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Information Systems Integration Mechanisms within Supply Chain Agility in the Chinese Automotive Industry

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INFORMATION SYSTEMS INTEGRATION MECHANISMS WITHIN SUPPLY CHAIN AGILITY IN THE CHINESE AUTOMOTIVE INDUSTRY

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Abstract

Information systems are a critical factor in achieving supply chain agility in fluctuating markets. However, there has been limited research on identifying specific mechanisms on how information systems may affect supply chain agility. This gap is addressed by illustrating the complementary role of supply chain agility across operational dimensions, such as flexibility, responsiveness and dependability and organizational learning leading to improved operational performance. A conceptual model is developed to explicate the significance of IS on these operational dimensions drawing examples from the context of Chinese automotive supply chains. The research finds that cost issues affect IS integration for suppliers while production capacity and changing business requirements and transparency of information inhibit supply chain agility.

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Keywords: Information system integration, supply chain agility, flexibility, responsiveness, dependability, organizational learning

1   INTRODUCTION

Information systems are recognised as a competitive tool in achieving supply chain agility (Power, Sohal and Rahman, 2001; Yusuf, Gunasekaran, Adeleye and Sivayoganathan, 2004), but there is little research or understanding of the mechanisms by which IS integration may affect supply chain agility. The question of how IS integration contributes to supply chain agility is important as organizations heavily invest on IS. This paper considers possible mechanisms within the context of the emerging Chinese automotive industry to answer the following questions: 1) what are the critical factors of IS integration? 2) What are the impacts of integrated IS in the context of supply chain agility? A conceptual model is developed from the literature to explore IS integration and its impact in the context of supply chain agility.   The model indicates that supply chain agility is supported by IS integration across four areas: customer sensitivity, process integration, network integration and virtual integration. This leads to improved operational performance in four areas: responsiveness, flexibility, dependability and organizational learning.

As this is an exploratory study, a case study based methodology has been deployed to test the model. Interviews are carried out with three automotive manufacturers and their first and second tier suppliers to investigate the relationship between IS integration and supply chain agility. Analysis of the interviews demonstrates IS integration supports supply chain agility better between automotive manufacturers and first tier suppliers than with second tier suppliers. While the literature is largely supported in finding that IS integration aids supply chain agility, the study identifies a number of other factors.   These include cost of IS integration and the need to account for changing business requirements and production capacity. The study recognizes the constraints of integrating IS in the context of achieving agile capabilities, and enhances the existing evidence on the impact of IS integration.

2   LITERATURE REVIEW

The concept of supply chain management is introduced and the importance of agility is discussed. Supply chain agility determinants are identified including the role of information systems integration in supporting operational performance. This leads to the development of four propositions for IS integration and the development of a research framework showing the relationships between IS integration, supply chain agility and operational performance.

2.1   Supply Chain Agility

In today's markets, firms face stiff competition due to time-based competition and fast technology development. Sustainable competitiveness focuses on supply chain management (SCM) (Swafford, Ghosh and Murthy, 2006). SCM usually consists of individual functional entities with commitments to provide related resources and information to achieve the objectives of efficient management of suppliers as well as the flow of parts (Lau & Lee 2000).

SCM has evolved from traditional command and control, vertical hierarchy based organization to one structured around process units (Van Hoek, Harrison and Christopher, 2001). Horizontal integration, involving outsourcing and inter-firm integration replaces traditional vertical integration. Organizations look to improve standardization and customization, as well as minimizing waste through streamlining business processes within the supply chain. Therefore, agility is becoming important as it is all about 'customer responsiveness and mastering market turbulences' (Van Hoek et al. 2001).

Supply chain agility can be seen as a measure of success of the relationships within a supply chain in the process of manufacturing, design, delivery and customer service (Yusuf et al 2004). This leads to the adoption of Christopher's (2000) definition of supply chain agility '*as a business-wide capability*

that embraces organizational structures, information systems, logistics processes and in particular, mindset'. Responsiveness is seen as a particularly important outcome of agility (Christopher & Towill 2000).

