A novelty hybrid method for integrated innovation in strategic supply chain management

Ming-Lang Tseng†
Department of Business Administration
Lunghwa University of Scicnce and Technology, Taiwan
Email: tsengminglang@gmail.com

Anthony SF Chiu
Department of Industrial Engineering
De La Salle University, Philippines
Email: anthonysfchiu@yahoo.com

Ming K. Lim
University of Coventry, United Kingdom

Abstract. This study proposes a novel hybrid approach to deal with the interrelationships and interdependence rel ations among the aspects and criteria in hierarchical structure in decision-making process. This novelty hybrid ap proach are (1) to build the hierarchical structure with interpretive structural modelling; (2) to use fuzzy set to int erpret the vague information into crisp weights; (3) to apply decision-making trial and evaluation laboratory to in terpret the interrelationships among aspects and presents the criteria's driving and dependence powers; and (4) usi ng the concept of analytical network process to approach interdependence relations, construct the hierarchical stru cture in supermatrix guided by interpretive structural modelling result and acquire the converged weights. This s tudy applied this hybrid method in Taiwanese high-tech industry in analyzing the integrated innovation in strategi c supply chain management to enhancing the firm's competitiveness. The hierarchical structure shows that supply chain operations, coordination, and strategic orientation are the most important aspects for the management to im prove their firms' performance. This study indicated that to success in building strategic supply chain managemen t, firms should notice in building technology-driven strategy, cost efficiency innovation and value co-creation inno vation criteria.

Keywords: maximum five keywords should be included

1. INTRODUCTION

In multi criteria decision-making (MCDM), a set of compatible criteria related to the formulation of the assumed theoretical model and the hierarchical structure is consisted with interrelationships and interdependence relations among the measures that also express information on the expert's preferences (Wu *et al*., 2015; Chen *et al*., 2015). In addition, the theoretical model is usually with hierarchical relation and such the expert's preference information is represented with a set of qualitative information related to the formulation and evaluation of the hierarchical structure. Still, the theoretical model is usually with a set of criteria that is with interrelationships and interdependence relations. The purpose of MCDM leads to infer to a reliable decision-making result. Especially, the methods are based on the expert's preference information are considered to express the preferences directly to technical or complex relations in the theoretical model or complex situation. However, what are those methods to be applied in a specific study. Moreover, the hybrid method approach exhibits the link between an inferred preference results and the suggested recommendation for a situation. Hence, this study would focuses on multiple criteria choice and ranking problem to dealing with the complex situation.

Hence, this study utilizes the interpretive structure modeling (ISM) to visualize the hierarchical interrelationships among criteria. ISM approaching is an interactive learning process whereby a set of different directly and indirectly related criteria are structured into a comprehensive systemic hierarchical structure (Kannan et al., 2009; Raj et al., 2010;

Ravi & Shankar (2005). Still, the driving, and dependent powers should be proper address to improve the performance. Due to the interrelationships and interdependence relations among criteria, the Decision-making Trial and Evaluation Laboratory (DEMATEL) using the inferential weights resolve the interrelationships. Tzeng & Huang (2012) and Liou (2015) applied the DEMATEL to construct the causal relationship among the evaluation system and the concepts of analytic network process (ANP) to derive the influenced weights of criteria, map out the structural relations among the aspects and criteria and identify the key criteria. However, the prior studies presented the hierarchical structure, but unreflect in the computational process and how the hierarchical structure arrived is unaddressed. Still, the interdependence relationships are applied ANP to weight the proposed aspects and criteria and ranks the decisive ones (Liou, 2015, Tseng, 2009; Tseng & Lin, 2009). Therefore, this study proposes this hybrid approach and contributes to the MCDM literatures by proposing ISM-DEMATEL-ANP (IDANP). This method distinguished the critical criteria for enhancing integrated innovation in strategic supply chain management (SSCM); furthermore and suggest the hierarchical structure for decision-makers and the infers results and suggestion to the industry.

In recent decades, the supply chain is now the arena for competition for global industries (Ketchen *et al.*, 2007; Govindan & Sivakumar, 2015). Ideally, supply chains capture the advantages of both markets and operations for avoiding risks together (Hult *et al*, 2004). To remain competitiveness in dynamic global market, supply chains need to take strategic approaches toward relationships, and resources (Storer *et al.,* 2014). Developing a well-managed SSCM might enhance a firm's performance due to firms concentrating to response and adapt to market demands more effectively than the rivals (Hult, *et al.*, 2002; Hult *et al.*, 2007; Lin *et al.,* 2010). The Taiwanese high-tech industry is comprised of a diverse group of intra- and inter-organizational relationships; face particular challenges to define their own competitive advantage from increasing competition. Focusing on SSCM, firms might facilitate to create their own competitive advantage to compete with those rivals (Upson *et al.,* 2007). Especially, the firm's internal process is connected with the driving and dependence degrees, directions of integrated alternatives and relationships with retailers, suppliers and customers (Lim *et al,* 2006).

