A hybrid multi-criteria decision model for performance evaluation of sustainable supply chain

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Summary Abstract

The implementation of Sustainable Supply Chain Management (SSCM) is at the forefront of organizational activities. However, with a lack of unanimity regarding the implementation of Key Performance Indicators (KPIs), and the ambiguity surrounding decision making in this turbulent and chaotic environment, it is a tasking process. This paper brings together the KPIs identified from literature and practice via Systematic Literature Network Analysis (SLNA) and Text Mining. Subsequently, this paper evaluates and weights these KPIs through expert opinions via an online survey grounded on a 4-level hierarchical Multi Criteria Decision Making (MCDM) model hinged on FAHP, FTOPSIS and TISM.

Keywords:

Multi Criteria Decision Making, Text Mining, Sustainable Supply Chain

Purpose

Sustainable supply chain has received a great interest from customers, firms, governmental organizations and academia in response to the escalated deterioration to the environment (Touboulic & Walker 2015; Tseng et al. 2013; Lim 2011; Carter & Easton 2011; Nathalie Fabbe-Costes et al. 2011; Gold et al. 2010; de Brito & van der Laan 2008; de Brito et al. 2008). Despite a growing research in this area, very limited research considered all three dimensions of sustainability (i.e. economic, environmental and social dimensions as outlined in the Triple Bottom Line (TBL)). One of the main challenges in this context is the broad range of influencing factors, key performance indicators and metrics associated with TBL of sustainability that need to be considered and many of which could not be fully integrated or measured (Sarkis et al. 2012; Liu et al. 2012; Winter & Knemeyer 2013; Wu & Pagell 2011; Carter & Rogers 2008; Markley & Davis 2007). There has been empirical evidence to support the hypothesis that distinct relationships exist between different dimensions of sustainability. However, the existing literature lacks in establishing inter-relationship among the KPIs and pinpointing the most influencing KPIs and metrics of sustainability. Accompanied with the lack of unanimity, both within the academic and practical fields, regarding the best KPIs to be utilized for the assessment and implementation of Sustainable Supply Chain Management (SSCM). This creates a research gap in the existing literature, wherein this paper aims to:

- Identify KPIs and metrics, which are most important in SSCM implementation based on the identification of current practices of organizations and opinions of sustainability experts.
- Establish the inter-relationship among the identified KPIs.
- Apply a hybrid methodology built on Systematic Literature Network Analysis, text mining of sustainability reports of global manufacturing firms, multi criteria decision making (MCDM) techniques and inter-dependency modelling.
- Develop research, which will allow organizations to better assess their sustainability decisions and performance while focusing their efforts on the most detrimental KPIs and metrics.

Design & Methodology

After completing a Systematic Literature Network Analysis (SLNA) (Colicchia & Strozzi 2012) of literature, and uncovering the Key Performance Indicators (KPIs) and organizational theories outlined therein. Accompanied with the Text Mining and content analysis of the sustainability reports of the top and bottom 50 manufacturing organizations worldwide; outlined in the fortune 5000 listings of 2015, and conducted through accumulation of the most recent reports from the company websites, their categorization, pre-processing and subsequent manual evaluation based on the codes established vis-à-vis the identified theories and KPIs from the literature. Subsequently, leading to the realization of the key themes and KPIs from both literature and practice, as can be seen in Table 1.

Table 1 - Table of KPIs

	Key Performance Indicator (KPI)	Code	Description	Main Source
Economic	*Operational*			
	Operational costs	EO1	Costs of running operations	(Morana et al. 2014)
	Customer satisfaction rates	EO2	Rates of customer satisfaction	(Morana et al. 2014)
	Production Efficiency	EO3	Efficiency of production rates	(Gunasekaran et al. 2001)
	Inventory costs	EO4	Costs of inventory holding	(Gunasekaran & Kobu 2007)
	Production flexibility	EO5	Flexibility of production processes	(Gunasekaran & Kobu 2007)
	Strategic			
	Investment costs	ES1	Costs of investment in sustainability	(Morana et al. 2014)
	Supplier Selection Costs	ES2	Decisions relating to selection of suppliers	(Gunasekaran et al. 2001)
	Logistics Costs	ES3	Costs related to logistics and transportation	(Gunasekaran & Kobu 2007)