The literature suggests that there are four determinants of success for supply chain agility. These are customer sensitivity, process integration, network integration and virtual integration Customer sensitivity is defined as developing co-operative relationships with customers. Process integration focuses on the core competences required to change business processes. Network integration is defined as co-ordination with partners Virtual integration is about leveraging information across the supply chain (Christopher, 2000; Goldman, Nagel and Preiss, 1995; Van Hoek et al, 2001).

These determinants are supported through organizational and supply chain design, information sharing among functional units (Crocitto & Youseeff 2003), internet-based collaboration and networking with partners rather than marketing alliances (Yusuf et al, 2004). Among these factors, IS integration has been identified as a key enabler to supply chain agility (Breu, Hemingway, Strathern and Bridger, 2001; White, Daniel and Mohdzain, 2005).

2.2   IS Integration

A key characteristic of supply chain agility is the instant availability of information to manage an 'on demand' business operation. IS integration provides the basis for information sharing and exchange among organizations (Yusuf et al., 2004; Auramo, Kauremaa & Tanskanen, 2005). There is some evidence that the lack of information sharing and sparse information prohibit supply chain coordination and lead to greater operational inefficiencies (Patnayakuni, Rai and Seth, 2006).

An integrated information system requires the integration of communication, data and application (Muller & Seuring, 2007; Ross, 2003) to enable consistent and real-time connectivity among function units across supply chains (Rai, Patnayakuni and Seth, 2006). IS cannot, per se, create any sustained performance or values (Powell & Dent-Micallef, 1997). Therefore, it is important for companies to integrate resources and embed them in their social and cultural context (Barua, Konana, Whinston and Yin, 2004) to develop operations and workflow coordination (Rai et al., 2006).

Rai et al's (2006) definition of IS integration is adopted. This definition has two aspects: data consistency and cross-functional SCM application system integration. Data consistency is 'the degree to which common data definition and consistency in stored data have been established across a focal firm's supply chain' (Rai et al., 2006). Cross-functional SCM application systems integration is 'the degree of real time communication of a focal firm's function-specific SCM applications with each other' (Rai et al., 2006), such as the connectivity between enterprise resource planning applications and transaction applications. Enterprise resource planning systems support procurement, production and logistics. Transaction applications realize the execution of order management, production management and distribution (Kalakota & Robinson, 1999).

2.3   IS Impacts on Supply Chain Agility

This research aims to determine the critical factors of IS integration and also to identify the impacts of integrated IS in the context of supply chain agility. The literature review indicates that IS integration can significantly enhance supply chain agility thus improving operational performance. Four propositions to investigate the research aims are developed:

P1:   IS has a positive impact on responsiveness to changes in production and services, and to market demands on new products.

Customer sensitivity emphasizes customers and markets, including customer-focused logistics and rapid response. Supply chains are becoming demand-driven rather than forecast-driven in order to effectively respond to real-time demand. Due to lack of direct feedback from the market firms rely heavily on forecasting techniques to predict manufacturing and inventory based on historical data. IS integration within and between organizations enables data capture on demand, leading to customer-focused supply chains (Christopher 2000).

Firms are more likely to gain competitive advantage through fast delivery and product variety rather than price. Therefore, the effectiveness of a supply chain can be measured by its responsiveness (Lee & Billington 1992). IS encourages a fast response to market requirements through sharing and transferring real time information among suppliers and customers.

P2:   IS increases the degree of dependability among partners in the supply chain.

There is a growing recognition that companies need strategic partnerships with shared targets to compete in competitive markets. Therefore, in order to sustain competitive advantage, it is critical to leverage the strengths and competencies of partners to realize fast responsiveness to market requirements (Christopher 2000). For example, in the automotive industry, first tier suppliers are involved in the design of car components and at the same time, automotive companies help suppliers achieve manufacturing process and technology improvement (Martinez & Perez 2005). Thus dependability among partners, such as the performance of suppliers in terms of speed and reliability of delivery is assured (Narasimhan & Jayaram 1998).

P3:   IS improves product and volume flexibility along the supply chain.