The previous studies concentrated to investigate the key criteria to effectiveness of SSCM to achieve profit optimization (Upson *et al.,* 2007; Hult *et al.,* 2007; Fandel & Stammen, 2004). However, these firms are prepared for the uncertainty and compete by adopting structures, and strategic positons in environment that related to supply chain management and integrated innovation activities (Lin *et al.,* 2010; Prajogo, 2015). Still, the integrated innovation activities involve higher risks, and its success does not guaranteed, the crucial point is to recognize thoroughly, and choose value-creating innovation in supply chain (Rhee *et al.,* 2010, Hjalager, 2010; Nybakk, 2012). Developing a supply chain's competitive advantage through the utilization of integrated innovations in supply chain networks often involves pooling together resources that reconfigure, adapt, and coordinate supply chain offerings in new, and more satisfying ways for customers, thus creating flexibility, and efficiencies in operations (Storer & Hyland, 2011). Ketchen *et al.* (2007) found that by combining tangible and intangible resources, the supply chain ensures both customers, and suppliers share some of the costs, risks, and benefits associated with innovation in supply chain. However, integrated innovation has not been thorough much empirical absorption (Arshinder & Deshmukh, 2008; Ferreira *et al.,* 2015; Storer *et al.,* 2014). Firms should look for collaboration and coordination opportunities with supply chain partners to make sure that their network is competitive, and respond quickly to customers' needs (Cao & Zhang, 2010). However, due to the hierarchical interrelationships among criteria, and the distinction in results of integrated innovation studies, it is necessary to understand the hierarchical relationships of integrated innovation on SSCM criteria.

- What are the driving, and dependence powers to improve the firms' performance through integrated innovation in SSCM?
- What are the most weighted criteria of integrated innovation in SSCM hierarchical structure under interdependence relations and interrelationships in hierarchical structure?

Taiwanese high-tech firm faces the challenges from severe competition with the foreign rivals. This study focuses on the industry due to its complex environment, and contains integrated innovation in SSCM, one of driving the criteria. To actualize worldwide supply chain network with varying degrees of operational productivity, this industry is considered a fast changing with new products, and services emerging rapidly. The implications provide insights for high-tech industry managements in enhancing their integrated innovation in SSCM. This study organized as follows. Section 2 provides a review, and discuss of the related literature of SSCM, and integrated innovation. Section 3 describes industry background, data sampling, and the method proposed. Section 4 presents the results. Section 5 discusses the results, providing several managerial and theoretical implications. Concluding remarks, and possible future studies are included in the last section.

2. METHODS

This section introduced the industrial background an d proposed ISM, DEMTAL, fuzzy set theory and the co ncept of ANP method in hierarchal structure.

2.1 Proposed IDANP hybrid approach

IDANP identified, and summarized the interrelationships and interdependencies in the hierarchical structure among aspects and criteria. It acts as a tool for imposing level, and trend on the complication of interactions among criteria in a hierarchical structure. Usually, ISM suggested using of expert opinions to identify contextual interrelationships among the criteria (Govindan *et al.,* 2001; Jharkharia & Shankar, 2005; Mathiyazhagan *et al.*, 2013; Ravi & Shankar, 2005). DEMATEL is to analyze the inter-relationships among system criteria, and visualizes this structure by cause-effect interrelationship diagram (Gabus and Fontela, 1973). This method feature is its function of building the interrelationships among aspects and criteria. The interrelationship is complex under uncertain circumstance. Hence, the referential weights to give fuzzy assessment rather than just by precise values (Tseng & Lin, 2009). This fuzzy referential weighted assessment situation is to address evaluation problems (Bellman and Zadeh, 1970; Zadeh, 1965). Through analysis of visual interrelationship of levels among system criteria, all criteria are divided into causal group and effected group. Especially, this novel IDANP performed as an examination of interrelationships and interdependencies among the aspects and criteria in hierarchical structure. This study used IDANP to give a holistic hierarchical view of situation rather than considering individual criterion alone in isolation or just one level alone.

1. interpretive structural modelling

A relation matrix (M) can be formed by asking the question like "Does the feature c_i inflect the feature c_j ?" If the answer is "Yes" then $x_{ij} = 1$, otherwise $x_{ij} = 0$. The general form of the relation matrix can be presented as follows:

$$M = \begin{matrix} \\ c_1 \\ c_2 \\ \cdots\cdots \\ c_m \end{matrix} \begin{matrix} c_1 \quad c_2 \quad \cdots \quad \cdots \quad c_n \\ \begin{bmatrix} 0 & x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & ::: & x_{2n} \\ x_{22} & \cdots & 0 & & \cdots \\ \cdots & \cdots & \cdots & 0 & \cdots \\ x_{m1} & x_{m2} & \cdots & \cdots & 0 \end{bmatrix} \end{matrix} \quad (1)$$

Where c_i is the i_{th} attribute in the system, x_{nm} denotes the relation between i_{th} and j_{th} criteria, M is the relation matrix.

Constructing the interrelation matrix, the reachability matrix using Eqs. (2) and (3) as follows

$$\mathrm{R} = \mathrm{M} + \mathrm{I} \quad (2)$$

$$\mathrm{R}^* = R^k = R^{k+1} \;\; k > 1 \quad (3)$$

Calculate the reachability set and the priority set based on Eqs. (4) and (5), respectively, as follows.

$$\mathrm{A}(t_i = \{t_j | x_{nm} = 1\} \quad (4)$$

$$\mathrm{R}(t_i = \{t_j | x_{nm} = 1\} \quad (5)$$

where x_{nm} denotes the value of the i_{th} row and the j_{th} column.

The levels and interrelationships among the criteria can be determined and the structure of the attribute interrelationships can also be expressed using the graph, presented as follows.

$$\mathrm{A}(t_i) \cap R(t_i) = R(t_i) \quad (6)$$

2. Defuzzification

The fuzzy referential weights are applied to the fuzzy aggregation that contains defuzzification method. Defuzzification is to convert fuzzy numbers into crisp score. This study applies the converting fuzzy data into crisp scores developed by Opricovic & Tzeng (2004), the main procedure of determining the left and right scores by fuzzy minimum and maximum; the total score is determined as a weighted average according to the membership functions. Let $\widetilde{m}_{ij}^k = (L_{ij}^k, M_{ij}^k, U_{ij}^k)$, mean the degree of criterion i that affects criterion j and fuzzy questionnaires k $(k = 1,2,3, \ldots, k)$.

