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Interactions among inter-organizational measures for green supply chain management

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Abstract

Collaboration among supply chain partners is essential to enhance environmental performance during the life cycle of a product. Inter-organizational measures for green supply chain management tend to show diverse patterns because of various requirements that emerge in a complex supply chain. However, this diversity hampers the comprehensive understanding and systematic adoption of these measures. Therefore, this paper classifies various inter-organizational measures for green supply chain management into several collaboration patterns and analyzes their structural relations through an interpretive structural modeling. The results reveal the collaboration patterns that have higher driving power and dependency than other patterns and, thus, require further attentions.

Keywords: Green supply chain management, inter-organizational collaboration, interpretive structural modeling, product life cycle

1. Introduction

Improving environmental performance of product life cycle is based on closed-loop and boundary-spanning collaboration to minimize negative environmental consequences along the various stages of the supply chain [50,53]. Several studies have defined the green supply chain management (GSCM) through inter-organization collaboration. Sharfman et al. [43] introduced the term "cooperative supply-chain environmental management," signifying activities

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in which the focal firm and its suppliers collaborate to reduce negative environmental impacts along the product life cycle. Vachon and Klassen [53] defined "environmental collaboration" as the direct involvement of an organization with its supply chain partners in conducting joint environmental management and developing environmental solutions. The GSCM collaboration focuses not only on reducing the environmental consequences of material flows but also on improving operational process and product quality by fulfilling the demands in the supply chain [46].

The collaborative measures for GSCM tend to show diverse patterns [34,41]. Various collaboration measures can be applied for GSCM to deal with multiple requirements occurring in the complex supply chain. This behavioral diversity causes difficulties in the understanding and systematic implementation of the collaborative measures. In the field of environmental management, several researchers endeavored to identify significant collaborative GSCM measures [7,10,26,34,36,37,42,48,52,58] and classify the measures to observe possible causal relationships between the measures [2,21]. However, a holistic view in explaining how various collaborative measures influence each other and how the company-overlapping measures can be integrated for better GSCM remain lacking [41]. The conditions under which the collaborative environmental management develops have been also hardly examined [43].

This paper aims to understand the formation and interaction mechanisms of collaborative measures for GSCM. This paper identifies various collaborative measures from the literature on GSCM, traditional supply chain management (SCM), and environmental management and classifies them into 12 collaboration patterns. Basing on this classification, this study scrutinizes inter-relations between these patterns by using an Interpretive Structural Modeling (ISM) framework. A cross-impact matrix called MICMAC (Matrice d'Impacts Croises Multiplication. Appliquee a un Classement) analysis is also carried out to evaluate the driving power and dependence of the collaboration patterns.

2. Classification of inter-organizational measures for green supply chain management

This section identifies 12 collaborative measures for GSCM through a review of GSCM and SCM literature.

2.1. Information and knowledge sharing

Information and knowledge sharing is one of the most critical collaboration pattern because it can promote the understanding of the partners' goals, values, present status, and activities among others [25,30,41,45,47,49].

One-way transfer of requests and information - Manufacturers can effectively adopt GSCM by informing their supply chain partners of their requirements and compelling them to improve their status quo [8,52]. By directly asking partners about the required actions, the integration of their supply chain processes can be facilitated and their long-term relationship can be established [4]. The one-way request can also accelerate the monitoring and evaluation system for GSCM, where the requested tasks may be bound to the level of requirements that suppliers should cope with [4,26].

Interactive communication - The interactive communication covers a wide range of strategic and tactical information on business plans, operational process, performance, and best practices [46]. According to literature analysis by Seuring and Mueller [41], company-overlapping communication is regarded as one of the most crucial factors for sustainable SCM, because it can integrate other collaboration measures into a whole [46]. First, the communication activities are positively related to inter-organizational sharing of technical knowledge [6,13,21]. Second, the data derived from the communication can be utilized to evaluate the suppliers' performance [21,46,52]. Third, the increased transparency and flexibility due to the shared information enables manufacturers to easily compare their supply chain options and impose pressures on their partners' activities [52]. Finally, the communication influences trust building in inter-organizational relationships to achieve GSCM goals [6].

Provision of technical expertise - Providing technical aids can support the diffusion of information on the tacit knowledge [9,52], because each firm has different knowledge and expertise about the overall performance of the supply chain [46,56]. Ravi Shankar [37] underlined that the provision of technical training and education to chain members can contribute to process integration and the implementation of reverse logistics, in the supply chain.

