**Explaining Environmental Sustainability in Supply Chains Using Graph Theory**

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**Abstract**

The need for theory building in environmental supply chains has been at the centre of many discussions in recent years. Existing research, however, does not typically consider methods that aim at theory generation. Current methods such as econometric modelling or structural equation modelling face challenges related to how causality is established due to potential issues regarding cross-sectional data sets. To address this gap, this paper suggests a Total Interpretive Structural Modelling (TISM) based approach. We use graph theory logic to synthesize expert interpretations in the form of a theoretical supply chain model. This method may prove to be an alternative method to econometric based modelling or structural equation modelling. We provide an application of the method in exploring the drivers of low carbon supply chain and their relationships. Limitations and future research opportunities are also provided.

***Key-words:*** Total Interpretive Structural Modeling (TISM), Organisational Theory, Environmental Sustainability, Supply Chain Management, MICMAC

**1. Introduction**

In recent years, anthropogenic climate change has become a major concern (Cook et al. 2016; Wang et al. 2015; Jabbour et al. 2016; Belkhir et al. 2017). Carbon emissions resulting from various activities across the supply chain account for nearly 50% of the total carbon emitted by large corporations (Norton et al. 2015). However, this may vary between 20% and 80% depending upon the nature of the goods produced by the firm. In response to the growing concerns resulting from carbon emissions, several corporations have embraced various strategies (Colwell and Joshi 2013; Svensson and Wagner, 2015); however, many of these strategies lack cogent conceptualization. In addition, the academic literature on environmental sustainability in supply chains and low carbon supply chains has failed to offer a holistic view of the issues involved (Christ and Burritt, 2013; Matthews et al. 2016) utilizing mostly either quantitative or qualitative approaches, or have proposed case based methods as alternatives for generating comprehensive theory (see Eisenhardt, 1989; Meredith, 1998; Pagell and Wu 2009; Wilhelm et al. 2016). However, case research method, despite of having several strengths, has some limitations: first, such studies required extensive time and costs. Second, it is difficult to generalize prescriptive findings due to a small sample (Boyer and Swink 2008).

Weick ([1995](http://onlinelibrary.wiley.com/doi/10.1111/jscm.12097/full#jscm12097-bib-0072)) makes clear distinctions between theory, as an end, and theorizing, as a means. Conversely, Davis et al. (2007), argue in favour of simulation techniques for generating theory. To address the limitations of the aforementioned approaches, Boyer and Swink (2008) argue in favour of multi-methods to provide a holistic view to any research problem. In a similar vein, Chandrasekaran et al. (2016) use multi-methods to address the limitations of the case-based method. Chandrasekaran and colleagues have used agent based simulation (ABS) to further validate their theory which they have developed using case method.

Besides the use of simulation techniques, graph theory can also be useful. Tichy et al. (1979) proposed the use of network analysis for the organizational research. Out of various network analysis techniques, the graph theory approach can be a powerful tool for theory generation. In the last two decades, interpretive structural modelling (ISM), a systematic application of graph theory, has attracted increasing attentions from the O&SCM community following a seminal publication by Mandal and Deshmukh (1994). However, ISM for theory development is still underutilised. This may be attributed to the limited understanding of the application of ISM method despite the attempts of scholars (e.g. Sushil, 2012) to use graph theory to build theory.

Given the limitations of ISM, we argue, following Boyer and Swink (2008), towards the use of multi-methods for theory building. However, the use of multi-methods in O&SCM field is scant with due exceptions (see Aksin et al. 2007; Chandrasekaran et al. 2016). Sushil (2012) evokes, Whetten (1989) to suggest that TISM can also be used for building theory like other alternative research methods which addresses the limitations of ISM method. Dubey et al. (2015, 2016) further this argument using seminal works on theory development (see Whetten 1989; Sutton and Staw 1995; Wacker 1998), that TISM method can be used as an alternative method for theory building. Hence, we argue that TISM may help to answer three important research questions: *what*, *why* and *how*.

