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Performance Assessment of an Operations Strategy under Uncertainty Integrating BSC Logic and Monte Carlo Simulation

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ABSTRACT: *This article discusses an approach to assess operations strategy (OS) performance in the face of uncertainties in lead measures, based on balanced scorecard (BSC) logic and Monte Carlo simulation (MCS). Most OS approaches assumed deterministic measures, implying their robustness and that uncertainty could be neglected. Since uncertainty has increasingly become a widespread concern in present operations, companies must consider stochastic tools to obtain sound OS performance estimates. To illustrate and examine the approach, this article presents a case study of a Puerto Rico manufacturing company, whose OS map was analyzed via MCS. The strategy map was validated utilizing structural equation modeling (SEM).According to this study; integrating MCS enhances understanding of relationships among measures, quantified by metrics, improving the likelihood of success. The approach should be tested in other contexts and with other methods to provide generalizability. Similar approaches could help organizations to assess values or constructs related to OS with a slew of significant uncertainties. This study is a stepping stone toward building a risk-management theory in the OS context.*

Keywords: Operations strategy, Monte Carlo simulation, balanced scorecard.

In the current uncertain and unstable competitive environment, measures' variability has become a crucial issue for many organizations (Bromiley, McShane, Nair & Rustambekov, 2014; Dobler, Lajili & Zéghal, 2014).Decision makers must manage and respond to variability, while striving to achieve fully aligned organizational events, creating and sustaining competitive advantage (Christopher & Towill, 2002). To this end, they must balance key operational decisions that drive customers' offering, while establishing a more resilient organization. Assessing those decisions requires an integrated approach linking operations strategy (OS) activities with stochastic tools such as Monte Carlo simulation (MCS).

Since the mid-1900s, numerous management practices across various organizational contexts have studied measures' variability. Foreseen and unpredicted variability can strain an organization, delaying or undermining essential strategic planning efforts. Considering significant challenges faced due to this state of affairs, businesses must integrate more systematic approaches into OS planning.

Studying uncertainty in operations management (OM) under risk management (RM) has become increasingly popular. Current practices presented in business literature vary in their use of terms and approaches, focusing on particular categories of uncertainty or business contexts such as projects, processes or supply chain (Ambulkar, Blackhurst& Grawe, 2015; Browning, 2014; González-Loureiro, Dabić & Kiessling, 2015).Whilein the RM literature it seems to be a consent on the term "uncertainty"as an instance where decision makers are unable to ascertain an event's probability or impact, and to "risk" as circumstances where probability is known (Merkurjevs, Kļimovs & Soško, 2007; Van der Vorst & Beulens, 2002), in this study these terms are used interchangeably.

Recent studies concluded that OM decisions and RM are related and should consider both quotidian and exceptional risks based on continuous risk assessment, reducing vulnerability and ensuring continuity (Chiang et al., 2014; Walker, Klassen, Sarkis & Seuring, 2014;Jüttner, 2005).While most studies consider variability spawned by risks a drawback, this variability could represent opportunities to replace existing productive capital with more resilient, robust, and efficient operational assets (Andresen, 2015; Power, 2008;Hillson, 2002).

This research draws on a balanced scorecard (BSC)/strategy map approach and MCS sampling. This article is structured as follows. First, it establishes fundamental BSC and OS concepts. Then, the approach is theoretically grounded and explained using a case study analysis of a Puerto Rico manufacturing company, whose name was redacted for confidentiality issues. Finally, the article concludes and discusses implications and areas for further research.

