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An Empirical Study on the Influencing Factors of Design Chain Integration

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Abstract: The main objective of this study is to identify the key factors that will affect the successful execution of design chain as integrating into a traditional supply chain. Facing the current highly volatile global market, the industries have well accepted the concept of Supply Chain Management (SCM) which integrating upstream and downstream to improve the competitiveness of products. However, product innovation capability would become critical when most of the competitors sit on equal SCM basis. It was found that the traditional supply chain management model is weak in product innovativeness due to over-emphasis on manufacturing operation in the past. Although, the design chain has been recently suggested to be integrated into traditional supply chain for improving product innovation capability by practitioners and scholars, the studies and literatures are still scarce especially for successfully implementing design chain. This empirical study uses regression method to test four proposed hypotheses with regarding to design chain effectiveness by citing IMSS-V database. The results of the analysis reveal that the situations of business process reengineering, as well as supplier management system, are the major factors. In addition, the empirical results also confirm that the successful execution of design chain will significantly affect the product innovation capability of manufacture firms.

Key words: Design chain, business process reengineering, supplier management system, product innovation capability, international manufacturing strategy survey

INTRODUCTION

In globalization decades, how to build an absolute competitive edge in competing markets around the world has always been an issue that constantly concerns manufacturers. Skinner (1969) pointed out that customers will choose the one who can produce the highest quality product in the lowest cost. Besides, if any manufacturer can further offer the shortest delivery time and have the high-flexibility response ability, it will be the first choice for customers. As a result, if manufacturers desire to gain a competitive edge, they should set up their performance goals on quality, cost, delivery time and flexibility (QCDF). How could an organization have the ability to achieve the four performance goals? According to the relevant scholars and the practitioners, if a manufacturer can establish a Supply Chain Management (SCM) in a global operation environment, it will enable them to achieve the abilities. Introduction of a SCM can shorten lead-time of manufacturing operations, effectively control product cost and quality and enable the organization to have a high-flexibility response ability in order to respond to a highly volatile market (Guillen *et al*., 2007; Kuei *et al*., 2002; Rosenzweig *et al*, 2003; Samiee and Walters, 2006; Wisner, 2003). Moreover, cases of SCMs, which were constructed by Wal-Mart, Dell, etc., also verify a positive effect of SCM.

Nevertheless, as most of the competitors have the equal SCM basis in recent years, manufacturers only own the aforementioned abilities are not adequate to be thought as having the global competitiveness. It is suggested that manufacturers must have a Product Innovation Capability (PIC) in order to secure their own global competitive edge indeed, i.e. if customers' needs can be known immediately and the physical products can be produced rapidly, they will retain customers and maintain high competitiveness. Therefore, in addition to QCDF, how to equip an organization's internal operations with PIC has become a critical issue that manufacturers concern commonly (Lin, 2002; Mohammadjafari *et al*., 2011).

Relevant researches addressed SCM and product innovation issues argued that "collaboration" between manufacturers and suppliers, which is a key to facilitate the product innovation performance. For instance, Kim (2000), Nieto and Santamaria (2007) and Ulusoy (2003)

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indicated that introducing collaborative design between manufacturer and supplier can indeed equip Supply-Chain (SC) operation results with PIC. However, the above conclusion is questioned by the industry practitioners. This is because the traditional SCM model underlines an upgrading ability in QCDF, though it is weak in product innovation. Besides, during recent years, in some illustrated successful cases, no strong relevance is ever found between successful operation of SCM and product innovation.

In order to arm SC with a high PIC, a set of management model which can upgrade PIC is suggested to be developed from the original SC operating environment. As such, Design Chain (DC) viewpoint gradually emerges. DC is a concept which evolved from collaborative design. It emphasizes on the integration with suppliers for setting up a product design/development process (Twigg, 1998). A number of empirical studies (Choi *et al*., 2005; Fagerstrom and Jackson, 2002; Shiau and Wee, 2008) showed that introducing a DC management model can certainly facilitate the effective execution of collaboration between manufacturer and supplier, thereby achieving PIC and avoiding negative problems derived from coordination operations. There are a couple of studies addressing how to effectively construct a DC framework. For example, Wu *et al*. (2007) formulated CDCORM (Collaboration Design Chain Operations Reference Model) and Choi *et al*. (2005) proposed a Design Chain Collaboration Framework.