The objective of our current study is to understand how we can use TISM as a multi-methods approach that can help advance low carbon supply chain literature. Following Sushil (2012) we look for *alternative method to generate a theoretical model*. Hence, we present an alternative approach not as a replacement but as an addition to the existing portfolio of theory building methods. Hence, our research question and its sub-questions are as follows:

*RQ1: How can TISM be used to propose an alternative theory for low carbon supply chains?*

To address our first research question, we further split it into two sub-questions in accordance with the suggestions of Whetten (1989):

*RQ1a: What are the building blocks of such a theoretical framework?*

*RQ1b: How are these building blocks linked to one another?*

By addressing these questions, our study offers two main contribution to the literature. First, building on the arguments of Sushil (2012) and Poole and Van de Ven (1989), we aim to generate a theoretical framework that leverages tensions and opposing arguments. This engenders a useful contribution to O&SCM methodological diversity. Second, we extend prior research by utilizing organizational theories to develop our theoretical model. In this way, a hierarchical relationship between drivers of supply chain sustainability can be developed. We can also address the growing concern among O&SCM academia regarding hypothesis testing using cross-sectional data. In a recent editorial note, Guide and Ketokivi (2015) have expressed their concerns related to empirical articles utilizing cross-sectional data. It has been observed that cross-sectional data pose multiple issues such as endogeneity and common method bias. However, obtaining longitudinal data poses its own challenges and methodological shortcomings. Furthermore, information asymmetry is a concern related to secondary data. We argue that TISM can help to resolve some of the existing concerns related to problems such as endogeneity and common method bias.

The remainder of this paper is structured as follows. In section 2, we review the literature related to low carbon supply chains and the use of graph theory in building our theoretical model. We then present our methodology in section 3, introducing the selection of the drivers of low carbon supply chains from an extensive literature review, sampling design and data collection. Next, in section 4 we describe our data analysis and the findings of the study. Then, the implications of the findings are discussed further in section 5. Finally, we conclude our study and underline limitations and further research opportunities in section 6.

**2. Literature Review**

***2.1 LOW CARBON SUPPLYCHAIN***

Low carbon supply chain strategies have become an important topic of conversation in recent years, due to carbon’s serious impact on climate change (Plambeck 2012; Song et al. 2012; Benjaafar et al. 2013; Norton et al. 2015; Zhang et al. 2015; Du et al. 2016; Jabbour et al. 2016). Plambeck et al. (2012) highlight the importance of low carbon emission in supply chainss and note how a focal firm can achieve desired environmental performance through collaboration and transparency. Achieving low carbon emissions in the supply chain has been the subject of attention for large corporations. Böttcher and Müller (2015) argues that low carbon supply chain addresses the issue of climate change caused by the emission of CO2 from a company’s core business processes. This focus on a single aspect within the much broader concept of sustainable operations management is justiﬁed by the magnitude and severity of climate change and the impact it has on businesses. However, it may not be feasible for corporations to look for immediate benefits from reducing carbon emissions (Hsu and Lin, 2015; Jabbour et al. 2015). Plambeck et al. (2012) noted that the benefits resulting from reducing carbon emissions are much higher than it is estimated. Consumers often held focal firms responsible for irresponsible behaviour towards environment in entire supply chains (Hartmann and Moeller 2014). Hence, the liability of the focal firms towards carbon emission in supply chains is much higher. Hartmann and Moeller (2014) noted that in case of Nestle, when a consumer has reported concerns related to irresponsible practices by one of the palm oil suppliers of Nestle, on Facebook, it has caused severe damage to their sales which is much higher in terms of magnitude in comparison to the cost incurred in lowering the carbon emissions in supply chains. Song and Zhou (2015) argues in context to Anhui province, China that population effects on increases in carbon emissions have declined gradually, and that increased energy consumption has promoted a reduction of carbon emissions. However, so far literature when examined using the Alvesson and Sandberg (2011) lens has not explored issues related to low carbon supply chains using alternative theories (Mathews et al. 2016), apart from due exceptions (see Pagell and Wu 2009; Wilhelm et al. 2016). Therefore, there is a need for independent theories which can offer better explanation to the issues related to low carbon supply chains. We aim to address this gap in the existing literature by arguing for the use of graph theory. Our arguments are unfolded in the next sections.