	Tactical			
	Return on investment	ET1	Return on Investment (ROI) rates	(Morana et al. 2014)
	Capacity utilization	ET2	The utilisation of the facilities' capacity	(Gunasekaran & Kobu 2007)
	Perceived value of product	ET3	The perceived value of the product	(Gunasekaran et al. 2001)
Environmental	*Operational*			
	Greenhouse gas emission rates	ENO1	GHG emissions from facilities	(Morana et al. 2014)
	Noise rates	EN02	Noise rates causing disturbance	(Morana et al. 2014))
	Waste Management	ENO3	Management of the waste	(Dubey et al. 2015)
	Strategic			
	Innovation & improvement	ENS1	Innovation & improvement of processes and products	(Kaplan & Norton 1996)
	Planning and Product Design	ENS2	Designing the products and planning their production	(Gunasekaran et al. 2001)
	Compliance to regulations	ENS3	Organizational adherence to regulations	(Gunasekaran & Kobu 2007)
	Environmental Quality management	ENS4	Managing quality with attention to environment	(Hofer et al. 2012)
	Governmental Regulations	ENS5	Regulations imposed by governmental bodies	Hussain et. Al (2015)
	Management Commitment	ENS6	Commitment of management to causes	Hussain et. Al (2015)
	Tactical			
	Resource Utilization	ENT1	The utilisation of all resources	Beamon (1999)
	Risk Management	ENT2	The management for risks	Hussain et. Al (2015)
	Reverse Logistics	ENT3	Operations based on reusing products and materials	(Dubey et al. 2015)
Social	*Operational*			
	Labour efficiency	SO1	Efficiency of labour employment and production	(Gunasekaran & Kobu 2007)
	Injury prevention	SO2	Preventative precautions within facilities	Hussain et. Al (2015)
	Stakeholders involvement	SO3	Involvement of stakeholders within organization	(Reuter et al. 2012)
	Strategic			
	Employment creation rates	SS1	Rate of new job creation and hiring cycles	(Morana et al. 2014)
	Training Rates	SS2	Rate of employee developmental trainings	(Morana et al. 2014)
	Adoption of Safety Practices	SS3	Safety practices implemented within organization	Hussain et. Al (2015)
	Tactical			
	Customer Retention	ST1	Rate of customer retention and turnover	(Beamon 1999)
	Labour Equity	ST2	Equality and diversity in employment	Hussain et. Al (2015)
	Quality of employee life	ST3	Employee life-quality balance	Hussain et. Al (2015)

Most of the previous research solely depended on either academic literature or on sustainability practices in industries (Wilmshurst & Frost 2000; Cerin 2002; Fowler & Hope 2007; Jose & Lee 2007; Montabon et al. 2007; Schneider et al. 2010; Tate et al. 2010), ignoring one or the other. Therefore, it is imperative to bridge the gap between literature and practice, in order to fully understand how SSCM is implemented and measured, as well as which KPIs are most influential and important for organizations implementation and assessment of sustainability within their supply chains. Figure 1 depicts the structural flow of the process utilized and Figure 3 represents the steps taken in administering the data collection instrument (survey).

The identified KPIs from the SLNA and Text Mining were grouped according to the Triple-Bottom-Line fundamental pillars of Economic, Environmental and Social (Winter & Knemeyer 2013; Carter & Easton 2011; Tate et al. 2010; Carter & Rogers 2008; Markley & Davis 2007) in an endeavor to encompass all aspects of SSCM. As delineated in Figures 1 and 3, they are further classified into the three key decision areas within an organization, in order to span the whole supply chain and all Operational, Strategic and Tactical decision levels (Hofer et al. 2012; Schneider et al. 2010; Montabon et al. 2007; Gunasekaran et al. 2001).