Literature Review

BSC assumes systemic links between the organization value drivers' components. These relationships may be clearly depicted on a strategy map (Kaplan & Norton, 1996).This map is a fundamental BSC tool, showing lead measures (or actions) and lag measures (or performances) in cause-and-effect relationships (Hoque, 2014; Melnyk, Bititci, Platts, Tobias& Andersen, 2014; Maltz, Shenhar& Reilly, 2003). However, if not validated by empirical evidence and statistical analysis, particularly by SEM, this assumption may be a disadvantage of BSC. If a hypothesis is represented in anon-statistically validated strategy map, it will only present rational connections between the four BSC measure perspectives, not causal relations, leading to incoherent measures and conclusions. Even when a strategy map has been statistically validated, lead measure point estimates are employed to justify strategy execution. Thus, another downside is the assumption of deterministic measures, denoting their robustness and that uncertainty could therefore be disregarded, which, in general, is inaccurate in OS decisions.

Operations Strategy

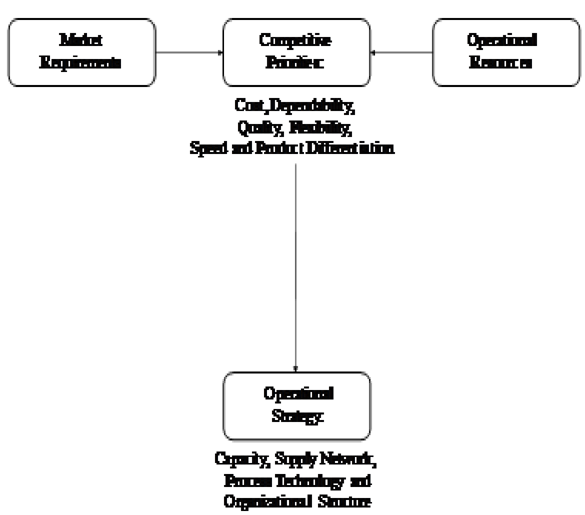
Until the late 1960s, business and corporate strategies were primarily geared towards marketing and financial priorities. In his seminal work, Skinner (1987) identified a gap between OM and corporate strategy in manufacturing organizations: the absence of manufacturing elements and concerns in most manufacturing companies' strategy planning.OM was constricted to a century old paradigm that emphasized mass markets, stable productions lines, standard designs, and mass production, and whose primary goal was to develop and manage all necessary systems and processes to meet those priorities and restrain production costs(Hayes & Pisano, 1994).

In the early 1980s, the rise of worldwide competition and technology imposed greater pressure on organizations to become highly responsive to their markets. As a result, a paradigm shift emerged as manufacturing strategies needed to (1) exploit specific core competencies, and (2)coordinate all functional efforts, supporting a particular competitive priority(i.e., cost, dependability, quality, flexibility, speed or product differentiation).During this period, Hayes &Wheelwright's (1984) manufacturing strategy definition ("…the deployment and development of manufacturing capabilities in total alignment with the firm's goals and strategies...") became a buzzword. At this juncture, most studies pondered (1) the competitive priorities trade-off, (2) order-winner and qualifiers, and (3) core competencies' identification and development (Hill & Hill, 2009).

During the 1980s, the OM function became crucial to obtain competitive advantage. Furthermore, services became the fastest-growing economy sector, giving rise to the OS concept, as opposed to the traditional manufacturing strategy. Simultaneously, researchers warned about counterproductive organizational behaviors, such as "Manufacturing Myopia" and the "Bullwhip Effect," caused by ignoring strategic implications when expending operational resources (Maylor, Turner & Murray-Webster, 2014; Skinner, 2007;Berry & Hill, 1992).By the end of the decade, a surge in studies and initiatives relating OM to other organizational functions was evident (Miller& Roth 1994; Adam& Swamidass, 1989). Practitioners and researchers integrated new theories, methodologies and concepts into OS, and the growing service sector demanded specialized tools and frameworks to manage service firms' operations(Slack, Lewis & Bates, 2004).In retrospect, the 1980s constitute OS' origin as a field of study.

Nowadays, some competitive priorities are considered synergistic and simultaneously attainable, namely, improving performance in one enhances performance in another. A general consensus exists that OS' main concern is reconciliation of primary market requirements with OS decisions (capacity, supply network, process technology, and structure).Hence, OS is critical to the organizations' transformation process, philosophy, and long-term and aggregate capabilities (Jayanthi, Roth, Kristal& Venu, 2009; Meredith, 1994).Figure 1illustratesthe OS constructs that describe the prevailing reconciliation model with major interacting measures groups that drive strategic operational considerations.