2.2. Process integration

Process integration encompasses the integration of decision process [3,16,46], operations, logistics, information systems [3,28,46] and joint research and development [52]. Process integration consists of the three patterns.

Joint planning and decision making – Supply chain partners can synchronize their GSCM goals and strategies for better performance and reliability [59]. Firms often operate particular decision synchronization bodies with the joint planning processes [3]. Joint planning and decision making has various effects on other collaboration measures. Joint planning and decision process can positively affect sharing of knowledge and information by unifying the type and form of data to be collected and shared [6,46,52]. Performance evaluation can also be promoted by joint planning and developing performance metrics [46,52]. Joint planning and decision synchronization can provide justifications about directly requesting for more involvement from the supply chain partners and increasing competitive pressures within the supply chain [52]. The relational conflicts in the supply chain are likely to be reduced by joint decision making [27]. Cheng et al. [6] suggested the positive effects of joint decision making on inter-organizational trust building.

Joint operation - Joint operation for GSCM means the integration of production processes, logistics, and facilities to mitigate negative environmental consequences along the supply chain. Previous literature highlighted jointly operation channels, especially virtual channels using information technology [28]. Joint operation can be effective on different collaboration patterns. In particular, joint operation can promote information sharing by enhancing visibility on process status [46,59]. The integrated joint operation process can have positive effects on partner training and resource convergence [8,37,59]. The connected operation systems are positively linked to the environmental monitoring of partners by enabling easy detection and correction of problems and real-time feedback [46,59].

Joint knowledge creation – Firms can improve their knowledge by directly involving their supply chain partners in the creation of technology, process, and market, among others [56]. Joint knowledge creation incorporates different sets of resources. The integration of technical knowledge may have a positive effect on the development of collective environmental goals and mutual understanding of environmental responsibilities as well as on decision synchronization about ways to reduce overall environmental impact of the products [52].

2.3. Joint performance management

Monitoring and evaluation of performance often entails performance reward process, such as ranking, awarding, and provision of monetary incentives [3,16,22,23,46,56].

Joint monitoring - Joint monitoring means the extent to which a firm is allowed to access to data on systems of all partners and observe progress of a product's lifecycle stages [46]. Monitoring environmental performance supports information sharing in the supply chain by enabling firms to control the GSCM performance during the product life cycle [37] and sharing evaluative feedbacks for improvement [21,23,59]. Gonzalez et al. [15] found that partner monitoring within EMS scheme motivates the automotive companies to impose the environmental demands on their suppliers. Monitoring environmental performance can also build a basis of collaborative relationships [1].

Joint evaluation – Evaluating the environmental performance of supply chain partners can be valuable when a manufacturer collaborates with its suppliers in design, production, and packaging processes [7,21,59]. Evaluation using performance metrics can also support the process integration [15,37]. Performance evaluation enables firms to compare partners' performance, causing a "push" effect on the suppliers into environmental practices [50].

Joint awarding and incentive alignment - Rewards for GSCM needs to be high enough to motivate the companies in several tiers of supply chain tiers for introducing GSCM practices because the focal firm's own bottom line can be affected by activities in other parts of the supply chain [1,14]. Bowen et al. [2] showed that awarding suppliers is essential for greening the supply process. Appropriate incentive schemes can establish stable relationships among suppliers [1]. A case study on assembly plants in the United States [12] showed that trusty relationship in the supply chain consolidated by incentive alignment facilitates the utilization of innovative environmental technologies. An effective rewarding system can also mitigate the conflicts in the supply chain because supply chain actors tend to self-enforce for the sake of sharing benefits derived from those collaborative efforts [46]. To maximize the effects of the reward system, incentives should be aligned in a reasonable and fair way. If incentives are available, timely, equitable, and performance-contingent, then the communication between manufacturers and their partners is improved [46].

2.4. Relationship management

Cooperative supply chain relationships can enhance the management of environmental demands [20,52].

Partner push – Firms with poor environmental performances can expose their supply chain partners to high levels of competitive risk [17]. Firms can ask partners to comply with certain requirements or warn them about possibilities of switching to an alternative supply chain [23]. Imposing competition in the purchasing phase can also facilitate joint knowledge creation for innovating products and process [7].

Conflict mediation - Firms can build GSCM partnership by resolving emergent conflicts and ensuring the benefits of GSCM for all supply chain partners. Cheng [5] analyzed green manufacturing firms in Taiwan and concluded that tangible relational value (relational benefits) and intangible relational value (quanxi) reduce relational risks in knowledge sharing for a greener supply chain.