***2.2 Graph Theory Approach in Operations and Supply Chain Management***

Graph theory has attracted significant attention from organizational researchers due to its power to solve some complex problems (see Rajagopalan and Batra 1975; Tichy et al. 1979; Zhang, 2015). In recent years, graph theory and its applications have been used in various fields. In the field of sustainability, graph theory is also gaining immense popularity among scholars who seek to depict complex interactions between large sets of variables (Eisenack and Petschel-Held 2002). Although many methods falling under the scope of graph theory can be useful, we will restrict our discussions here to interpretive structural modelling (ISM) and total interpretive structural modelling (TISM), and their application in organizational research in consideration of Warfield’s (1973; 1974) research on solving complex social issues. The base technique is popularly called ISM. The ISM technique has been used extensively to generate models or hypotheses when existing evidence regarding the nature of the interaction between these variables is limited (e.g. Raj et al. 2008; Luthra et al. 2014). The ISM method has gained its popularity due to its ability to solve complex issues based on discrete mathematics (Dubey et al. 2015b) and requires less resources in terms of time and investment. However, despite its popularity the ISM method has attracted criticism from organizational researchers (see Sushil, 2012) due to lack of clarity in terms of transitive links and causality. To address these limitations Sushil (2012) proposed a TISM approach to building theory, which has attracted significant attendtion from scholars in recent years (e.g. Dubey et al. 2015, 2017; Yadav, 2014; Khatwani et al. 2015; Yadav and Barve, 2016). Despite its increasing application, the use of the TISM method is still limited. Sushil (2016) has further clarified some of the missing links which prior literature using TISM method has failed to address. In this paper, we argue for and justify the use of TISM method as a methodology by which issues related to environmental sustainability issues (such as carbon reduction) in supply chains can be explored.

**3. Methodology**

***3.1 Drivers of Low Carbon Supply Chain***

Our first sub-research question is exploratory in nature. Research question 1a is the fundamental building block of any theory development (see Dubin, 1978; Whetten, 1989). Following Whetten (1989) we use two guiding principles: first, the constructs or factors or drivers identified for our study must be comprehensive and second, they are parsimonious in nature. To ensure that the drivers are comprehensive in nature we adopt a two-stage process. Firstly, we have undertaken an extensive review of existing literature following Carter and Liane Easton (2011) guidelines and secondly, following Tranfield et al. (2003) guidelines we have attempted to avoid overlapping drivers or constructs to ensure that the drivers are parsimonious in nature. However, this is a critical stage of theory development (Whetten, 1989), and thus we have taken utmost care to ensure parsimony of the drivers (Böttcher and Müller, 2015). Böttcher and Müller (2015) argues that drivers are those external and internal conditions that drive the adoption of low carbon supply chain practices. Böttcher and Müller (2015) further noted that stakeholder pressure and competitiveness expectation are the main drivers of the adoption of low carbon supply chain practices. Hence, we have identified our drivers of low carbon supply chains following arguments set forth by Whetten (1989) (see Table 1).

**Table 1: Drivers of low carbon supply chains**

|  |  |
| --- | --- |
| **Drivers** | **References** |
| Regulatory pressures | Zhu and Sarkis (2004); Shi et al. (2012); Böttcher and Müller (2015) |
| Waste reduction | Sundarakani et al. (2010); Dues et al. (2013) |
| Manufacturing flow management | Diabat and Simchi-Levi (2009); Yang et al. (2011); Böttcher and Müller (2015) |
| Reverse logistics | Sundarakani et al. (2010); Govindan et al. (2015); Böttcher and Müller (2015) |
| Customer focus | Gopalakrishnan et al. (2012); Zhao et al. (2012); Hannon et al. (2013) |
| Suppliers involvement | Walker et al. (2008); Shi et al. (2012); Wilhelm et al. (2016) |
| Information sharing | Melville (2010); Colicchia et al. (2011); Shaw et al. (2012); Shi et al. (2012) |
| ICTs | Halldorsson and Kovacs (2010); Elliot (2011); Bengtsson and Agerfalk (2011) |
| Competitive advantage | Nidumolu et al. (2009); Flint and Golicic (2009); Wu et al. (2015); Böttcher and Müller (2015)  |