Figure 1. Operations strategy constructs



Balanced Scorecard and Strategy Map

According to Kaplan and Norton (1996), BSC enhances long-established financial measures by adding three non-financial perspectives: customers, internal business processes, and innovation and learning.(Authors may use different terms across studies.)Since companies create value through customers, grasping how customers view performance becomes a major component of performance measurement and its financial derivatives. The internal-business-processes perspective concerns transformation processes to provide goods and services that meet customer requirements (Othman, 2006).The innovation-and-learning perspective identifies actions an organization must build to create long-term growth and foster an improvement environment. It includes employee training and corporate culture related to both individual and company's self-improvement. Nonetheless, within BSC financial measures remain an important dimension, as they specify whether a company's strategy implementation and execution contribute to end-result outcomes (Luft, 2009).Hence, altogether, the four BSC perspectives enable organizations to trail developments and necessary resources for acquiring desired financial and operational performances (Sim & Koh, 2001).

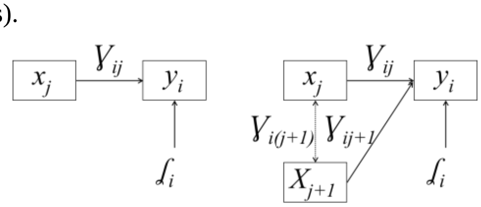
Three BSC generations exist. The first employs a few measures in each perspective, which could imply the use of 10 to 25 metrics. Given that BSC requires a limited number of metrics for each dimension, it aids organizations to focus on their strategic vision and operational actions. Figure 2 shows fundamental elements of all perspectives.

Figure2. The Balanced scorecard

First generation approaches greatest achievement was complementing traditional financial measures with non-financial measures, stressing the importance of viewing the organization from different perspectives and the necessity of developing KPIs to all perspectives. The emphasis in second generation practices was on adding strategy maps that showed causalities between non-financial and financial measures, and the specification of action plans to achieve specific targets. However, limited stakeholder participation in BSC formulation process was a latent ambiguity and weakness of first and second generation BSC approaches .Kotter (1995) and Senge (1990)stated that these two generations' approaches disregarded wide participation in the formulation process, hampering the understanding of a shared organizational vision.

In the late 1990s, Cobbold and Lawrie (2002) acknowledged new approaches based on management and stakeholder participation, referring to these approaches as "third-generation BSC."Third generation approaches try to eliminate the shortcoming of First and Second generations' approaches, adding greater functionality providing a framework which were adaptable to the changes in the organization's dynamic environment and a clear destination statement useful as a reference point for setting of the organization's objectives(Savsar, 2015; Neely et al, 2003.)Empirical research confirmed how this new generation BSC has been successfully applied as a strategic control tool in both private and public organizations (Lawrie, Cobbold, & Marshall, 2004;Robson, 2004; Shulver & Antarkar, 2001).

In BSC, the main tool to outline and communicate strategy is a strategy map, comprised of metric-estimated lead and lag measures. Leading measures (or performance drivers) reflect indispensable actions to cause a needed change. Lagging measures (or outcomes) are effects of implementing leading actions. Financial measures are lag measures, and learning-and-growth measures are lead measures. Consequently, causality is measured by studying relationships between leading and lagging measures. The following general path diagrams provide a conceptual structure for modeling causal relationships. These diagrams are based on actual expected actions or outcomes of each measure, usually referred to as "metrics" or "key performance indicators" (KPIs).