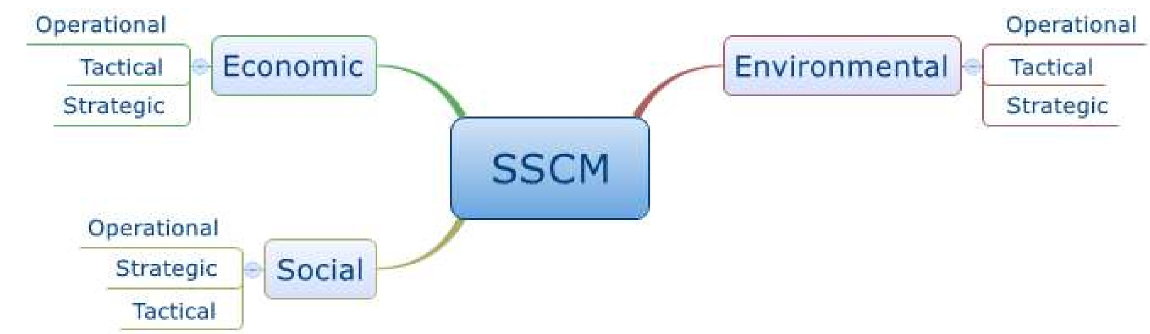

Figure 1 - Map showing structure of SSCM KPIs

As is shown in Figure 2, this research commences by SLNA & Text Mining. These both feed into the accumulation of the KPIs (Table 1) that set the base for rest of this study. Subsequently, according to Saaty (2008) as per Keeney (1996), the process starts with defining the problem, followed by structuring a hierarchical framework for the decision-making process, followed by constructing sets of pair-wise comparison matrices and finally obtaining the weight-age.

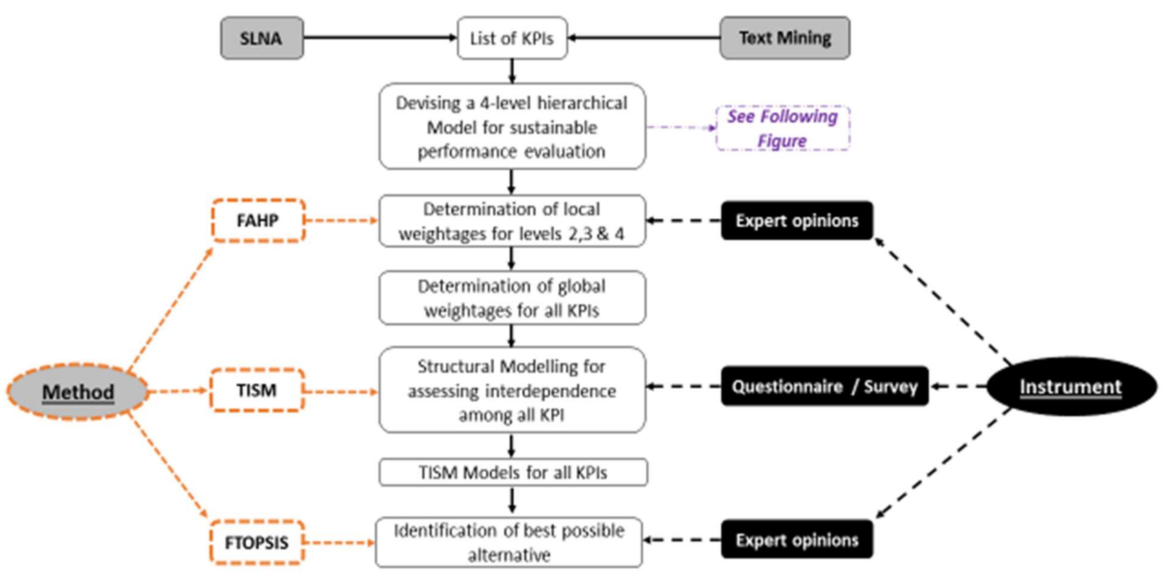

Figure 2 - MCDA model for SSCM KPI evaluation

To that end, in order to resolve the problem of identifying the most important and influential KPIs in sustainable supply chain implementation, the following 4-level hierarchy (Figure 3) has been established. As per Kilincci & Onal (2011), Level 1 outlines the overarching objective, which is broken down into the Triple Bottom Line (TBL) criteria in Level 2, followed by further breaking down of the TBL layers according to the organizational decision-making levels in Level 3 as the attributes, finally reaching the decision alternatives in the fourth level of the hierarchy, which consists of the most influential KPIs, as a list of alternatives.