Process integration relates to uncertainty across the supply chain, placing emphasis on self-management teams instead of standardization so that core modules of products can be delegated within networks of agile competitors. Therefore, alliances among various suppliers, manufacturers and customers will be inevitable and enable collaborative working methods such as joint product design (Christopher & Towill 2000). For example, Taiwan Semiconductor Manufacturing Company gives suppliers proprietary tools and product data requirements so that they can execute changes accurately. Therefore, while focusing on their own competencies, companies are much more likely to increase product variety and improve the ability to handle orders with special customer requirements. Meanwhile, the availability of real time demand data improves company volume flexibility - that is, increasing or reducing production based on demand. Flexibility is another important operational dimension which can improve the company's competitiveness (Martinez & Perez, 2005), and in the context of supply chain management, it is a significant measure for supply chain performance (Vickery, Droge and Markland, 1999).

P4:   IS positively impacts information acquisition and information dissemination of organizational learning.

Virtual integration emphasizes leveraging people and information along the supply chain. Supply chains can be structured around the flow of information to ensure that members within organizations along the supply chain have access to relevant information (Tippins & Sohi, 2003). IS integration contributes to organizational learning by enabling more effective information gathering and dissemination between customers and suppliers making consensus focussed development more

efficient (Tippins & Sohi, 2003). Organizational learning is a key dimension of competitive supply chains, given the complex and often dynamic nature of supply chain management (Hult, Hurley, Giunipero and Nichols, 2000).

From these propositions a framework demonstrating the operations impact of IS integration on agile capabilities of the supply chain is proposed (see Figure 1).
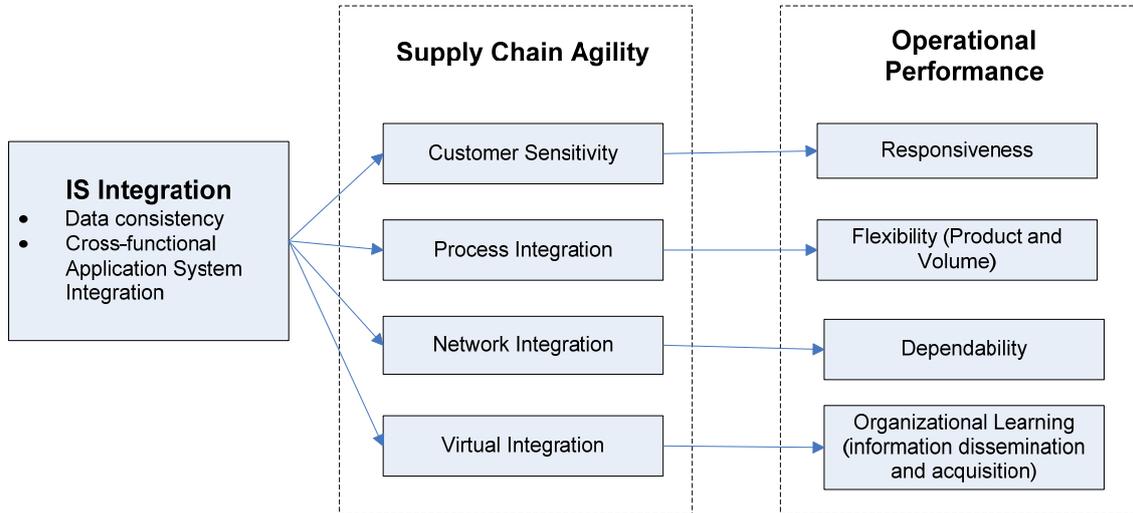

Figure 1 Research framework

3   BACKGROUND TO THE RESEARCH: THE CHINESE AUTOMOTIVE INDUSTRY

The Chinese automotive industry is suitable for this study for a number of reasons. It is one of the leading automotive sales and production markets in the world (Gao, 2005). Many western automotive manufacturers are working in collaborative partnerships with Chinese firms to develop the market. Significant parts of the automotive industry in China are subject to government intervention. The Chinese government promotes regional policy through the location of certain equipment and parts manufacturers.   Supply chain management is becoming of importance as there is increasing emphasis on sourcing all production within China (Thru, 2006). Agile capability is becoming vital to supply chain operations in the Chinese automotive industry as it faces intense competition for market share (Chen, 2004). As supply chain maturity and complexity increases automotive firms seek to improve business processes and technology by pushing other members of their supply chain to adopt IT (Fulcher, 2004). IS applications have reshaped the automotive manufacturing sector towards the goal of building vehicles to customer orders (Howard, 2005).