Table 1 indicates the drivers of low carbon supply chains. However, in the absence of adequate literature the nature of the associations between these drivers is not well understood. In the past, researchers have attempted to ground their theoretical model in existing organizational theories (see Ketchen and Hult, 2007a, 2007b; Sarkis et al. 2011). However, Poole and Van de Ven (1989) have noted that organizational theorists have attempted to generate internally consistent theories and have failed to exploit the paradoxical views which could have advanced the organizational research to a next level. The existing organizational theories in recent years have attempted to capture multifaceted reality with a finite, internally consistent statement. Next, we exploit the existing tensions or oppositions in surrounding organizational theories, and use an interaction process to stimulate the development of more encompassing theories.

 ***3.2 Sampling Design and Data Collection***

The drivers we identify in section 3.1 of this paper may be interacting with each other and/or may not necessarily share the same level of criticality/importance in practice. Hence, we need to capture direct relationships among them. To understand the interaction among these drivers, a survey instrument was developed in which each possible connection between two drivers two questions were asked: for example, “*Technology leads to competitive advantage*” and next “*Competitive advantage leads to technology*”. Each relationship between two drivers were measured on a five-point Likert scale with anchors ranging from strongly disagree (1) to strongly agree (5). In prior research, scholars have used dichotomous scales (Yes/No) (see, Sushil 2016). However, the Likert scale provides greater statistical variability among survey responses in comparison to the dichotomous scale.

Before using a questionnaire for data collection, we pre-tested our survey instrument in two stages. In the first stage, five experienced researchers were asked to critique the questionnaire for ambiguity, clarity and appropriateness of the drivers used (Chen and Paulraj 2004). Based on the feedback, minor modifications in language were made to enhance clarity of the questions. Following Dillman’s (2011) total design test method, the survey then was e-mailed with a cover letter to senior members of APICS. From the APICS membership directory, 86 senior members with more than 10 years experience in supply chain management, purchasing management, materials management and operations management were identified and solicited. We received 49 usable responses representing a 56.98% response rate. We believe that we owe such a high response rate to the use of email for the survey and follow-up telephone calls to each respondent.

**4. Data Analysis and Results**

***4.1 Total Interpretative Logic Matrix***

Based on the 49 survey responses, we calculated a mean score for each direct relationship between two drivers. In our study, we assume that a driver does not impact another if the mean score is less than three. The bidirectional relationship (*i→j, j→i*) is represented with mean scores as ($\overbar{w}\_{ij,}\overbar{w}\_{ji}$). We capture the bidirectional relationship between two drivers using the letters V, A, X and O.

The letter V denotes a relationship in which node *i* leads to node *j* ($\overbar{w}\_{ij}>3$) but the connection is not reciprocal (i.e. *j* does not lead to *i* or $\overbar{w}\_{ji}\leq 3$). Letter A denotes a relationship in which driver node *j* helps to achieve node *i* ($\overbar{w}\_{ji}>3$) but the reverse is not true (i.e. *i* does not lead to *j* or $\overbar{w}\_{ij}<3$). Hence, A is the opposite of V. The letter X denotes a relationship in which both nodes impact each other (i.e. *i* impacts *j*, but also *j* impacts *i* ($\overbar{w}\_{ij}>3 and \overbar{w}\_{ji}>3$)). Similarly, the letter O represents a relationship in which neither node is associated with one another (i.e. there is no connection between *i* and *j* ($\overbar{w}\_{ij}<3 and \overbar{w}\_{ji}\leq 3$)). Based on 49 survey responses, we developed the total interpretive logic matrix (see Table 2).