In the first path, the model tests the causal of x_j on metric (y_i), specified in terms of equations as:

$$y_i = \gamma_{ij} x_j + \zeta_i \text{ for } i=1,...m \text{ and } j = 1,...,n$$

In the second path, the model tests the causal of x_j and x_{j+1} on metric (y_i), stated in terms of equations as:

$$y_i = \gamma_{ij} x_j + \gamma_{i(j+1)} x_{j+1} + \gamma_{j(j+1)} x_j x_{j+1} + \zeta_i \text{ for } i=1,...m \text{ and } j = 1,...,n$$

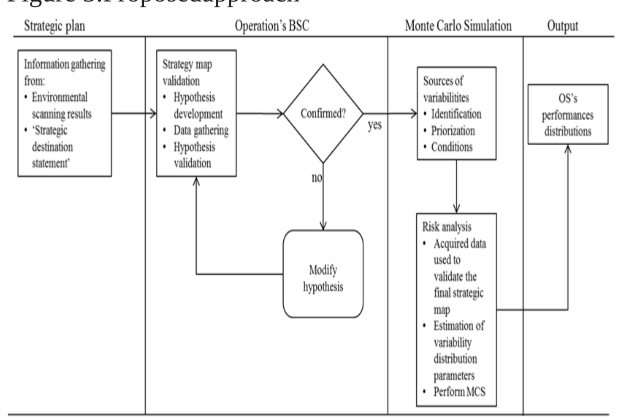
where $\gamma_{j(j+1)} x_j x_{j+1}$ represents the interaction between x_j and x_{i+1}.

Methodology

The approach is a procedure for thinking proactively about potential variability in lead-measure metrics and the effects on lag-measure metrics associated with the customer perspective. To illustrate this approach, the article puts forth a Puerto Rico manufacturing company (the "Company" or the "Entity" or the "Enterprise") case study. As(1) its parent company considered the Company a cost center and (2) the study focused on operational resources' elements, which in the BSC context are associated to learning and growth, and internal business processes, the study did not consider the financial perspective, as shown in Table 1.

Comprised of sequential procedure shown in Figure 3, the approach begins with strategic plan information. The Entity summarized its strategy in a destination statement, as advised for building third BSC generation strategic maps (Janeš, 2014; Lawrie &Cobbold, 2004).From prior information, the company developed a strategy map that reflected and summarized the OS hypothesis, validating goodness-of-fit with SEM. Then, searching the SEM database for each metric ,it applied a simulation analysis to generate various scenarios and identify probable input ranges (lead-measure variables) and expected performance outcomes (lag-measure variables), drawing several conclusions.

Figure 3.Proposedapproach



Discussion

The Enterprise compiled its proprietary database via various methods, including internal reports, surveys, interviews, and meetings. The information was available at its offices head quarters only for analysis purposes. The Entity had 75 data samples, each containing information on 15metricscollected monthly, and tested each metric for reliability and validity, including Cronbach's coefficient alpha. The results were as follows:

Metric?	T1	T2	S1	S2	PP1	PP2	SP1	SP2	CS1	CS2
α?	0.87	0.91	0.82	0.90	0.79	0.81	0.82	0.78	0.87	0.84

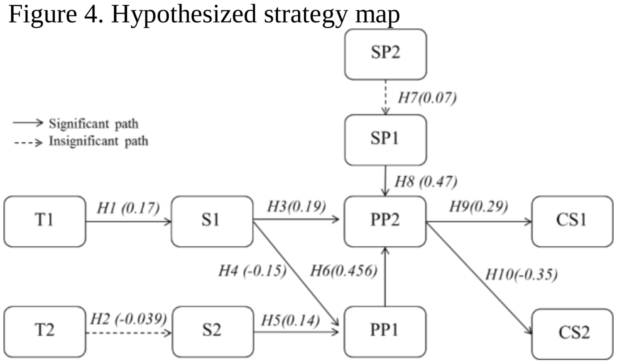
Also, the ratio($\frac{\chi 2}{\text{degrees of freedom}}$)was less than 3,p-valuewas above0.05, and goodness-of-fit index was above 0.9, thus, the model fit the data. Table 1 lists and describes the final leading and lagging measure metrics used in this study.