Although, relevant literatures have verified that introducing DC can upgrade SC's PIC, as a matter of fact, successful cases are still rare. The practitioners believe that it may be the negative effect of "coordination operation" of manufacturer and supplier. In fact, when manufacturer and supplier desire to undertake product design and development activities under DC framework, coordination plays a key role if mutual collaboration is to be completed. In a SC operating environment, all partners' operations must go through the coordination in order to make operations more effective (Nieto and Santamaria, 2007). In order to coordinate effectively, researchers like Ghiassi and Spera (2003), Goutsos and Karacapilidis (2004) proposed increasing coordination ability through the information technique. Nevertheless, Langerak and Hultink (2008) found that coordination operations are time-consuming. Even if they go through the aid of relevant techniques, a great quantity of time will still be needed. This result is very likely to prolong time-to-market so that the new product may not meet customer's needs in the end. Langerak and Hultink's research result corresponds to the observations of the industry practitioners. Consequently, how to conquer the negative effect derived from coordination before introducing and constructing DC is critical to the effective execution of DC. According to some successful cases of DC such as Kwang Yang Motor, Sanyang Industry, AAEON Technology Inc., etc., the practitioners believe that before introducing and constructing DC, these cases have executed some key operations to change collaboration model between supplier and manufacturer. Therefore, both of them could raise their innovation ability under the control of DC effectively. Although there were key operations successfully improved the negative effect of the coordination operation between supplier and manufacturer, it did not be well defined yet.

Based on the above discussion, the objective of this empirical study is to identify the key factors that will affect the successful execution of DC. This study is based on the samples from the International Manufacturing Strategy Survey (IMSS) database, a global research network initiated by London Business School.

LITERATURE AND HYPOTHESIS

An observation showed that, before introducing DC, two key operations would be carried out to change the cooperative relationship between supplier and manufacturer-Business Process Reengineering (BPR) and establishment of a Supplier Management System (SMS). BPR becomes a critical cause because it can solve the problems which could only be undertaken through coordination in the past. Langerak and Hultink (2008) pointed out that coordination operations are time-consuming. In practice, a number of manufacturers have also found that, in introducing for product collaborative design with their suppliers, coordination was definitely time-consuming and it brought a negative effect on product design results. This is because manufacturer and supplier are two independent companies which have different operating models. As a result, every time a message of need for the new product is received, operations for each other must first be coordinated before proceeding to further collaborative design. As such, even though there is a good management system, as long as there is coordination, it may affect the performance of product innovation. Those successful cases showed that, in the process of introducing DC, the first step is to integrate the relevant operations of manufacturer and supplier to avoid the subsequent coordination. Thus, the positive effect of BPR on product design was increasingly noticed by industry practitioners (Allen and Brady, 1997; Pawar and

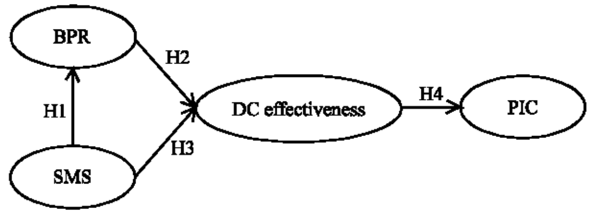

Fig. 1: Construct model

Driva, 1999). Sharma (2005) also indicated that the practitioners found integration of business process has a definite effect on execution of product collaborative design.

That establishment of an SMS is crucial because it can ensure the stability in relationship with suppliers. DC is a management concept which promotes collaborative design between manufacturer and supplier. If they have an unstable or poor relationship, it will be very likely lead to the problems in product collaborative design for the manufacturer under a DC framework, lead to a delay in design process, poor design quality, etc. As a result, to make DC executing effectively, a solution for selecting the best suppliers in advance through an SMS is also an important operation. Yang *et al*. (2010) pointed out that construction of an SMS and its effectiveness would certainly affect PIC. Besides, Petersen *et al*. (2003) also mentioned the influence of construction of an SMS on production innovation.

Furthermore, an observation on successful cases also found that BPR and SMS affect each other. It is because the subject of business process reengineering is a selected supplier. If manufacture firms can get an outstanding supplier through SMS, it would facilitate the BPR. Kallio *et al*. (1999) pointed out that supplier had some influence on BPR and that poor supplier management would negatively affect the result of the BPR.

According to the above discussion, the construct model was built as Fig. 1 and the following hypotheses were tested in this study:

H1: SMS positively affects BPR
H2: BPR positively affects DC effectiveness
H3: SMS positively affects DC effectiveness
H4: DC effectiveness positively affects PIC

RESEARCH DESIGN

Survey database and test samples: This study is based on the database of International Manufacturing Strategy Survey (IMSS). The IMSS is an international cooperative research network focusing on manufacturing strategy and SCM. It gathers data about the practice and performance that related to manufacturing strategy in a global setting. And the data pertaining to the practice in SCM are also collected. The survey employed questionnaire of five-point Likert scale as the means of measurement.