Long-term partnership - Trust in a long-term partnership facilitates the exchange of in-depth information and knowledge [2,5,6]. Cheng et al. [6] showed how trust building factors can influence knowledge sharing.

3. Results of interpretive structural modeling

This section applies the ISM methodology for examining the relations among the collaborative patterns. ISM is an algebraic technique and philosophical concept introduced by Warfield [55]. ISM reduces complex system interactions to a logical matrix, which is adapted to impose order and direction on these interactions [37]. ISM is structural because an overall structure is extracted from the complex set of variables based on their relationships [37]. At the same time, the ISM method is interpretive due to the fact that the judgment of the group decides whether the variables are related. ISM is useful in deriving visible models from unclear systems without any prior knowledge [29,38]. ISM is widely utilized for defining a problem in the context of systems theory, policy analysis, and management science [8,38,55].

The ISM analysis begins with classifying 12 inter-organizational measures for GSCM, each one having different goals, intentions, and characteristics. Table 1 shows the classification and information sources. Subsequently, this study investigates the contextual relationship among the identified GSCM collaboration patterns to explain how each collaboration pattern triggers other such patterns. This investigation is based on the review of literature that provides empirically observed results. The internal review of the investigation is repeated numerous times, and is followed by an external review conducted by other experts from academia and industry. The contextual relationships among the identified patterns are represented in a structural self-interaction matrix (SSIM).

Table 1. Collaboration patterns for GSCM.

Pattern	Sub-patterns	Sources
P1 Information and knowledge sharing	P1.1 One-way transfer of requests and information	Chiou et al. (2011), Gonzalez et al. (2008), Koplin et al. (2007), Testa and Iraldo (2010), Vachon and Klassen (2006), Zhu et al. (2008)
	P1.2 Interactive communication	Bala et al. (2008), Cheng (2011), Cheng et al. (2008), Koplin et al. (2007), Large and Thomsen (2011), Vachon and Klassen (2006)
	P1.3 Provision of technical expertise	Bala et al. (2008), Cheng (2011), Cheng et al. (2008), Chiou et al. (2011), Koplin et al. (2007), Large and Thomsen (2011), Ravi Shankar (2005)
P2 Process integration	P2.1 Joint planning and decision making	Cheng et al. (2008), Chiou et al. (2011), Diabat and Govindan (2011), Vachon and Klassen (2006), Zhu et al. (2008)
	P2.2 Joint operation	Chiou et al. (2011), Diabat and Govindan (2011), Gonzalez et al. (2008), Ravi Shankar (2005), Zhu et al. (2008)
	P2.3 Joint knowledge creation	Diabat and Govindan (2011), Zhu et al. (2008)
P3 Joint performance management	P3.1 Joint monitoring	Bala et al. (2008), Vachon and Klassen (2006), Zhu et al. (2008)
	P3.2 Joint evaluation	Chiou et al. (2011), Diabat and Govindan (2011), Gonzalez et al. (2008), Koplin et al. (2007), Large and Thomsen (2011), Testa and Iraldo (2010), Zhu et al. (2008)
	P3.3 Joint awarding and incentive alignment	Bala et al. (2008), Cheng (2011), Chiou et al. (2011)
P4 Relationship management	P4.1 Partner push	Bala et al. (2008), Chiou et al. (2011), Gonzalez et al. (2008), Vachon and Klassen (2006)
	P4.2 Conflict mediation	Bala et al. (2008)
	P4.3 Long-term partnership	Cheng (2011), Cheng et al. (2008)

Based on the SSIM, the initial reachability matrix is developed. The final reachability matrix is then obtained from the initial reachability matrix based on the transitivity rule. The matrix also shows the driving power of each collaboration pattern, which is the total number of patterns including the focal pattern itself being stimulated by the focal pattern, and the dependence of each collaboration pattern, which is the total number of patterns helping to achieve the given pattern. These are applied in the MICMAC analysis in the forthcoming step.