Table 1.List of measures and metrics

Perspective	Measure	Metric	Description	Units
Learning and growth	Training	T1	Total days of training per floor employee	Days
		T2	Total days of training per administrative personnel	Days
	Staff	S1	% Floor employees on total employees	percentage
		S2	Employee absenteeism	percentage
Internal business processes	Process performance	PP1	Equipment downtime	percentage
		PP2	Overall product quality	0-100 scale
	Supplier performance	SP1	Percentage of incoming shipments acceptable	percentage
		SP2	Percent of suppliers certified	percentage
Customer	Customer satisfaction	CS1	Customer retention rate	percentage
		CS2	After delivery complaints	number of complaints

Once all data were collected, parsed, and organized, the Enterprise divulged the information to management, who developed the OS map. Figure 4 states these results and shows the standard coefficients between metrics. This map represents the hypothesized cause-and-effect relations among main OS elements.

Figure 4. Hypothesized strategy map



The first eight hypotheses (H1-H8) represent relationships among endogenous metrics. For instance, concerning the link between T1 and S1, the hypothesis was"H1: Total days of training per floor employee had a positive impact on % Floor employees on total employees."The other links among endogenous metrics followed the same definition pattern. The last two hypotheses, H9 and H10, were related to OS performances ("customer retention rate" and "after delivery complaints").The lag-measure metrics equate canonical variants used in SEM analysis. Table 2 provides summary statistics on the hypotheses.

The Table 2 results led to various conclusions.H5 and H6 predicted that (a)"% floor employees on total employees" and (b) "employee absenteeism" were associated with (c) "equipment downtime."As expected, these relations' directions were negative and positive, respectively. However, the results did not support two hypotheses,H2 and H7, and no significant correlation between "total days of training per administrative personnel" and "employee absenteeism" was found. Further consideration revealed that "available training hours" did not differentiate between management's training hours by occupation. Management found interesting the weak relationship between "percent of suppliers certified" and "percentage of incoming shipments acceptable." Recently, the Entity established a supplier certification program, attempting to gain competitive edge in certain logistics elements and improving their suppliers' on-time delivery.

Table2.Results for hypothesized model

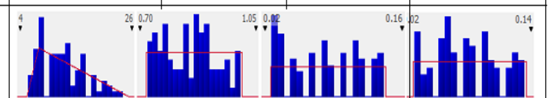
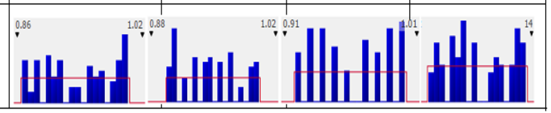
Dependent variable	Independent variable	Hypothesis	Direction of hypothesis	Std coefficient	*p*-value
% Floor employees on total employees	Total days of training per floor employee	*H1*	+	0.173	0.11
Employee absenteeism	Total days of training per administrative personnel	*H2*	-	-0.039	0.02
Overall product quality	% Floor employees on total employees	*H3*	+	0.191	0.07
Equipment downtime	% Floor employees on total employees	*H4*	-	-0.152	0.23
Equipment downtime	Employee absenteeism	*H5*	+	0.143	0.8
Overall product quality	Equipment downtime	*H6*	-	-0.465	0.11
Percentage of incoming shipments acceptable	Percent of suppliers certified	*H7*	+	0.071	0.01
Overall product quality	Percentage of incoming shipments acceptable	*H8*	+	0.476	0.07
Customer retention rate	Overall product quality	*H9*	+	0.292	0.11
After delivery complaints	Overall product quality	*H10*	-	-0.355	0.14