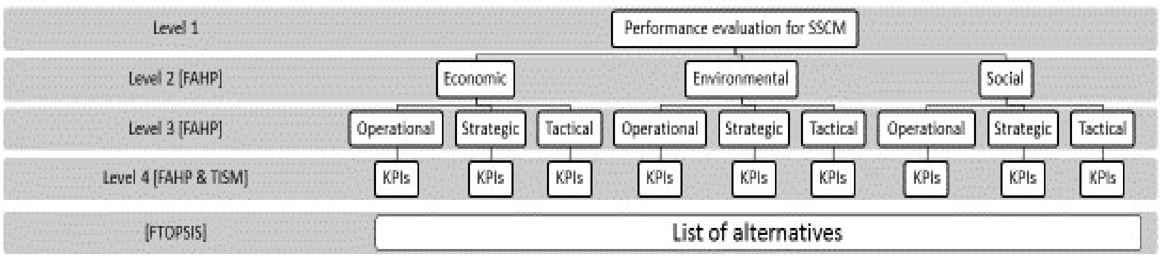

Figure 3 - Hierarchical Model for SSCM performance evaluation

After determining the local weight-age for each of the items at levels 2, 3 and 4 (as shown in Figure 3), the global weightages for all KPIs are calculated. However, due to chaos and personal judgment bias during the pair-wise comparison (Snowden & Boone 2007), utilization of fuzzy set theories are required to eradicate the involved vagueness. Accordingly, Fuzzy Analytical Hierarchy Process (FAHP) is utilized in order to assign priority for these KPIs in level 3 and 4. The acquired weightage after performing FAHP are utilized to evaluate the best alternative by employing FTOPSIS. Subsequently, a Total Interpretive Structural Modelling (TISM) based hierarchical structure model was devised in order to delineate inter-relationship among all the identified KPIs within level 4. Alternatively, the acquired rank for the identified KPIs (as determined by FAHP) also endorses the attained level of KPIs in the TISM-based model. Eventually, identification of the best possible alternative, and the cumulative performance scores, is exercised by employing Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS).

Throughout these methods, experts' opinions have been sought via a structurally developed questionnaire (Forza & Padova 2002) that was disseminated electronically to the identified experts in the field of SSCM; the entire processes is delineated in Figure 4. While the experts' opinions for the first and final stages, as outlined in Figure 1, were acquired through in-person meetings with a panel of 3 experts in the field for validation and selection.