The final reachability matrix is partitioned into different levels. The reachability and antecedent sets of each collaboration pattern were identified from the final reachability matrix. The reachability set of a collaboration pattern consists of itself and the other patterns that are triggered by the respective pattern. The antecedent set of a collaboration pattern consists of itself and the other patterns that help in achieving the given pattern. Subsequently, the intersection of these sets is derived for all patterns. If the reachability and intersection sets for a collaboration pattern are found to be identical in the first iteration step, then that pattern is considered to be in level I, which is at the top of the ISM hierarchy [18]. After the first iteration shown, the patterns ranked at level I are discarded and the same procedure is repeated with the remaining patterns at the second iteration step. These iterations are continued until the levels are assigned to all patterns. From the level partition, a structural diagram of the collaboration patterns for GSCM is generated, as shown in Figure 1. An arrow pointing from i to j shows that the relationship exists between the patterns i and j. The digraph is converted into the ISM model by removing the transitivities as described in the ISM methodology.

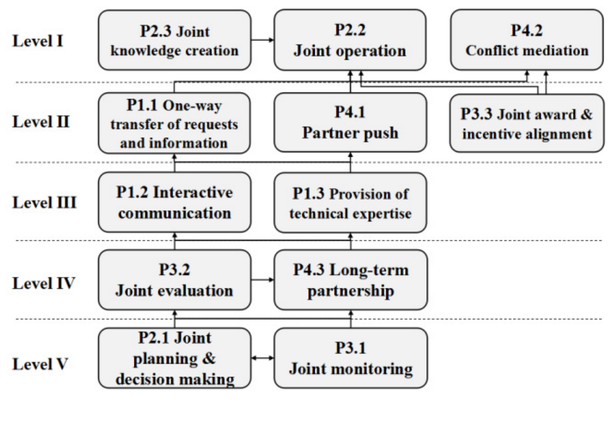

Fig. 1. ISM model for collaboration patterns.

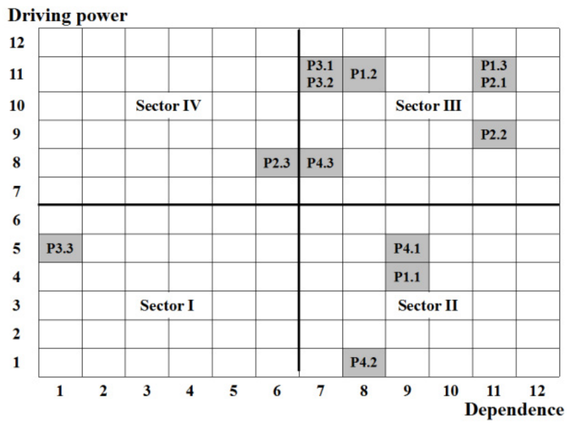

Fig. 2. Driving power-dependence power diagram.

4. Discussions

The findings from Figure 1 reveals that joint monitoring of mutual performance (P2.1) as well as joint planning, and decision making (P3.1) can play a fundamental role in facilitating collaborative GSCM at the first level of the ISM model. They also support the introduction of other collaborative initiatives. An interactive supply chain requires such a mutual recognition by the chain members of the current performance status and the collective plans and necessity to improve SCM performance. Having similar perceptions regarding goals and behaviors can reduce the possibility of misunderstanding in communications and increase opportunities to share information and knowledge.

At the second level, the shared information on plans and status from the first level is evaluated (P3.2) and the shared information also contributes to consolidating the partnership with chain members (P4.3). Once the supply chain partners have common beliefs regarding the importance and appropriateness of their behaviors and policies, they tend to become highly devoted to their relationship [31]. By helping chain members understand mutual strategies, the sharing of collective environmental plans and establishing monitoring mechanisms for the GSCM performance can enhance mutual trust in inter-organizational relationships [6].

At the third level, the effective joint evaluation and established long-term partnership trigger the interactive communication (P1.2) and sharing of technical expertise (P1.3) among the supply chain partners. The evaluation results of partner performance in the supply chain can provide valuable information on areas of weakness where performance improvements are necessary [56], thereby leading to the sharing of technical expertise specifically required for those areas. A study by Large and Thomsen [26] suggests that trust building based on long-term partnership has a positive influence on sharing technical and operational knowledge for GSCM among supply chain partners. The accumulation of trust can also positively affect the level and intensity of communication because companies are often unwilling to exchange information on business plans, processes, and environmental performance as they fear exposing their disadvantage or giving other companies competitive advantage [31]. In fact, the GSCM-related information can be confidential with potential improvement in competitiveness, and the confidentiality is frequently regarded as a major difficulty in green supply chain collaboration [32,57]. Partners might engage in open and effective knowledge sharing with the trust based on the long-term partnership [33,39].