**Table 2: Total Interpretive Logic Matrix**

|  |  |  |
| --- | --- | --- |
| **Drivers numeric code** | **Drivers** | **Drivers** |
| **IX** | **VIII** | **VII** | **VI** | **V** | **IV** | **III** | **II** | **I** |
| I | Regulatory pressures | V | A | A | V | V | V | V | V |  |
| II | Waste reduction | V | A | A | V | V | X | V | - |  |
| III | Manufacturing flow management | V | A | A | O | V | O | - | - |  |
| IV | Reverse logistics | V | A | A | O | V | - | - | - |  |
| V | Customer Focus | V | A | A | O | - | - | - | - |  |
| VI | Suppliers involvement | V | A | A | - | - | - | - | - |  |
| VII | Information sharing | V | A | - | - | - | - | - | - |  |
| VIII | ICTs | V | - | - | - | - | - | - | - |  |
| IX | Competitive advantage | - | - | - | - | - | - | - | - |  |

***4.2 Final Reachability Matrix***

To obtain a final reachability matrix from Table 1, we followed two steps (Mandal and Deshmukh, 1994; Sushil, 2012). In the first step, the variables V, A, X and O are converted into 0s and 1s. This matrix is often referred to as the initial reachability matrix (see Table 3) using the following rules:

First, if the entry (i, j) is “V”, then the corresponding entry in the reachability matrix (i, j) is replaced with 1 and the (j, i) entry is 0;

Second, if the entry (i, j) is “A”, then the corresponding entry in the reachability matrix (i, j) is 0 and the (j, i) entry is 1;

Third, if the entry (i, j) is “X”, then the corresponding entry in the reachability matrix (i, j) is 1 and the (j, i) entry is also 1;

Fourth, if the entry (i, j) is “O”, then the corresponding entry in the reachability matrix (i, j) is 0 and (j, i) entry is also 0.

**Table 3: Initial reachability matrix**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | I | II | III | IV | V | VI | VII | VIII | IX |
| I | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| II | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| III | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| IV | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| V | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| VI | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| VII | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| VIII | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| IX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

In the next step, we checked the transitivity between the links. The transitivity uses triads as the unit of anlaysis. The transitivity principle is used in interpretive links to check the consistency of the model developed (Farris and Sage 1975, 1975a; Sushil, 2012). As per the transitivity principle, if i leads to j and j leads to k, then the supposition that i leads to k must hold true. The transitivity property also helps to remove any possible gaps in the realized relationships among the variables. The final reachability matrix for drivers shown in Table 4 is prepared by adopting the criteria and the transitivity principle.

**Table 4: Final Reachability Matrix**

|  |  |  |
| --- | --- | --- |
|  | Drivers | Driving Power |
| I | II | III | IV | V | VI | VII | VIII | IX |
| I | 1 | 1 | 1 | 1 | 1 | 1 | 1\* | 0 | 1 | 8 |
| II | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 6 |
| III | 0 | 0 | 1 | 1\* | 1 | 1\* | 0 | 0 | 1 | 5 |
| IV | 0 | 1 | 1\* | 1 | 1 | 0 | 0 | 0 | 1 | 5 |
| V | 0 | 0 | 0 | 0 | 1 | 1\* | 0 | 0 | 1 | 3 |
| VI | 0 | 0 | 0 | 0 | 1\* | 1 | 0 | 0 | 1 | **3** |
| VII | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | **8** |
| VIII | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **9** |
| IX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | **1** |
| Dependence | 3 | 5 | 6 | 6 | 8 | 7 | 3 | 1 | 9 |  |

***4.3 LEVEL PARTITIONING***

The process of ranking different drivers into hierarchical levels is called level partitioning. To obtain the levels of drivers, the first step is the calculation of reachability and the antecedent sets from Table 3 (Warfield 1974; Sushil, 2012). In any iteration, if the reachability set intersection with the antecedent set is the reachability set itself, then that variable will be placed in the top level of the hierarchy. The final output of level partitioning is shown in Table 5 and the conceptual framework of drivers of low carbon supply chain is shown in Figure 2. The MICMAC analysis showed in Figure 1 for the drivers clearly bifurcate the drivers into four quadrants depending on their power and dependency.