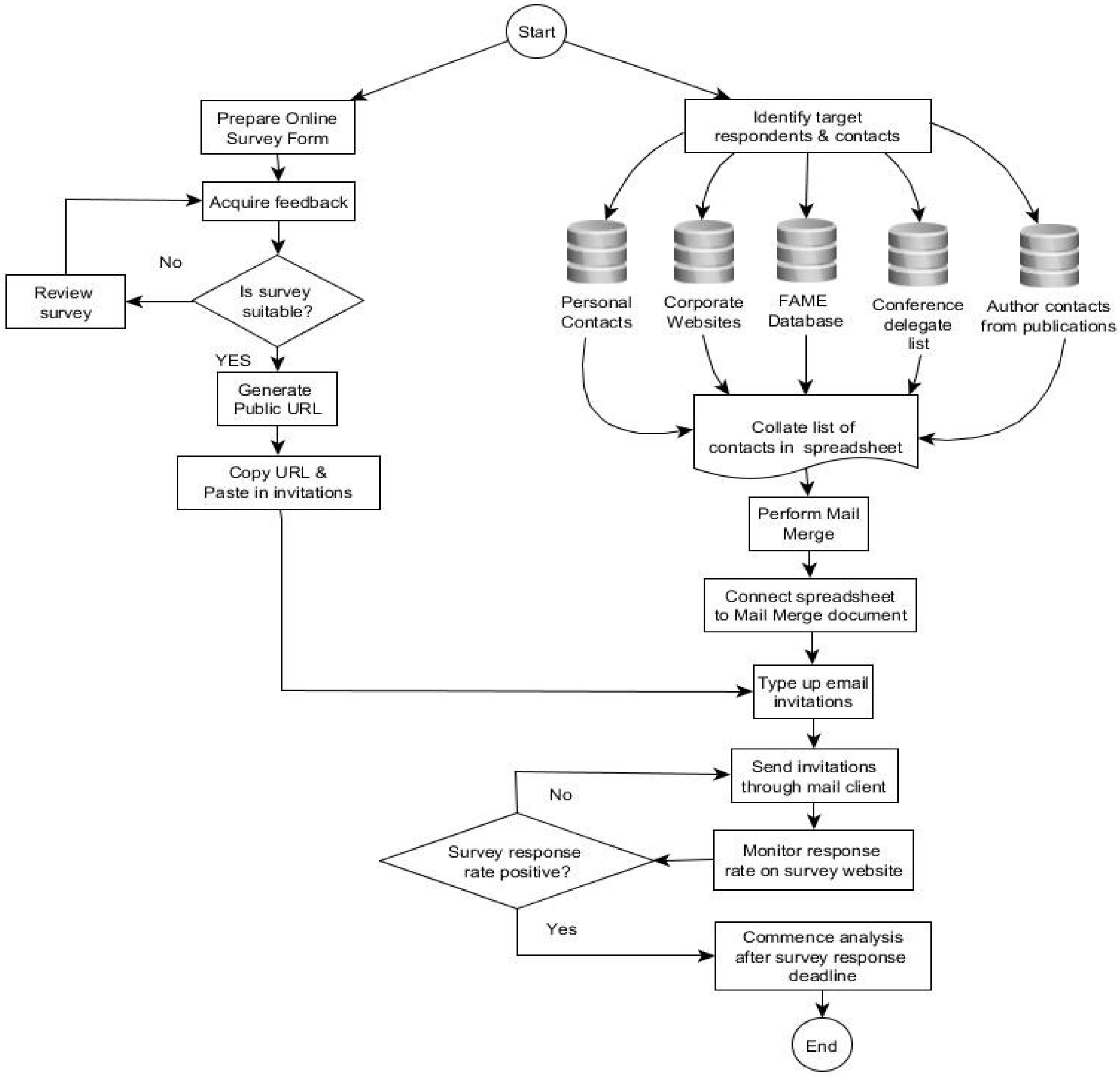

Figure 4 – Flowchart for MCDA data collection

Findings

The results of this research are currently undergoing assessment and analysis. However, it is worth mentioning that the results are poignant in their identification of the weight-age relevant to each KPI and metric, as well as the supporting feedback that has been provided by respondents. These results shall showcase the most pertinent KPIs and metrics, and ascertain which of them are most important for managers to focus on when making a decision pertaining to SSCM implementation. Feeding into a Decision Support System (DSS) built on the weight-age acquired and acknowledged, and aiding and supporting managers in making informed decisions to assess their supply chain's sustainability.

Contribution

The outcomes of this study have implications for both researchers and managers, contributing to bridge the gap between academia and practice. With methods build on both literature and practice stemming from the SLNA and Text mining, and hinged on three MCDA methods, the hybrid methodology and its application will bridge the existing research gap and set up a direction of future research for the development of supply chain sustainability assessment tool.

Future Research

Albeit a novel approach to the identification of the KPIs for SSCM implementation, this research has endeavored to set the precedent for the establishment of a Decision Support System (DSS) for SSCM evaluation and guiding managers. Future research would collect the empirical evidence outlined herein and utilize it in the DSS development. We hope that future research could endeavor to further develop the outlined KPIs and collectively propagate the results as we propel the field through abridging the literary and practical sides of the SSCM implementation coin.

Conclusion

Thus, it is apparent through the SLNA and Text Mining implemented that there exists a lack in unanimity regarding the implementation of SSCM and its relevant KPIs. This research has strived to bring together these understandings and KPIs from both literature and practice and then through a hybrid MCDM approach (consisting of FAHP, TISM and FTOPSIS) hinged on a 4-level hierarchical model and revolving around input from worldwide experts, identify the most pertinent and influential KPIs. Presenting the organizations with the most influential KPIs that they should focus on for SSCM implementation and contributing through the acquired weight-age to the development of a DSS that would aid organizations in assessing their supply chains' sustainability and make informed decisions pertaining to their strategization. Thus, allowing them to compete on par with the leading international organizations and assessing their sustainability as per the most influential KPIs from literature and practice and according to the weight-age provided by international experts in this field.

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