At the fourth level, the interactive communication and sharing of technical expertise result in a one-way transfer of requests and information (P1.1) and the introduction of partner push measures (P4.1). The multidirectional communication among all chain members promotes deep information flows along the supply chain, such that all the members can gain detailed insights into the subsequent stages of the lifecycle and supply chain as a way to comprehend why such improvements are required [41]. This intense information and knowledge exchange in the supply chain can lead to the theme-specific interaction among the supply chain members by allowing them to ask for concrete information, urge their partners to adopt GSCM measures, and impose pressures on the partner's business during the purchasing process. In the knowledge sharing process, for example, a manufacturer and its suppliers can detect the demands for sharing necessary information even in the early stages of product development to find solutions to problems regarding product design and material sourcing [3].

At the fifth level, urging partners for new challenges through requests and push measures causes joint operation (P2.2). Joint operation involves the integration of the operational process and infrastructure of the chain members to reduce the negative consequences of the business activities in the supply chain. The improved information and knowledge sharing through the partner push enables transparency and flexibility when integrating operational processes of the entire supply chain in an environment-friendly manner [52], in particular to integrate inventory and logistics management, production planning and scheduling, and computer linkages [11,52]. However, a successful GSCM collaboration necessitates synergistic interaction between push and pull measures. Supply chain members need to provide rewards for the improved GSCM performance and agree on the incentive alignment (P3.3) to facilitate joint operation (P2.2) and resolve supply chain conflicts (P4.2). The reason is that the transparent alignment of incentives can visualize actual links between the measures, performance results, and incentive levels provided to the supply chain members [46]. In addition, the successful joint operation can be promoted through joint knowledge creation (P2.3), which involves joint research and development of the greener products and processes. By reducing knowledge asymmetry among the chain members, joint knowledge creation can contribute to mitigating negative environmental consequences in the operational process among the supply chain partners [6].

The diagram in Figure 3 shows that joint awarding and incentive alignment (P3.3) in Sector I is autonomous and relatively disconnected from the system, with which it has only few but potentially strong links. The one-way transfer of requests and information (P1.1), partner push (P4.1), and conflict mediation (P4.2) in Sector II are dependent on other collaboration patterns. Most collaboration patterns that fall under Sector III are called linkage patterns because they have both strong driving power and dependence. These patterns are unstable because any action on them will have an effect on other patterns and also a feedback effect on themselves [35]. Providing technical expertise (P1.3) as well as joint planning and decision making (P2.1) are the most powerful linkage patterns because their driving power and dependence are the highest with a score of 11. First, this result is consistent with previous findings from SCM and GSCM that have emphasized knowledge sharing and common goal synchronization as keys to supply chain collaboration. These patterns can be regarded not only as antecedents of collaboration to introduce other inter-organizational measures but also as outcomes of collaboration. Other patterns also have high levels of driving power and dependence but with a slight imbalance between both variables. On the one hand, interactive communication (P1.2) as well as joint monitoring and evaluating (P3.1, P3.2) have the highest driving power with scores of 11, but their dependence scores are relatively weak at 7 and 8, respectively. On the other hand, joint operation measures (P2.2) have the highest level of dependence with 11 points but their driving power is limited to 9. Finally, Sector IV includes the joint knowledge creation (P2.3) pattern, which is an independent pattern characterized by strong driving power but weak dependence. This finding signifies that joint knowledge creation can be regarded as a prerequisite for collaboration than as a result of it.

This study imposes order and direction on the complexity of relationships and analyzes the interdependencies of the various collaboration patterns for GSCM, which can provide company managers with a realistic representation of the tasks in conducting GSCM with their supply chain partners. This approach can aid the top management in prioritizing so that it can proactively take steps to improve inter-firm collaboration for GSCM. However, the ISM methodology has its own limitations [18]. The relations of the collaboration patterns presented in this study are based only on the statistically significant relations from the previous literature with empirical evidence. However, each of the previous studies applied various terminologies, definitions, and categories. Interpreting the collected measures and classifying them into the present framework embeds the subjective bias of the person who is judging the variables because this process is affected by the person's knowledge and familiarity with the company, its operations, and its industry. Furthermore, the ISM methodology cannot measure the relative importance of the variables because of the lack of weights associated with the variables. To overcome these limitations, structural equation modelling (SEM) can be applied in future research to test the validity of this hierarchical model. SEM can only statistically test an already developed theoretical model, whereas ISM is able to develop an initial model. Therefore, ISM can serve as a basis of forthcoming studies that employ SEM. In addition, this study can be empirically complemented with the case studies, as the GSCM collaboration in real world can be complicated which might cause difficulties in operation.

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