4   RESEARCH METHODS

The research has been carried out through multiple case studies. Case studies are useful when exploring new areas of research (Eisenhardt, 1989), particularly in information systems because they cope with technical situation with many variables (Yin, 2003). Three supply chain cases in the automotive sector in China are investigated. The supply chains are shown in Table 1 below.

Automotive Manufacturer	1st Tier supplier	2nd Tier Supplier	Description
A			A joint venture of automotive manufacturer with one European company.
	A1a		A joint venture with one American company, producing harness for company A and B, with 1,500 employees.
	A1b		A state-owned small and medium sized enterprise (SME), manufacturing sampling parts for automotives.
		A2a	A joint venture of manufacturing connectors for A1a, with 1,000 employees.
B			A joint venture of automotive manufacturer with one American company
C			A joint venture of automotive manufacturer with one Korean company
	C1		A joint venture of producing automotive seating systems for C
	C2		A company with 100% foreign investment, producing injection mouldings for C.

Table1: Supply chain case firms

Open-ended questions were developed from the literature to test the propositions and to explore the issues related to IS integration and supply chain agility. Forty semi-structured interviews were conducted to collect data from senior managers in departments related to IS, procurement, manufacturing, and logistics within all the organizations. Interviewees included eight senior managers at IS departments, twenty nine senior managers at departments related to the supply chains, two general managers and one CEO. Each of the interviews lasted between thirty minutes to one hour. The interviews were taped with interviewees' permission. Confidentiality of the participant firms was assured.

In order to minimize the bias of interpretation, a summary of the interview was written up and passed back to interviewees in order to justify and improve the accuracy of our understanding of each interviews. 45% feedback has been received confirming the interview transcripts. Each interview was coded using NVivo to identify the communication approach within the supply chain, the level of IS integration and the operational performance arising from the integration process as proposed within the research framework.

5   RESULTS AND DISCUSSION

IS integration issues between automotive manufacturers and their suppliers are analysed. These indicate some support for the four propositions, between automotive manufacturers and 1st tier suppliers, but less for 2nd tier suppliers. The propositions are discussed and the research framework revised.

5.1   Information system integration across supply chains

Automotive manufacturers in this research developed their IS through different periods. They use enterprise resource planning (ERP) to help integrate processes, but IS managers have some concern about systems compatibility. Automotive manufacturers systems are usually more complex in comparison to their suppliers.

To improve responsiveness first tier suppliers usually set up plants close to automotive manufacturers. Therefore, each plant only has one customer—the automotive manufacturer that is close to the plant. Material requirements planning (MRP) systems are commonly used by first tier suppliers. IS systems in use by 1st tier suppliers are developed by their headquarters where the IS department is located. There is no local IS support and maintenance provided at the plants.   Second tier suppliers also have MRP systems.

The use of IT for communication along the supply chain is limited (see Figure 2). Automotive manufacturers supply IS technologies to first tier suppliers. Portals are adopted to publish and exchange general information, such as long term planning of automotive manufacturers and order confirmation from suppliers. WebEDI is used to deliver daily schedules to 1st tier suppliers. First tier suppliers apply just-in-time (JIT) delivery for auto-parts. E-mail is the main means of communication between 1st tier suppliers and 2nd tier suppliers.