Table 1: Respondents in the different country

Region	No. of respondents	Country	No. of respondents
		Romania	31
		Estonia	27
		Hungary	71
		Belgium	36
		Germany	38
		Ireland	6
Europe	445	Netherlands	51
		UK	30
		Denmark	18
		Sweden	31
		Italy	56
		Portugal	10
		Spain	40
		Canada	19
		USA	48
America	121	Brazil	37
		Mexico	17
		China	59
Asia	159	Japan	28
		Korea	41
		Taiwan	31
Total	725		725

The survey of fifth iteration (IMSS-V) was performed in 2009 and the data were published in 2010. It was involved by the worldwide researchers, shown as Table 1, including Europe (13 countries), America (USA, Canada, Brazil and Mexico) and some of Asia countries (China, Japan, Korea and Taiwan). The author was responsible for performing the survey in Taiwan and collected 31 respondents' data. IMSS-V focuses on the manufacture firms which related to fabricated metal products; machinery and equipment; office, accounting and computing machinery; electrical machinery and apparatus; radio, television and communication equipment and apparatus; medical, precision and optical instruments, watches and clocks; motor vehicles, trailers and semi-trailers; other transport equipment. Total 725 respondents from 21 countries were recorded in the final releasing. These data were used for this study.

First, the samples were classified by citing the method of Frohlich and Westbrook (2001). As a result, only 313 samples were able to fit the research's purpose. And then, 75 samples were eliminated for whose responses were not completed or with missing values for variables of SMS, BPR, DC effectiveness and PIC. Therefore, only 238 of the 725 respondents are remained, i.e., the sample size of this study is 238.

Table 2: Result of data normality test

Constructs	Mean	Std. Dev.	Skewness	Kurtosis
BPR				
Rules and standards	3.95	0.951	-0.589	-0.195
Formal meetings	3.86	0.863	-0.285	-0.471
Standard process	3.59	1.078	-0.505	-0.276
Concurrent engineering	3.31	1.073	-0.130	-0.682
SMS				
Logistical costs	3.40	0.953	-0.225	-0.294
Innovation and co-design	3.36	1.069	-0.240	-0.398
Physical proximity	2.99	1.127	0.061	-0.618
Information sharing	3.26	1.071	-0.266	-0.420
Potential to measure	3.65	0.964	-0.352	-0.451
DC effectiveness				
Inventory level information	3.71	0.939	-0.408	-0.134
Product/production planning	3.85	0.871	-0.443	-0.055
Order tacking/tracing	3.86	0.906	-0.478	-0.410
Delivery frequency	4.13	0.809	-0.822	0.893
PIC				
Product customization ability	3.56	0.848	0.136	-0.649
Time to market	3.40	0.888	0.290	-0.623
Product innovativeness	3.44	0.858	0.238	-0.568

Table 3: Result of factor analysis and reliability test

Constructs	Factor loading	Cronbach's α
BPR		0.776
Rules and standards	0.798	
Formal meetings	0.751	
Standard process	0.802	
Concurrent engineering	0.749	
SMS		0.760
Logistical costs	0.696	
Innovation and co-design	0.700	
Physical proximity	0.653	
Information sharing	0.800	
Potential to measure	0.728	
DC effectiveness		0.602
Inventory level information	0.749	
Product/production planning	0.802	
Order tacking/tracing	0.608	
Delivery frequency	0.521	
PIC		0.736
Product customization ability	0.784	
Time to market	0.791	
Product innovativeness	0.853	

Operationalization variables and independent construct measurement: In terms of research's purpose, this study involves the testing of four variables: BPR, SMS, DC effectiveness and PIC.

Definition of BPR in this study focused on the activities of organizational integration when manufacture companies try to improve product's innovativeness. IMSS-V provided four kinds of organizational integration operations for product's research and development with suppliers and manufacturers, including: (1) Rules and standards, (2) Formal meetings, (3) Standard process and (4) Concurrent engineering, to measure the effectiveness of organizational business process integration and reengineering. For these four kinds of integration activities, this study firstly used the mean value, standard deviation and Skewness and Kurtosis to check whether the data are normally distributed. The result indicated that data distribution has shown normally (please see Table 2 for details). To ensure these test variables meet the research's requirements, a construct validity test for BPR by factor analysis was performed. The results indicated that the Kaiser-Meyer-Olkin (KMO) measure of performance adequacy was 0.78, Bartlett's test of sphericity was significant, the factor loading for all four items exceeded 0.74 (please see Table 3 for details) and the value of Cronbach's α in factor exceeded 0.77.