Table1. Referential fuzzy weights

Preferences	Interrelationships	Referential fuzzy weights
Very important	X	(0.5,0.75,1)
Moderate important	V	(0.25,0.5,0.75)
Important	A	(0,0.25,0.5)
Unimportant	O	(0,0,0.25)

Normalization the referential fuzzy weights

$$L'^k_{ij} = (L^k_{ij} - \min L^k_{ij}) / \;\; \delta^{\max}_{\min} \quad (7)$$
$$M'^k_{ij} = (M^k_{ij} - \min M^k_{ij}) / \;\; \delta^{\max}_{\min}$$
$$U'^k_{ij} = (U^k_{ij} - \min U^k_{ij}) / \;\; \delta^{\max}_{\min}$$

, Where $\delta^{max}_{min} = max\ r^n_{ij} - minl^n_{ij}$.

Compute right (rs) and left (ls) normalized values

$$ls'^k_{ij} = M'^k_{ij} / (1 + M'^k_{ij} - L'^k_{ij})$$
$$rs'^k_{ij} = U'^k_{ij} / (1 + U'^k_{ij} - M'^k_{ij}) \quad (8)$$

Compute total normalized crisp values:

$$cv^k_{ij} = \left[ls'^k_{ij}\left(1 - ls'^k_{ij}\right) + rs'^k_{ij} \times rs'^k_{ij}\right] / \left[1 - ls'^k_{ij} + rs'^k_{ij}\right]$$
(9)

Compute total normalized crisp values:

$$\widetilde{\omega}^k_{ij} = \min\ m^n_{ij} \;+\; cv^k_{ij}\ \delta^{max}_{min} \quad (10)$$

Integrate crisp values from different opinions of k

respondents:

$$\tilde{\omega}_{ij}^{ka} = (\tilde{\omega}_{ij}^{1} + \tilde{\omega}_{ij}^{2} + \ldots + \tilde{\omega}_{ij}^{k})/\mathrm{k} \quad (11)$$

3. DEMATEL

Then, the $\tilde{\omega}_{ij}^{k}$ are applied in to the direct-relation matrix (DM) (Tseng, 2009; Tseng & Lin, (2009). The normalized DM can be obtained through following

$$DM = \begin{bmatrix} \frac{\tilde{\omega}_{11}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & \frac{\tilde{\omega}_{12}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & \frac{\tilde{\omega}_{13}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & \cdots & \frac{\tilde{\omega}_{1n}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} \\ \frac{\tilde{\omega}_{m2}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & & \cdots & & \vdots \\ \frac{\tilde{\omega}_{m3}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & & & & \vdots \\ \frac{\tilde{\omega}_{mn}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} & & \cdots & & \frac{\tilde{\omega}_{mn}^{k}}{\max_{1\le i\le n}\sum_{j=1}^{n}\tilde{\omega}_{ij}^{k}} \end{bmatrix} \quad (12)$$

I denoted as the identity matrix. The total relation matrix (TM) is from following equation

$$TM = DM\ (I - DM)^{-1} \quad (13)$$

Producing a causal diagram. The sum of rows and the sum of columns are separately denoting as vectors X and Y within the TM. A causal and effect graph can be acquired by mapping the dataset of$(X + Y, X - Y)$. The horizontal axis vector $(X + Y)$ named "Prominence" is made by adding X to Y, which reveals how much importance the criterion has. Similarly, the vertical axis $(X - Y)$ named "Relation" is made by subtracting X from Y, which may group criteria into a cause group. Or, if the $(X - Y)$ is negative, the criterion is grouped into the effect group.

$$TM = [tm_{ij}]_{n \times n}, i, j = 1,2, \ldots, n \quad (14)$$

$$X = \left[\sum_{i=1}^{n} tm_{ij}\right]_{1\times n} = \left[tm_j\right]_{n\times 1} \quad (15)$$

$$Y = \left[\sum_{j=1}^{n} tm_{ij}\right]_{1\times n} = \left[tm_j\right]_{n\times 1}$$

(16)

Obtaining the interdependence matrix, in this step, the sum of each column in total relation matrix is equal to 1 by the normalization method, and then the interdependence matrix can be acquired.

4. Analytical network process

Supermatrix allows ANP to manage the interrelationship of and interdependence within the aspects and criteria. The hierarchical structure, interrelationship and interdependencies are presented, the decision maker is required to offer the weight to adjust into column stochastic (Tseng et al., 2015). Then, it becomes a weighted supermatrix SM^*. Finally, the converged weighted supermatrix SM^*can be acquired, which states the accurate relative weights within the aspects and criteria in hierarchical structure.

$$SM = \lim_{* \to \infty} SM^* \quad (17)$$

2.2 Proposed analytical steps

To further apply the IDANP method, the analysis procedures are explained as follows:

1. Developing a hybrid method to deal with the interrelationships and interdependencies in hierarchical structure – the nature of criteria is with hierarchal situation and with interrelationships within the cluster of criteria.
2. Identifying the integrated innovation in SSCM aspects and criteria with interrelationships and in hierarchical structure - to gain a structural model dividing evaluation criteria, the ISM is appropriate to be applied in this study, using Eqs. (1) - (6).
3. Interpret the fuzzy referential weights into DEMATEL and divides the criteria into the prominence and relation groups - using fuzzy referential weights to convert fuzzy numbers into a crisp score, the fuzzy assessments applying in Eqs. (7) – (11) are defuzziffied and aggregated as a crisp value $\tilde{\omega}_{ij}^{k}$. The crisp values applied to the DEMATEL, applied in Eqs. (12) - (16).
4. Developing the hierarchical supermatrix with interdependencies relation accordingly - the crisp value is composed of the un-weighted supermatrix. The converged weights can be obtained through Eq. (17).