Figure 2 shows three connected entities with bidirectional arrows:

- **2nd tier supplier** — connected via:
  - E-mail
  - MSN
  - Phone
  - Fax
  - Meeting
- **1st tier supplier** — connected via:
  - Portal
  - Web EDI
  - E-MAIL
  - Phone
  - Fax
  - Meeting
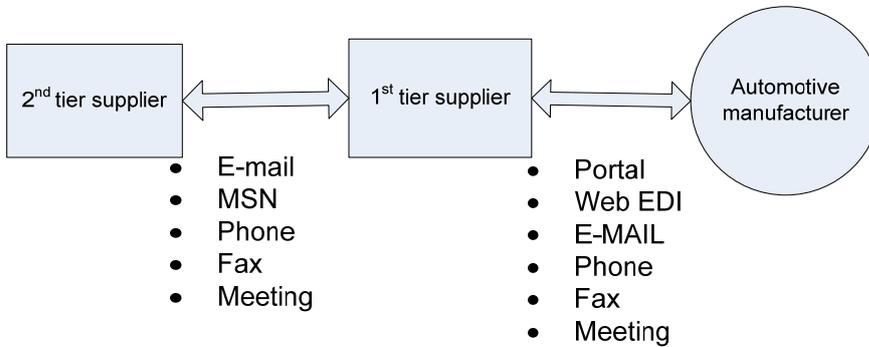- **Automotive manufacturer**

Figure 2 Communications from 2nd tier suppliers through to Automotive Manufacturers

Automotive manufacturers are switching from importing components to local 1st tier suppliers as their component prices are low and their quality has improved (Thru, 2006). This encourages the use of integrated IS between automotive manufacturers and 1st tier suppliers and facilitates IS adoption in domestic SMEs. Where both 1st and 2nd tier suppliers are SMEs, IS integration is problematic. They prefer communicating through instant messenger, or telephone, as one senior manager from C1says '*it is much easier and cost-effective to communicate in this way than using information systems.*' First tier suppliers may have portals provided by their headquarters or by application service providers to communicate with 2nd tier suppliers. No direct communication has been set up between 2nd tier suppliers and automotive manufacturers.

Specifically, common data definitions and consistency has been set up 1) between automotive manufacturers and 1st tier suppliers, for example about car models, and 2) between 1st tier suppliers and 2nd tier suppliers, for example about auto parts. These common data definitions are regarded as the basis of integrating IS.

The study shows that cross-functional application systems integration does not take place across a focal firm's (automotive manufacturer) supply chain, instead portals or webEDI are more commonly used to link partners across supply chains. As a senior manager from automotive manufacturer A says, '*it works well in this way so far and at present, the business does not require the whole integration of systems*'.

5.2 Achieving agile capabilities of supply chains

Proposition 1 contends that IS has a positive impact on responsiveness to changes in production and services, and to market demands on new products. The proposition was developed from the impact of IS integration in the context of achieving customer sensitivity. Many organizations intend to implement build-to-order (BTO) respond quickly to customers. Interviews with suppliers indicate that suppliers still have to respond to automotive manufacturers' volatile schedules changed at the last minutes and with relatively little adherence to the original plans. However, '*compared to the time without integrated IS, the extremely volatile changes are becoming less and less*' (senior manager from A1b). This leads to problems for BTO. '*If operations are executed only based on BTO, without*

order confirmation, the production line will cease. The worst scenario is to stop the production line, partially because of the cost issue' (senior manager from C).

The study indicates that firms have a better understanding of the market and customer requirements as a consequence of IS integration. Integrated IS helps firms to gather and analyze available information on existing and potential customers to plan more effectively through synchronizing data across supply chains. The automotive manufacturers' role is critical in supply chains because their forecast or manufacturing long/short time planning influences suppliers.

The second proposition suggests that IS increases the degree of dependability among partners in the supply chains. All interviewees agree that IS integration helps to achieve a closer relationship between automotive manufacturers and first tier suppliers by providing real-time manufacturing data or sharing production planning, to achieve greater supplier responsiveness. IS integration simplifies the process of product design and development and stresses firms' core competencies.

The study shows that real time communication helps to increase the efficiency of sequenced in-line supply operations by providing up-to-date information. This helps suppliers anticipate changes in the production schedule, preventing material short-falls and improving responsiveness. However, 1st tier suppliers expressed concern with IS integration in terms of data visibility.

