenario was the most favorable for the organization basing on the forecasted impact of the B2C e-commerce implementation on the NPV of the cash flows without compromising the *end customer satisfaction*. This result demonstrates how adopting SD and statistics may increase the strategic effectiveness of the BSC model, specifically supporting scenario analysis. Indeed, although the causal relationship between goals and KPIs is straightforward, often strategy maps do not clarify the policies aimed at achieving desired levels for the chosen KPIs. Strategy maps, in the description of policies and the definition of goals, use a text mode and a conversational style, making it difficult to elucidate feedback loops and other systemic structures. Also, although strategy maps contain target values for selected KPIs, the nature of the tool does not allow performing simulations (considering different scenarios), or connecting results referring to variables with different metrics, or comparing unlike options by passing judgment on them.

As verified in our case study, the combined use of a BSC and SD instead not only allows the development of a more comprehensive and quantitative model of the strategy and the business domain under analysis, but also contributes to extensively testing and revealing “hypothesized relationships among BSC variables: such statistical analysis enables managers to estimate historical relationships among Balanced Scorecard measures and to establish the validity of the causal linkages in the strategy map” (Kaplan, 2012, p. 244). In detail, despite the initial hesitation related to the simulation process (perceived as quite complex), the three managers confirmed the support provided by the combination of the SD-based BSC with statistics to improve their decision-making and, particularly, to evaluate the consequences of strategic decisions such as the implementation of the B2C e-commerce. On this point, the action research approach has proved to be particularly useful to overcome the initial hesitation and facilitate the implementation of the simulation process by favoring the development of the practical knowledge required through the interaction between researchers and practitioners (Reason and Bradbury, 2001).

Third, the article contributes to emphasizing the role played by statistics not only in validating the SD-based BSC (Barlas, 1996) but also in increasing managers’ confidence in its reliability. This was directly confirmed by the three managers involved in this case study. First of all, they were favorably impressed by the results of the simulation process that was able to make clear some perceived problems of their organization, such as the liquidity tensions linked to the seasonality affecting sales. Moreover, comparing the alternative result distributions, they were persuaded to implement in their organization the B2C e-commerce, thus introducing the possibility of buying or reserving the services provided directly through the online system. Notably, the adoption of statistics in increasing the reliability of the SD-based BSC is assisted by the same structure of an S&FD that, corresponding “exactly to a system of integral or differential equations” (Sterman, 2000: 229), may facilitate the insertion of equations and compute values.

6. Limitations and further research

This article contributes to exploring the potentials of an SD-based BSC developed and implemented to produce simulated data in order to support strategic decision-making and evaluate different alternative scenarios and strategic choices. To conduct the study, first we surveyed the relevant literature and identified the key strengths of the BSC model, as developed by Kaplan and Norton (1992, 1996a, 1996b, 2000, 2004), then we relied upon the evidence offered by a case study to analyze the potentialities of combining the BSC model with SD principles and statistics.

Rather than by focusing on the BSC model itself, this article adds new evidence on the potentialities of combining the BSC with SD principles and with statistics mainly in terms of the strengthening of some success factors of the BSC, support to the decision-making process, and enhancement of the managers’ confidence in the reliability of the BSC model.

However, this article also has some limitations that anyhow provide the basis for further research. Above all, the method we suggest was applied only to one organization. Future research may be oriented towards developing other case studies, from different industries. Moreover, to validate the SD-based BSC we adopted one specific statistical technique. With reference to future research, additional tools could be relied on - such as Structural Equation Modeling - also to develop further the implementation of an SD-based BSC, thus adopting a comparative perspective which could highlight the peculiar features, strengths, and drawbacks of such techniques, while providing more evidence from the field.

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