3. RESULTS

Using a visual driving and dependent powers to draw the four quadrants to locating the criteria. The driving and dependence power among the criteria are presented in Table 9.

The criteria have strong driving and dependence power, the most effective criteria that included collaborative communication innovation(C6), Joint knowledge creation innovation (C7), collaborative communication innovation(C9), incentive alignment(C8), buyer-vendor coordination innovation(C10), operational information sharing(C15) and market orientation (C18). These criteria fall into the group of connective criteria. These criteria's instability means that any action on these criteria has an influence on others and a re-influence among themselves. Therefore, providing them to SSCM has to be concluded as a most urgency to improve in SSCM.

The criteria in strong dependence and weak driving power quadrant included embedding operant resource (C2), procurement-production coordination innovation(C13), multi-plant coordination innovation(C14), strategic human resources management(C16) and technology-driven strategy(C17).

The strong driving and weak dependence power quadrant are included co-creation innovation (C1), process alignment innovation (C5), inventory-distribution coordination innovation (C12) and resource orientation (C19). These criteria are relatively independent to each other but with strong driving power.

The weak driving and dependence power are relatively disconnected from the management system; these criteria have only limited effect that included value constellations (C3), resource integration innovation (C4), Production-distribution coordination innovation (C11), customer responsiveness innovation (C20) and cost efficiency innovation (C21). Hence, using simple visual analysis, the strengths and weaknesses of the criteria under reflection and this draws managerial implications for resource re-allocation.

Table 2. DEMATEL

	X	Y	X+Y	X-Y
AS1	3.529	1.902	5.431	1.626
AS2	2.403	2.749	5.151	(0.346)
AS3	2.748	3.353	6.101	(0.605)
AS4	2.407	3.082	5.489	(0.675)
AS5	2.889	2.859	5.748	0.030
AS6	2.968	3.125	6.093	(0.157)
Max	3.529	3.353	6.101	1.626
Min	2.403	1.902	5.151	-0.675