The study finds no direct link between automotive manufacturers and 2nd tier suppliers. The level of IS integration between 1st and 2nd tier suppliers is limited, with cost and responsiveness cited as the main reason. Second tier suppliers implement MRP or MRPII within the organization, but some resist IS integration, because it introduces an extra layer of complexity to existing systems and requires training and investment. The proposition is supported by automotive manufacturers and 1st tier suppliers but it is not clear for 2nd tier suppliers.

The third proposition advocates that IS improves product and volume flexibility along the supply chain. Interviews demonstrate that where IS is integrated in business processes, there is improvement in traceability or ownership of a product from the inclusion of serial numbers, time of manufacturing, and employee numbers leading to quality improvement..

However, IS does not improve product and volume flexibility when changes in production are made at short notice. Limited flexibility is due to organizations' inability to make changes quickly to computerized business processes. However, if changes are made before IS processing begins, some flexibility is achieved particularly through data synchronization. The majority of managers interviewed question this proposition, hence it is not proven.

The fourth proposition suggests that IS positively impacts on information acquisition and information dissemination of organizational learning. The study shows that IS integration will only be implemented when required by the business strategy. Firms should seek the best IS competencies to further develop their business strategy focusing on cost, quality and dependability of IS. '*Now it is much easier for us to find the data I want across functional units without running around company to gather the data. It saves lots of time so that we can actually have more time to analyze data and make decision*' (senior manager from automotive manufacturer B).

Currently firms are operating in connected links but not viewing them as a holistic chain. Therefore, supply chain agility is limited. Relationships in the participating companies tend to be based on cost-reduction, even though they intend to build the relationship on value-adding.

However, operational performance is beginning to improve through implementing IS for better supply chain management. Overall operations are more efficient, responsive, traceable, and dependable. Thus, there is some evidence that organizational learning is improved through IS.

The findings from the study lead to the development of a revised research framework (see Figure 3) that indicates IS integration is influenced by cost, which acts as an inhibitor. Application integration is refined to include the use of portals and real time information transformation. Additional factors influence supply chain agility and operational performance. Customer sensitivity is more focussed on