IMSS-V included five measurement items regarding to SMS for selecting strategic suppliers: (1) logistical costs, (2) innovation and co-design, (3) physical proximity, (4) information sharing and (5) potential to measure. Following the same processes, mean value, standard deviation and Skewness and Kurtosis were used to verify data normality; significant results were achieved for these five items. And then, a factor analysis was done to check the construct validity of SMS. The results showed that the Kaiser-Meyer-Olkin (KMO) measure of performance adequacy was 0.802, Bartlett's test of sphericity was significant, the factor loading for all five items exceeded 0.65 and the value of Cronbach's α in factor exceeded 0.76.

According to IMSS-V, there were four measurement items of supply chain operations for investigating the integration level of product development and production with suppliers: (1) Inventory level information, (2) Product and production planning, (3) Order (including new product) tacking/tracing and (4) Delivery frequency. As usual, mean value, standard deviation and Skewness and Kurtosis were firstly checked to test data normality and the result showed that all data of three measurement items are normally distributed. And then, a factor analysis was done to check the construct validity. The results indicated that the Kaiser-Mayer-Olkin (KMO) measures of performance adequacy was 0.633, Bartlett's test of sphericity was significant, the factor loading for all four items exceeded 0.52 and the value of Cronbach's α in factor exceeded 0.60.

Finally, according to IMSS-V, there were also three measurement items for investigating the firm's PIC: (1) Product customization ability, (2) Time to market and (3) Product innovativeness. The results of mean value, standard deviation and Skewness and Kurtosis showed the data normality is significant for these three measurement items. The results of construct validity test indicated that the Kaiser-Mayer-Olkin (KMO) measures of performance adequacy were 0.667, Bartlett's test of sphericity was significant, the factor loading for all three items exceeded 0.78 and also, the value of Cronbach's α in factor exceeded 0.73

RESULTS AND DISCUSSION

In this section, analyses of the empirical results for those four hypotheses in this study are presented. The regression method was employed for the analysis.

The empirical results proved that performing BPR ($p<0.05$, $F = 16.985$) and the establishment of SMS ($p<0.05$, $F = 16.934$) both had significant positive effect on DC effectiveness. And also, DC effectiveness by BPR and SMS was certainly good for achieving high PIC ($p<0.05$, $F = 7.657$). In addition, the empirical results also proved SMS had significant positive effect on BPR performance ($p<0.05$, $F = 29.645$). All of the empirical results to those four hypotheses are summarized as shown in Table 4.

Performing BPR and establishing of SMS while introducing DC, according to the empirical results, they were the critical successful factors for manufacture firms to build an effective SC framework for upgrading their PIC. Meanwhile, it could also be deduced why the BPR and SMS play important roles on DC.

According to the empirical results, there were some implications to manufacturers in managing real practices:

- Manufacture companies were able to integrating DC into traditional supply chain framework effectively, to improve product innovativeness, by establishing a SMS for selecting strategic suppliers by considering of logistical costs, ability to provide innovation and co-design, physical proximity, willingness to share information and potential of product development programs
- Meanwhile, by performing BPR activities such as integrating the rules and standards, formal meetings, standard process and concurrent engineering with suppliers, manufacture companies can also gain the benefits of effectively integrating DC into traditional supply chain framework
- Manufacture companies could improve their performance of PIC such as product customization ability, time to market and product innovativeness by effectively integrating DC into traditional supply chain framework. Especially for, those collaborative activities with suppliers which related to inventory level information, product and production planning, order (including new product) tacking/tracing and delivery frequency

Table 4: Empirical results

Hypotheses	Results
H1: SMS positively affects BPR $F = 29.645$ $p = 0.000$***	Supported
H2: BPR positively affects DC effectiveness $F = 16.985$ $p = 0.000$***	Supported
H3: SMS positively affects DC effectiveness $F = 16.934$ $p = 0.000$***	Supported
H4: DC effectiveness positively affects PIC $F = 7.657$ $p = 0.006$***	Supported

CONCLUSION

The objective of this empirical study is to identify the key factors that will affect the successful execution of DC. The empirical results showed that two factors, BPR as well as SMS, are able to influence the effectiveness of DC significantly. In addition, the results also proved that an effective DC framework can significantly improve the PIC of manufacture companies. In the implication, manufacturers can consider the result to construct an effective DC framework and to secure the high innovative performance through successful execution of DC. On the other hand, researchers can refer to the result to explore the issues of DC deeply.

Since empirical studies with regarding to DC are still rare, future research may consider exploring more thoroughly which could improve that factors affect the successful introduction and execution of DC. Moreover, the impact of integrating DC to traditional SCM on the performance goals, QCDF, is definitely needed to be studied further as well.

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