Table 3. Results

	As1	As 2	As 3	As 4	As 5	As 6	RC1	RC2	RC3	RC4	RC5	RC6	RC7	RC8	RC9	RC10	RC11	RC12	RC13	RC14	RC15	RC16	RC17	RC18	RC19	RC20	RC21	Ranking
As 1	0.0819	0.0815	0.0820	0.0818	0.0819	0.0821	0.0819	0.0819	0.0819	0.0819	0.0818	0.0819	0.0818	0.0819	0.0819	0.0819	0.0819	0.0819	0.0819	0.0819	0.0818	0.0818	0.0819	0.0819	0.0819	0.0819	0.0818	5
As 2	0.0742	0.0747	0.0745	0.0746	0.0745	0.0744	0.0745	0.0746	0.0745	0.0745	0.0745	0.0745	0.0746	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745	0.0746	0.0746	0.0745	0.0745	0.0745	0.0745	0.0745	6
As 3	0.0843	0.0843	0.0843	0.0843	0.0844	0.0844	0.0844	0.0844	0.0844	0.0844	0.0843	0.0844	0.0843	0.0843	0.0844	0.0844	0.0844	0.0844	0.0844	0.0843	0.0843	0.0844	0.0843	0.0843	0.0843	0.0844	0.0844	3
As 4	0.0893	0.0894	0.0893	0.0892	0.0893	0.0892	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0893	0.0894	0.0893	0.0893	0.0893	0.0893	0.0893	0.0894	0.0893	0.0893	0.0893	1
As 5	0.0857	0.0859	0.0857	0.0859	0.0858	0.0858	0.0857	0.0858	0.0857	0.0857	0.0859	0.0858	0.0859	0.0858	0.0858	0.0858	0.0858	0.0857	0.0857	0.0857	0.0858	0.0858	0.0858	0.0857	0.0858	0.0857	0.0858	2
As 6	0.0843	0.0841	0.0843	0.0844	0.0842	0.0844	0.0842	0.0843	0.0842	0.0842	0.0843	0.0842	0.0842	0.0843	0.0842	0.0842	0.0842	0.0842	0.0842	0.0842	0.0843	0.0843	0.0843	0.0842	0.0843	0.0842	0.0843	4
RC1	0.0296	0.0295	0.0296	0.0297	0.0295	0.0297	0.0296	0.0296	0.0295	0.0295	0.0295	0.0296	0.0295	0.0296	0.0295	0.0296	0.0295	0.0296	0.0296	0.0295	0.0296	0.0296	0.0295	0.0294	0.0295	0.0295	0.0296	3
RC2	0.0274	0.0272	0.0271	0.0272	0.0274	0.0273	0.0273	0.0272	0.0273	0.0273	0.0273	0.0273	0.0273	0.0271	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	0.0273	6
RC3	0.0187	0.0187	0.0188	0.0188	0.0187	0.0188	0.0187	0.0187	0.0187	0.0187	0.0188	0.0188	0.0187	0.0188	0.0187	0.0187	0.0187	0.0187	0.0188	0.0187	0.0187	0.0187	0.0188	0.0187	0.0188	0.0187	0.0187	15
RC4	0.0216	0.0217	0.0215	0.0214	0.0216	0.0215	0.0216	0.0216	0.0216	0.0216	0.0216	0.0216	0.0216	0.0215	0.0217	0.0216	0.0216	0.0216	0.0216	0.0216	0.0216	0.0216	0.0216	0.0217	0.0216	0.0216	0.0216	14
RC5	0.0219	0.0221	0.0219	0.0220	0.0220	0.0219	0.0219	0.0220	0.0220	0.0219	0.0220	0.0219	0.0220	0.0220	0.0220	0.0219	0.0220	0.0220	0.0219	0.0220	0.0220	0.0219	0.0220	0.0220	0.0220	0.0219	0.0220	13
RC6	0.0225	0.0226	0.0226	0.0226	0.0226	0.0225	0.0226	0.0226	0.0226	0.0226	0.0226	0.0226	0.0226	0.0227	0.0225	0.0226	0.0226	0.0226	0.0226	0.0226	0.0225	0.0225	0.0226	0.0227	0.0226	0.0226	0.0225	10
RC7	0.0174	0.0174	0.0175	0.0175	0.0175	0.0175	0.0175	0.0174	0.0174	0.0174	0.0175	0.0175	0.0174	0.0175	0.0174	0.0174	0.0174	0.0174	0.0175	0.0174	0.0175	0.0175	0.0175	0.0174	0.0175	0.0174	0.0174	19
RC8	0.0264	0.0261	0.0264	0.0263	0.0263	0.0263	0.0264	0.0263	0.0262	0.0264	0.0264	0.0264	0.0263	0.0264	0.0262	0.0264	0.0264	0.0264	0.0264	0.0263	0.0262	0.0262	0.0264	0.0265	0.0264	0.0263	0.0262	7
RC9	0.0281	0.0282	0.0279	0.0280	0.0281	0.0281	0.0280	0.0282	0.0282	0.0281	0.0279	0.0280	0.0280	0.0279	0.0283	0.0280	0.0280	0.0280	0.0280	0.0280	0.0281	0.0282	0.0280	0.0279	0.0280	0.0281	0.0282	4
RC10	0.0177	0.0178	0.0179	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	0.0178	18
RC11	0.0179	0.0180	0.0180	0.0179	0.0179	0.0179	0.0180	0.0179	0.0179	0.0180	0.0180	0.0180	0.0180	0.0180	0.0179	0.0180	0.0180	0.0180	0.0180	0.0180	0.0179	0.0179	0.0180	0.0181	0.0180	0.0179	0.0179	17
RC12	0.0223	0.0222	0.0221	0.0222	0.0222	0.0222	0.0221	0.0221	0.0222	0.0221	0.0222	0.0221	0.0222	0.0222	0.0222	0.0221	0.0222	0.0221	0.0221	0.0222	0.0222	0.0221	0.0222	0.0222	0.0222	0.0221	0.0221	11
RC13	0.0247	0.0246	0.0246	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0246	0.0245	0.0246	0.0246	0.0246	0.0245	0.0246	0.0245	0.0245	0.0246	0.0245	0.0245	0.0246	0.0247	0.0246	0.0245	0.0245	8
RC14	0.0173	0.0174	0.0175	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	0.0174	21
RC15	0.0365	0.0368	0.0362	0.0364	0.0365	0.0364	0.0364	0.0367	0.0366	0.0366	0.0363	0.0363	0.0364	0.0362	0.0368	0.0364	0.0364	0.0364	0.0363	0.0364	0.0366	0.0366	0.0363	0.0362	0.0363	0.0365	0.0367	2
RC16	0.0244	0.0246	0.0244	0.0244	0.0244	0.0244	0.0244	0.0245	0.0245	0.0245	0.0245	0.0244	0.0245	0.0245	0.0245	0.0244	0.0245	0.0245	0.0244	0.0245	0.0245	0.0244	0.0245	0.0246	0.0245	0.0244	0.0245	9
RC17	0.0284	0.0280	0.0280	0.0281	0.0283	0.0283	0.0282	0.0281	0.0283	0.0282	0.0282	0.0283	0.0281	0.0280	0.0283	0.0282	0.0282	0.0282	0.0282	0.0283	0.0281	0.0282	0.0282	0.0283	0.0282	0.0282	0.0282	5
RC18	0.0174	0.0174	0.0175	0.0175	0.0174	0.0174	0.0175	0.0174	0.0174	0.0175	0.0175	0.0175	0.0175	0.0175	0.0174	0.0175	0.0175	0.0175	0.0175	0.0175	0.0174	0.0174	0.0175	0.0175	0.0175	0.0174	0.0174	20

4. IMPLICATIONS

This section presents theoretical implications to contribution to the academia and provides managerial implications to enhancing the high-tech industry.

Theoretical implications

This study integrates the literatures on process management to create essential visions to integrate the innovation in SSCM (Hult *et al.*, 2007; Upson *et al.,* 2007; Lin *et al.,* 2010). A six-level hierarchical structure is created for understanding the interrelationships and interdependence relations among these aspects and criteria. This study contributes to the existing literature by exploring the role of integrated innovation criteria, thereby providing better insights in SSCM. The result suggests that supply chain operations (AS5), Supply chain coordination (AS3) and Strategic orientation (AS4) are the important decisive aspects for this study. Moreover, the supply chain operations (AS5) and supply chain networks integration innovation (AS1) are the most influence aspects in the causal mapping. Specially, this study suggests that supply chain operations influences the integrated innovation in SSCM, this result is partially similar to Tseng et al. (2015).

Especially, supply chain coordination is the basis that facilitating communication among supply chain networks that influence on aspects in various interactions. This allowed information to be shared across the supply chain, and for activity to be coordinated, thus, enabling integrated innovation which helping in managing, and controlling supply chain activities by providing Technology-driven strategy (C21), Cost efficiency innovation (C15), and value co-creation innovation (C1). Besides, it facilitates the integrated innovation in supply chain networks and enhancing the strategic orientation in the case firm performance. Thus, enhancing supply chain operations and coordination have been viewed as an important way to improve SSCM (Tang, 2012; Tang, 2014). This evidence is provided with the ranking of criteria that Multi-plant coordination innovation (C9) and Production-distribution coordination (C17) are the decisive criteria for improving the SSCM. In addition, this study recognizes the role of integrated innovation as an important aspect, in turn archiving profit maximization, respectively to some studies (Hult *et al.*, 2007; Lin *et al.*, 2010).