**Table 5: Level Partitioning**

|  |  |
| --- | --- |
| Drivers | Level |
| IX | Level 1 |
| V, VI | Level 2 |
| II, III, and IV | Level 3 |
| I, VII | Level 4 |
| VIII | Level 5 |

***4.4 FUZZY MICMAC ANALYSIS***

Prior studies have used conventional MICMAC analysis (see Mandal and Deshmukh, 1994; Dubey et al. 2015, 2015a, 2015b, 2016). Gorane and Kant (2013) noted that conventional MICMAC analysis only considers 0 or 1. Hence, the binary interaction between two drivers may not adequately reflect reality in practice. The judgement has some degree of fuzziness and thus the fuzziness element of decision making must be reflected in the final reachability matrix. To address this concern, we have used fuzzy sets following Kandasamy (2007). In our case, we have considered that the interaction between any two drivers may acquire any value ranging between 0 to 1 (where no interaction=0; very low=0.1; low=o.3; medium=0.5; high=0.7; very high=0.9; complex=1) based on expert judgement. However, in this case we calculated the mean score for each link based on 49 responses and divided by five. Hence, the mean score (between 4 to 5) lies between 0.8 to 1 after dividing by 5.

To interpret results, we have considered the degree of interaction as very high when equals to (at least) 0.9. Similarly, the mean score for the links which lie in between 3 and 4 is divided by 5 which yields a ‘normalized’ score between 0.6 and 0.8. In this case, we treated the interaction as high=0.7. The mean score for the links in between 2 and less than 3 when divided by 5 yields a normalized score in between 0.4 and less than 0.6 is treated as medium=0.5. The mean score of 1 to 2 yields a normalized score in between 0.2 to less than o.4 is treated as low=0.3 and the mean score between 0 and 1 yields a normalized score between o and less than 0.2 is treated as low=0.1. We have obtained fuzzy direct reachability matrix (FDRM) (see Table 6).

**Table 6: Fuzzy Direct Reachability Matrix (FDRM)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | I | II | III | IV | V | VI | VII | VIII | IX |
| I | 0 | 0.9 | 0.9 | 0.5 | 0.5 | 0.7 | 0.5 | 0.3 | 0.7 |
| II | 0.3 | 0 | 0.5 | 0.7 | 0.9 | 0.7 | 0.1 | 0.1 | 0.7 |
| III | 0.3 | 0 | 0 | 0.1 | 0.9 | 0.1 | 0.1 | 0.3 | 0.7 |
| IV | 0.1 | 0.7 | 0.1 | 0 | 0.9 | 0.1 | 0.3 | 0.3 | 0.7 |
| V | 0.3 | 0.1 | 0.1 | 0.1 | 0 | 0.1 | 0.5 | 0.5 | 0.7 |
| VI | 0.1 | 0.3 | 0.3 | 0.1 | 0.5 | 0 | 0.7 | 0.7 | 0.7 |
| VII | 0.7 | 0.9 | 0.7 | 0.9 | 0.7 | 0.7 | 0 | 0.7 | 0.7 |
| VIII | 0.9 | 0.7 | 0.9 | 0.9 | 0.7 | 0.7 | 0.9 | 0 | 0.9 |
| IX | 0.1 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0 |

Next, to obtain a fuzzy stabilized MICMAC matrix, we have taken the FDRM as the base to begin the process. The matrix is multiplied repeatedly until the hierarchies of the driver power and dependence stabilize (Kandasamy 2007; Gorane and Kant 2013; Dubey and Ali 2014). The multiplication process follows the principle of fuzzy matrix multiplication law (Kandasamy 2007) (see Cik= max. [min. (Aij\*Bjk)]). We have obtained the stabilized matrix as shown in Table 7.