production capacity rather than overall sensitivity to the market. Hence, forecast accuracy rather than responsiveness is the operational performance outcome. Virtual integration is determined by business requirements, primarily within the automotive manufacturers. There is a clear recognition of the need to have better information that can be used to support production efficiencies, thus supporting the proposition that virtual integration leads to organizational learning. Process integration is influenced by organisational maturity. This leads to the introduction of a new aspect of operational performance, product quality control or ownership which leads to business process optimization. However, flexibility is still contentious. Network co-ordination is dependent on the development of relationships between suppliers and automotive manufacturers. Responsiveness to changes in orders and products is important here. By recognizing core competences, dependability is appreciated. .
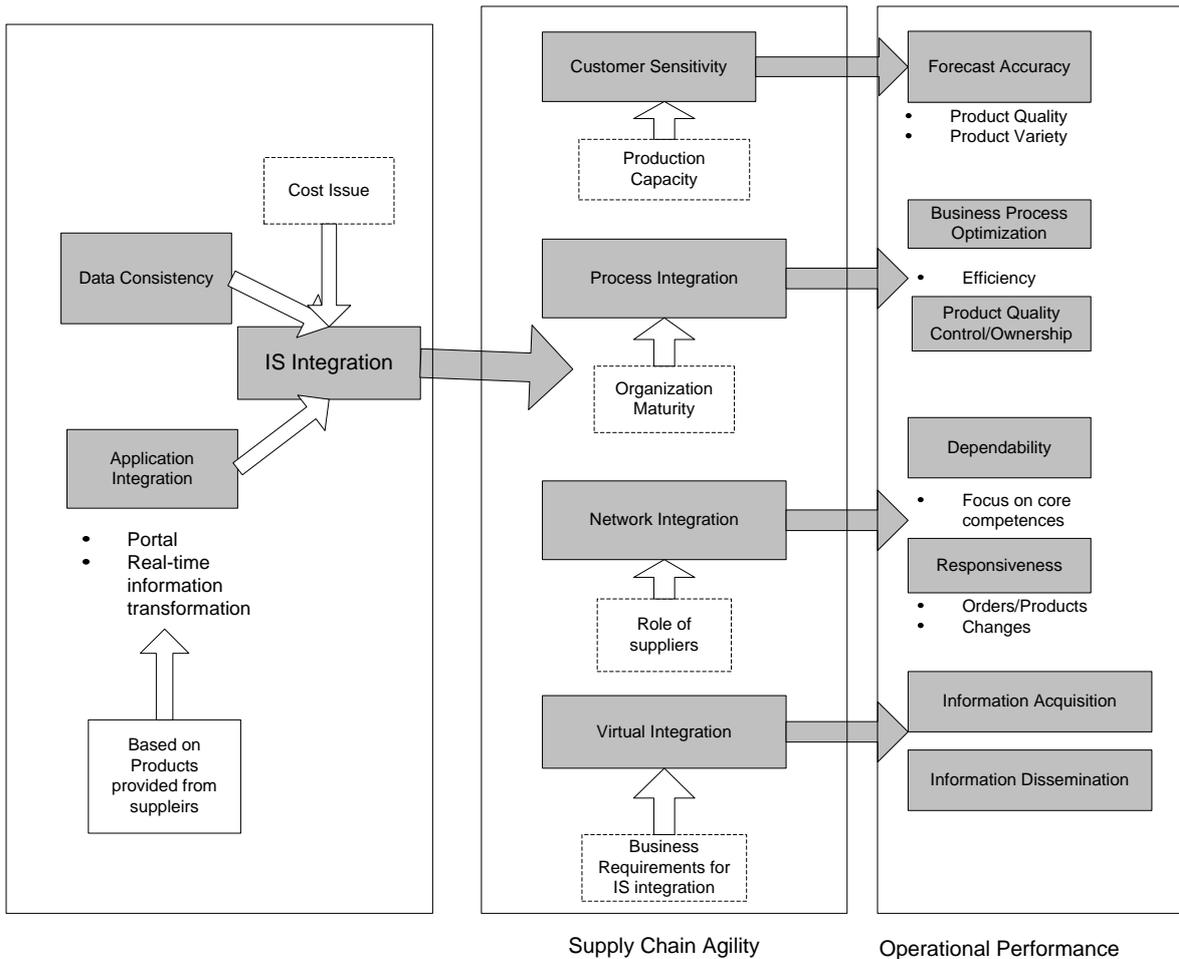

Figure 3: Revised Research Framework

6   CONCLUSIONS

In this paper, indirect links of IS integration and corporate value creation are investigated by focusing on supply chain agility. The research is motivated by the importance of IS on supply chain agility in complex manufacturing environments such as Chinese automotive industry. A conceptual model is developed to address the theoretical gap of IS and supply chain agility. The empirical research demonstrates that IS integration impacts on operational performance to improve supply chain agility in a number of areas. While there is a great improvement of information visibility across supply chains,

some data are treated as business secrets: for example suppliers can not access to real time front-end data for example, demands from car dealers. Hence, transparency of information is still lacking, compounding further inherent upstream problems (Childerhouse, Hermiz, Mason-Jones, Popp and Towill, 2003). Suppliers indicate that IS integration currently helps data visibility, but real time front-end data, including demands and sales, will help them in production planning and cooperation with automotive manufacturers to improve product delivery, and inventory management.

The empirical research enhances existing evidence on the impact of IS integration on supply chain agility. The study recognizes the constraints of improving operational performance through integrating IS, due to the consideration of production capacity, business requirements and cost issues. The paper provides an in-depth understanding of IS integration in Chinese automotive supply chains and suggests how to maximize the benefits from IS integration in Chinese business.

Further investigation needs to validate the revised model, along with the emerging concepts pertaining to customer sensitivity, process integration, network integration and virtual integration in achieving agile capabilities of supply chains. As IS plays an increasingly important role in enabling the operations of business, developing such understanding at a theoretical level is critical. In addition, the research only focuses on automotive industry. Therefore, the model and propositions should also be tested on other industrial sectors.

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