Integrated innovation helps for better performance. Previous studies have resulted significance between the integrated innovation and firm performance (Lin et al., 2010). However, the insights of innovation criteria to effectively SSCM are remaining blurring and lacking of detailed explanations. The Technology-driven strategy, as an attribute of innovation, facilitates resource orientation to create cost efficiency (Cao & Zhang, 2010), and further upgrading supply chain performance. Moreover, it confirms the integrated innovation might be enhanced if it is existed throughout the whole supply chain activities (Lin et al., 2010). The embedded operational resources complement for the strategic orientation by determining the role of operational information sharing, and technology-driven strategy. Furthermore, the findings of value co-creation to supply chain performance give insights on managing the supply chain networks integration innovation in supply chain network. Therefore, the strategic orientation

(AS4) is considered as indispensable part to assist with SSCM to archive superior firm performance.

Multi-plant coordination innovation in supply chain context refers as a tool to redesign capabilities and resources among the partners to archive better performance (Lee, 2000). It deliver substantial benefits, and advantages to its supply chain partners by enabling firms to quickly adapt to market changes, and to improve their capabilities to fulfill customer needs by flexible offerings. Moreover, Value co-creation innovation among the partners might be sources of new product or service ideas. The result evidences supporting the causal relationships among the aspects. For example, the earlier and more extensive information for enhancing firm performance is argued to be one of the ways to enhance supply chain operations (AS5) in terms of cost efficiency innovation and process alignment innovation. As such, the problems in integrating supply chain activities that often hindered by process alignment innovation and Value co-creation innovation could be key improved criteria.

Managerial implications

This section presents several implications for practice. The causal decisive criteria of SSCM are provided in the result session, which turn in several managerial insights for high-tech industry. Given the high complex nature of supply chain in high-tech industry, the fundamental criteria which have high influence in supply chain are explored, shedding light for high-tech firms to improve their supply chain. Basing on the position, there are five criteria with the most driving and dependence power. Those are value co-creation innovation (C1), multi-plant coordination innovation (C9), cost efficiency innovation (C15), process alignment innovation (C17), and technology-driven strategy (C21). The implications for high-tech firms derived from this study result are discussed as follow.

Value co-creation innovation (C1) is a way to improve SSCM. As goods flow from more than one supplier to more than one manufacturing, and distribution site, supply chains in high-tech firms are complex. For the effective integrated of information, systems, processes, efforts, and ideas across all functions of the entire supply chain, an effective value co-creation in a firm’s supply chain is important. It facilitates and ensures product information flow and communication among departments, thus, assisting in improving coordination in the supply chain as well as improving the cost efficiency. Targeting on the value co-creation might help increase productivity in the supply chain networks, allow for better business decision-making. Such inter and intra-organizational information sharing should be implemented and serves as the backbone of a firm’s business goal and supply chain coordination. Particular for high-tech firms which often have a complex supply chain, effective value co-creation is necessary for the supply chain partners.

Multi-plant coordination innovation (C9) is essential in SSCM. Since great diversity of products and services are distributed across the supply chain, coordination provides an ideal platform for learning and utilizing the knowledges together. This coordination can be an effective means of transferring knowledge and new technical skills across firms for appropriate response to changes and customer needs. This could benefit firms in term of faster product output, reduction of production, logistical cost and increase of efficiency as well as maximizing return on investments. Hence, high-tech firms suggest to make efforts that encouraging multi-plant coordination innovation such as outsourcing agreements, product or service innovation and cooperative research to lowering the costs. There are chances for learning from the partners, who might have successfully implemented similar concepts, practices, or technologies. Moreover, coordination improves the operation concentrated on proficiency, and adapts the customer responsiveness.

One of the success criteria in enhancing SSCM is cost efficiency innovation. This might affect resource integration process to decrease execution costs and lead to better SSCM. This considers as an essential condition to improve performance and satisfaction in supply chain. Improving the cost efficiency innovation, firms can lead to superior integrated innovation in the SSCM. High-tech firms should pursue process alignment innovation in term of improving cost efficiency; management suggests to be open and responsive to different perspectives, which could generate more new knowledge, open and responsive to different perspectives come up with innovative solutions that can make the firm more competitive.

Process alignment innovation is as a processing of business transactions by computers connected in networks. With the complex, and developed dramatically growth like high-tech industry, to scale up the SSCM, transactions must execute concurrently. This study suggests that a good operational system to radically increase the effectiveness and efficiency of process alignment. In detail, process alignment in supply chain is a significant use of technologies for interaction with both suppliers and customers of a firm. It offers a certain advantage in managing supply chain. Technology-driven strategy integrates the process alignment related to the competitive environment (Deutscher *et al.,* 2016). In the result, it is found to have strong certainty with SSCM. The finding confirms that technology-driven plays a central role in SSCM; it helps directly the resource integration. Moreover, it provides path to superior cost efficiency. It enables these firms to successfully exploit arising opportunities through the development of integrated innovation in supply chain networks. Decision makers should develop a stronger innovation orientation due to its responding and adapting to its customers’ demand better than rivals develop and implement supply chain performance.