**Table 7: Fuzzy Stabilized MICMAC Matrix**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | I | II | III | IV | V | VI | VII | VIII | IX | Driving Power |
| I | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.7 | 0.9 | 7 |
| II | 0.3 | 0 | 0.5 | 0.7 | 0.9 | 0.7 | 0.7 | 0.7 | 0.7 | 5.2 |
| III | 0.3 | 0.7 | 0 | 0.7 | 0.9 | 0.1 | 0.7 | 0.7 | 0.7 | 4.8 |
| IV | 0.3 | 0.7 | 0.5 | 0 | 0.9 | 0.7 | 0.5 | 0.5 | 0.7 | 4.8 |
| V | 0.3 | 0.3 | 0.3 | 0.3 | 0 | 0.1 | 0.7 | 0.7 | 0.7 | 3.4 |
| VI | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 0 | 0.7 | 0.7 | 0.7 | 3.8 |
| VII | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.7 | 0 | 0.7 | 0.7 | 6.4 |
| VIII | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.7 | 0.9 | 0 | 0.9 | 7 |
| IX | 0.1 | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0 | 1.2 |
| Dependence | 3.2 | 4.8 | 4.6 | 5 | 6 | 4 | 5.2 | 4.8 | 6 |   |

Using the data shown in Table 7, the co-ordinates of each driver are noted in the Table 8, which are used as input for generating the MICMAC structure (see Figure 1).

**Table 8: Co-ordinates of the Drivers**

|  |  |  |
| --- | --- | --- |
| Driver | X | Y |
| I | 3.2 | 7 |
| II | 4.8 | 5.2 |
| III | 4.6 | 4.8 |
| IV | 5 | 4.8 |
| V | 6 | 3.4 |
| VI | 4 | 3.8 |
| VII | 5.2 | 6.4 |
| VIII | 4.8 | 7 |
| IX | 6 | 1.2 |

**Figure 1: Classification of Drivers**

From Figure 1 we can see that nine drivers of the low carbon supply chain are classified into four clusters based on their driving power and dependent nature. Prior studies (see Mandal and Deshmukh 1994; Gorane and Kant 2013; Dubey and Ali 2014; Balaji and Arshinder 2016), have explained each of the clusters. Hence, here we reserve our discussion related to the drivers and their nature and how the four clusters can be used to generate the theoretical model.

**Level 1**

**Level 2**

**Level 3**

**Level 4**

**Level 5**

**Figure 2: Hierarchical model**

***4.5 Synthesis of TISM and MICMAC Analysis***

Following a synthesis of the TISM and MICMAC analyses, we develop a theoretical model (see Figure 3). The model shows regulatory pressures (regulatory pressures are also termed external pressures or institutional pressures resulting from government or regulatory bodies) have a direct influence on the adoption of ICTs and information sharing between partners. This observation supports earlier work (see Oliver, 1997) arguing how institutional theory can address the limitations of the resource-based view of the firm (RBV).

*Institutional pressures* refer to the external pressures exerted on organizations within the same field to constrain organizational choice and ensure organizational conformity (Colwell and Joshi, 2013; Seles et al. 2016). DiMaggio and Powell (1983) argue that there are three types of isomorphism, namely coercive, normative and mimetic isomorphism. Coercive isomorphism occurs from both formal and informal pressures exerted on organisations by other organisations (e.g. government agencies, regulatory norms) and from expectations from society (DiMaggio and Powell, 1983). Sarkis et al. (2011) argues that the coercive pressures, generally originate from the government are key drivers for environmental practices. Hence, we can argue that organizations are under pressures originating from government to maintain desired sustainability standards in supply chain. Normative isomorphism occurs because of professionalization which is defined as “the collective struggle of members of an occupation to define the working conditions and their methods to work and in future guide the future professionals through legitimacy” (DiMaggio and Powell, 1983). Sarkis et al. (2011) argues that normative pressures arise from the consumers. Hence, we can argue thatexports and sales to foreign customers are two important drivers that prompt organizations to implement sustainability in supply chain. Mimetic isomorphism results from mimicking other organisational actions. An organisation mimics other actions when there is lack of clarity in organisational goals or there is environmental uncertainty or technology is not well understood (DiMaggio and Powell, 1983).

The resource based view (RBV) asserts that an organization can achieve competitive advantage by creating bundles of strategic resources and / or capabilities (Barney, 1991). Hence, using RBV logic we can argue, that how strategic resources such as ICTs and information sharing can be utilized to create organizational capabilities such as waste reduction, to streamline manufacturing flow, reverse logistics, improve customer focus and involve suppliers which in turn can generate competitive advantage.