Once management statistically validated and endorsed the model, the Enterprise (1) studied the variability sources of lead-measure metrics, (2) incorporated probability distributions for each lag-measure metric in the OS map model, (3) ran MCS, and (4) assessed the impact of variability of lag-measure metrics. It had documented the variability sources and supplied them for this study. Using version 6.01 of Palisade's @Risk Software, it estimated probability distributions and ran MCS. Table 3 shows these probability distributions. Due to the paucity of causal evidence of metrics T2 and SP2,it excluded these metrics from further analyses. Based on the Akaike information criterion (AIC), the MCS results indicate that the metrics' probabilities distributions were better fitted by uniform distributions, excepting "total days of training per floor employee," which was better fitted with a triangular distribution. In terms of the simulation, the only significant correlation between metrics (0.67) with validated relationships was between "equipment downtime" and"% floor employees on total employees." Utilizing @Risk CORRMAT function (Palisade Corporation), which is used to correlate sampled values of at least two variables, the Company included this correlation in the simulation model.

The value of the lag-measure metric "customer retention rate" varied from 92 percent to 100 percent. Systemically, the metrics that most impacted this metric were "overall product quality," a direct link, and "employee absenteeism, "an indirect link, highlighting the need to implement initiatives to reduce absenteeism, such as organizational support to improve job satisfaction and enrichment .These initiatives would have an indirect impact on (1) "process quality" and, eventually, (2) "overall product quality," closing the "customer retention rate" range.

"After delivery complaints, "the other lag-measure metric, varied from 0 to 14 complaints per month. A previous benchmark study commissioned by the Company concluded that the company's strategic group had an average of nine delivery complaints per month, and that its relative position was at least "parity" in that group, and with some effort, the Entity could transform this metric into an "advantage." As in the previous case, "overall product quality" had a direct effect on lag-measure metrics, as did "% floor employees on total employees." The cited initiatives had a direct bearing on this metric. Moreover, at the other end of the supply chain, initiatives related to customer relationship management could have been implemented to complement these efforts. Summarizing, these findings suggest that if the Company develops and executes initiatives aimed at improving lead-measure metrics, the systemic effect would close lag-measure metrics gaps.

Table 3.Results for hypothesized model

Name	T1	S1	S2	PP1
Best Fit (Ranked by AIC)	Triangular(5.751,8,25.086)	Uniform(0.727,1.003)	Uniform(0.029,0.141)	Uniform(0.001,0.131)
Function	12.945	0.865	0.085	0.065
AIC	497.633	-224.922	-384.755	-355.012
Minimum	5.749	0.727	0.029	0.018
Maximum	25.086	1.003	0.141	0.132
Mean	12.945	0.865	0.085	0.065
Mode	8	0.727	0.029	0.001
Median	12.233	0.865	0.085	0.065
Std. Deviation	4.317	0.080	0.033	0.038
Graph				
Name	PP2	SP1	CS1	CS2
Best Fit (Ranked by AIC)	Uniform(0.869,1.001)	Uniform(0.898,1.001)	Uniform(0.919,1.001)	Uniform(0.148,13.148)
Function	0.935	0.95	0.96	6.500
AIC	-355.0196	-401.720	-441.44	464.701
Minimum	0.869	0.899	0.919	0.1477
Maximum	1.000	1.000	1.000	13.148
Mean	0.935	0.95	0.96	6.5
Mode	0.869	0.899	0.919	0.148
Median	0.935	0.95	0.96	6.5
Std. Deviation	0.038	0.029	0.024	3.838
Graph				

Conclusion

This study shows a sound approach that incorporates BSC and MCS operations strategy development. Merely developing and validating an OS map does not guarantee an organization's success. OS may fail when the model is based on flawed assumptions, such as assuming deterministic (point estimate) measures, implying their robustness and that uncertainty may be ignored. This issue could be addressed by incorporating MCS, which provides a reliable process for formulating and implementing OS. An MCS model was defined to identify the dynamics in lead-measure metrics associated to operational resources. The recommendations are based on the assumption that managing performances in companies consists of continuously orchestrating initiatives related to lead-measure metrics, which have direct and indirect impact on lag-measure metrics. The presented case study of a Puerto Rico manufacturing company supports this assumption.

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