5. CONCLUSIONS

Innovation topic and SSCM have been widely conducted by various studies, however, the role of integrated innovation in SSCM is remaining lacking. Therefore, this study provided insights of a precise and thorough study of the positioning criteria. To explore such complex phenomenon, this study proposed to compose a hybrid method, called IDANP. Unlike the DANP is only handling the one level structure, the management issue is always with a multi-hierarchical structure and the prior studies are lacking of interpretive the multi-hierarchical interdependence relations (Liou, 2015; Shen et al. 2014). Hence, this study utilized ISM to firm the hierarchical structure, the ISM is more imprecise because it uses experts' experience, and knowledge in practicing to compose a complex system into many criteria, and reconstruct into hierarchical structural (Mathiyazhagan *et al.,* 2013). In addition, the study of Govindan et al. (2013) applied ISM to provide more valuable information of driving and dependent powers. However, the input information is presented on the linguistic preferences and the driving and dependent powers should be more precisely presented. Therefore, the DEMATEL needs to apply in this interrelationship situation and mapping out the causal relations among the aspects and judge the driving and dependent powers among the criteria. Hence, the translation of this ISM blur information needs to apply fuzzy set theory in order to translate the information properly into DEMATEL to acquire the detailed result. Still. To handle the interdependence relations in multi-hierarchical structure, hence, the supermatrix is responsible for constructing the hierarchal structure and acquires the converged weights of aspects and criteria.

The findings implied that the supply chain operations, supply chain coordination and strategic orientation are important aspects and specifically the supply chain operations should be focusing as higher priority in decision-making. In the practices, technology-driven strategy leads the integrated innovation in SSCM delivers the better performance in high-tech industry due to the complicated supply chain networks. A well-managed technology-driven strategy has a significant effect to the integrated innovation. The role of technology is largely in operations due to all aspect of coordination, operations and strategic integration in competitive market. The technology embeds in recording how people works and improvements in technology applications can be a significant source of differentiation. Technology-driven strategy is not only for their end product, technology itself has nevertheless become a significant domain for integrated innovation and forming the strategic orientation in supply chain management; technology-driven innovation is central to their competitive position in high tech industry. In this context, technology-driven innovation refers to address the complex innovation dynamics that emerge together to bring new capabilities into practices.

The contribution of this study are (1) in practices, to find out the causal relations among the aspects and the criteria's driving and dependence powers of the integrated innovation in SSCM by building the six levels hierarchical structure; (2) to form a hybrid method, called IDANP, to deal with vague information translation to explore the interrelationships and interdependence relations among the measures; and (3) the existing DANP literatures are lacking to address the vague information and handle the proposed aspects and criteria in a multi-hierarchical structure. However, this study also has limitations. First, this study was conducted using existed SSCM literatures to explore the interrelationship of relevant criteria, thus, the set of criteria might not comprehensive, future study should expand more in the SSCM context. Second, the sample collection focused only on high-tech industry. Hence, the external generalizability is limited. Future study suggests to apply the data in cross-industry, and in several countries, which might overcome the potential problems with generalizability. Likewise, the expert's sample could be categorized into different industry that may benefit for comparison and examine the effective of aspects and criteria. Third, this study using ISM approach based on the experts' experience in practice. Furthermore, to promote the accuracy of analysis, uncovering, and include more potential criteria is necessary.

REFERENCES

1. Arshinder, A.K., Deshmukh S.G., (2008). Supply chain coordination: Perspectives, empirical studies and research directions. *International Journal of Production Economics*, **115(2)**, 316-335.
2. Bello, D.C, Lohtia, R., Sangtani, V., (2004). An institutional analysis of supply chain innovations in global marketing channels. *Industrial Marketing Management*, **33(1)**, 57-64.
3. Benner, M., Tushman, M.L., (2003). Exploitation, exploration and process management. *Academy of Management Review*, **28(2)**, 238-256.
4. Bessant, J., (2006). Dealing with discontinuous innovation the European experience. *International Journal of Technology Management,* **42(1)**, 8-12.
5. Bessant, J., Lamming, R., Noke, H. Phillips, W. (2005). Managing innovation beyond the steady state. *Technovation*, **25(12)**, 1366-1376.
6. Cao, M., Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, **29(3)**, 163-180.
7. Deutscher, F., Zapkau, F.B., Schwens. C., Baum, M., Kabst, R. (2016). Strategic orientations and performance:

A configurational perspective. *Journal of Business Research*, **69(2)**, 849-861.

8. Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A.B.L.S, Jabbour, C.J.C., (2013). Analysing green supply chain management practices in Brazil's electrical/electronics industry using interpretive structural modelling. *International Journal of Environment Studies*, **70 (4)**, 477-493.
9. Hakala, H. (2011). Strategic orientations in management literature: Three approaches to understanding the interaction between market, technology, entrepreneurial, and learning orientations. *International Journal of Management Reviews*, **13(2)**, 199-217.
10. Hsu, C., Kuo, T., Chen, S., Hu, A.H., (2013). Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. *Journal of Cleaner Production*, **56**, 164-172
11. Hult, G.T.M., Ketchen, D.J.Jr., Nichols, E.L. (2002). An examination of cultural competitiveness and order fulfilment cycle time within supply chains. *Academy of Management Journal*, **45(3)**, 577-586.
12. Hyland, P.W., Soosay, C., Sloan, T.R. (2003). Continuous improvement and learning in the supply chain. *International Journal of Physical Distribution and Logistics Management*, **33(4)**, 316-335.
13. Ittner, C.D., Larcker, D.F. (1997). The performance effects of process management techniques. *Management Science*, **43(4)**, 522-534.
14. Kannan, G., Pokharel, S., Sasi Kumar, P., (2009). A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. *Resources, Conservation and Recycling*, **54(1)**, 28-36.
15. Ketchen Jr., D.J., Guinipero, L.C., (2004). The intersection of strategic management and supply chain management. *Industrial Marketing Management*, **33 (1)**, 51-56.
16. Kim, D., Cavusgil, S.T., Calantone, R.J., (2006). Information system innovations and supply chain management: channel relationships and firm performance. *Journal of the Academy of Marketing Science*, **34(1)**, 40-54.
17. Krisztina, D., Andrea, G., Istvan, J., (2006). The effect of strategy on supply chain configuration and management practices on the basis of two supply chains in the Hungarian automotive industry. *International Journal of Production Economics*, **104(2)**, 555-570.
18. Rhee, J., Park, T. & Lee, D.H. (2010). Drivers of innovativeness and performance for innovative SMEs in South Korea: mediation of learning orientation. *Technovation*, **30(1)**, 65-75.
19. Rungtusanatham, M., Salvador, F., Forza, C., Choi, T.Y., (2003). Supply-chain linkages and operational performance: a resource-based perspective. *International Journal of Operations and Production Management*, **23**, 1084-1099.
20. Seo, Y.J., Dinwoodie. J., Kwak, D.W., (2014). The impact of innovativeness on supply chain performance: is supply chain integration a missing link? *Supply Chain Management: An International Journal*, **19**, 733-746.
21. Storer, M., Hyland, P., (2011). Utilizing industry-led innovation capacity to enhance supply chain performance: an empirical study. *Modern Applied Science*, **5(6)**, 55-81.
22. Storer, M., Hyland, P., Ferrer, M., Santa, R., Griffiths, A. (2014). Strategic supply chain management factors influencing agribusiness innovation utilization. *The International Journal of Logistics Management*, **25(3)** 487-521.
23. Sum, C.C.T., Chew, B.N., Kwan, K., (2001). Strategic logistics management in Singapore. *International Journal of Operations and Production Management*, **21(9)**, 1239-1260.
24. Tang, X., Rai, A. (2012). The Moderating effects of supplier portfolio characteristics on the competitive performance impacts of supplier-facing process capabilities. *Journal of Operations Managemen*t, **30**, 85-98.
25. Tang, X., Rai, A., (2014). How should process capabilities be combined to leverage supplier relationships competitively? *European Journal of Operational Research*, **239(1)**, 119-129.
26. Tzeng, G.H., Huang, J.J., (2011). *Multiple attribute decision making: Methods and applications*. CRC Press, Taiwan.
27. Vargo, S.L., Lusch, R.F., (2004). Evolving to a new dominant logic for marketing. *Journal of Marketing*, **68**, 1-17.
28. Warfield, J. N. (1982). *Interpretive structural modeling. Group planning and problem solving methods in engineering*, 155-201. New York: Wiley. USA.
29. Wright, P.M., and McMahan, G., (1992). Theoretical perspectives for strategic human resource management. *Journal of Management*, **18**, 295-320.
30. Wu, I.L., Chuang, C.H., Hsu, C.H., (2014). Information sharing and collaborative behaviors in enabling supply chain performance: A social exchange perspective. *International Journal of Production Economics*, **148**, 122-132.
31. Zhao, W., Wang, Y., (2002). Coordination of joint pricing-production decisions in a supply chain. *IIE Transactions*, **34(8)**, 701-715.
32. Govindan, K., Sivakumar, R. (2015). Green supplier selection and order allocation in a low-carbon paper industry: integrated multi-criteria heterogeneous decision-making and multi-objective linear programming approaches. *Annals of Operations Research* (Article in Press)

33. Wu, K.J, Liao, C.J., Tseng, M.L., Chou, P.J. (2015). Understanding the innovation for sustainable business management capabilities and competencies under uncertainty. *Sustainability*, **7(10)**, 13726-13760
34. Chen, R.H., Lin, Y.H., Tseng, M.L.,* (2014). Multi-criteria analysis of sustainable development indicators in the construction minerals industry in China. *Resources Policy*, **46**, 123-133
35. Tseng, M.L. and Lin, YH. (2009). Application of Fuzzy DEMATEL to develop a cause and effect model of municipal solid waste management in Metro Manila. *Environmental monitoring and assessment*, **158**, 519-533
36. Shen, K.Y., Yan, H.R., Tzeng, G.H. (2014). Combining VIKOR-DANP model for glamor stock selection and stock performance improvement. *Knowledge-Based Systems*, **58**, 86-97
37. Liou, J.H. (2015). Building an effective system for carbon reduction management. *Journal of Cleaner Production,* **103**, 353-361
38. Utterback, J.M. (1986). Innovation and corporate strategy. *International Journal of Technology Management*, **1(1/2)** 119-132.
39. Gatignon, H., Xuereb, J.M., (1997). Strategic orientation of the firm and new product performance. *Journal of Marketing Research*, **34(1)**, 77-90.
40. Seuring, S., Goldbach, M., Back, S., (2003). Coordinating sustainable cotton chains for the mass market. *Greener Management International*, **43**, 65-78.
41. Tseng, M.L. (2009). Application of ANP and DEMATEL to evaluate the decision-making of municipal solid waste management in Metro Manila. *Environmental monitoring and assessment*, **156(1-4)**, 181-197
42. Hjalager, A.M., (2010). A review of innovation research in tourism. *Tourism Management*, **31(1)**, 1-12.
43. Raj, T., Shankar, R., Suhaib, M., (2010). An ISM approach for modeling the enablers of flexible manufacturing system: the case for India. *International Journal of Production Research*, **46(24)**, 6883-6912.
44. Wang, W., Lin, Y., Lin, C., Chung, C., Lee, M., (2012). DEMATEL-based model to improve the performance in a matrix organization. *Expert System with Application*, **39(5)**, 4978-4986.