Since, RBV focuses on the characteristics of resources and the strategic factor markets from which they are derived to explain firm heterogeneity and sustainable competitive advantage (Oliver, 1997). Hence, firm’s decisions about selecting and accumulating resources are characterised as economically rational within the constraints of limited information, cognitive biases and causal ambiguity. However, despite of the extreme usefulness of the RBV approach, the logic has failed to look beyond the properties of the resources and resource markets to explain firm heterogeneity. The RBV has failed to emulate social context which has an important influence on the managerial decisions about selection and allocation of the resources. Thus, our framework developed using TISM approach support the Oliver (1997) core arguments related to integration of institutional theory and RBV to explain the complex managerial decisions. Hence, TISM method can be used as an alternative approach to theory focused research.

**Figure 3: Theoretical Model**

**5. DISCUSSION**

The current study contributes to the existing literature focusing on alternative methods for generating theory to advance environmental sustainability. Matthews et al. (2016) argue that the development of sustainable supply chain management (SSCM) theory has been impaired by a lack of paradigmatic diversity in the field. Hence, following Matthews et al. (2016), Poole and Van de Ven (1989) and Alvesson and Sandberg (2011) arguments we adopted graph theory approach to generate a comprehensive framework. Our study is firmly grounded in existing seminal works (Whetten, 1989; Sutton and Staw, 1995). Sushil (2012), proposed TISM as an alternative method to generate a theoretical framework using graph theory. The TISM approach is based on the limitations of the ISM based model. However, the existing literature have failed to exploit ISM or TISM based techniques to generate theory within supply chain environmental sustainability. With this attempt, we make two important contributions to the supply chain theory. Firstly, we address the endorsement by Matthews et al. (2016) for alternative theories for advancing SSCM literature. Matthews et al. (2016) argue that in recent years’ management scholars are engaged in discussions surrounding theory and how to generate theory (Whetten, 1989; Sutton and Staw, 1995; Alvesson and Sandberg, 2011). However, the environmental supply chain is far more complex than what it has been reported in the literature. Hence, the process of theorizing will require an alternative to positivistic approaches to theory development that seek conceptual closure.

This is where TISM can contribute as an alternative method to generate theory of environmental supply chain. Secondly, by synthesizing the hierarchical TISM structure with MICMAC analyses, we developed a theoretical model. This model is a conclusive framework based on interpretive logic. Hence, we argue that the model may be an alternative to theoretically derived framework and tested using survey based research. Such approach helps addressing the endogeneity and common-method bias which are two pressing concerns associated with survey based cross-sectional data. As per Guide and Ketokivi (2015), the problem of endogeneity is this: when a researcher is using non-experimental data (i.e. survey based data) to test the research hypotheses that independent variable (X) influences dependent variable (Y), it is possible that the variance of the X is not exogenous but endogenous to the model. The result is that the model is misspecified.

This approach makes an important contribution to the complex econometric or structural equation modelling techniques since it applies not just to cross-sectional data but even in case of longitudinal data, the problems remain same. Thus, to address the limitation we argue that TISM based approach may offer better solution in terms of establishing causality with limited data set. However, it may be too early to conclude and thus in future we recommend some further investigation using robust data to establish our claim.

**6. CONCLUSION**

Drawing broadly on arguments made by both Alvesson and Sandberg (2011) and Matthews et al. (2016), we examined the use of TISM as a multi-method approach for studying environmental sustainability in supply chains. We attempted to address the complexity involved in defining low carbon supply chains and showed how the TISM method can be a favorable approach for theory development.

The synthesis of TISM structure and MICMAC analyses, which utilizes the interpretive logic to establish causal links, may be considered as an alternative method for theory building research. Through this method, we show how cross-sectional data can be used to establish causality. Following a synthesis of TISM and MICMAC analyses, we generated a theoretical model, which may help to address the criticism associated with survey based research. However, the current research has its own limitations related mainly to the testing of the model. Therefore, we further recommend testing the model using robust longitudinal data sets to support our claims. In addition, the current study can also be extended using agent-based simulation modelling to refine and further test the results.

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