WEB-BASED APPLICATION TECHNOLOGY IN SUPPORTING VMI: ENABLING FACTORS AND EXPECTED OUTCOMES

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ABSTRACT

This paper uncovers the experiences of automotive suppliers in Thailand, which have implemented web-based application to support vendor managed inventory (VMI). First, we identify enabling factors with greatest influence on the outcomes of web-based application implementation. Data was obtained from seventy tier-1 suppliers of the two biggest automobile assemblers in Thailand. Then, exploratory factor analysis was employed to construct enabling factors and outcomes of this implementation support VMI. The results indicate technology readiness is the most important enabler in implementing web-based application technology to support VMI. It is followed by leadership, and systems integration. In the implementation of such technology, it is important to understand the crucial role that management support and the deployment of relevant technical skills play in the success of such implementation.

Keywords: Web-based application, vendor managed inventory, VMI, automotive industry

INTRODUCTION

The benefits of information and communication technology (ICT) on supply chain operations are identified in many studies [6] [30] [31] for instance, suggested that the after implementing electronic data interchange (EDI) within an organization and/or web-based application between suppliers and buyers in the automotive supply chain, organizations are able to increase the data transaction capability leading to increased visibility of supply chain operations. In addition, those technologies are considered as a key organizational resource in supporting firms to create strategic competitive advantages including cost reduction and improving customer responsiveness [2]. Lo et al. [27] suggested that the key strategic roles of web-based application technology or EDI cover the following: (a) Transaction Execution: reducing the friction in transactions between members through cost-effective information flow/communication (Telephone, Fax, E-mail, and Internet); (b) Collaboration and Coordination: providing cost-efficient way to tie suppliers and buyers; and (c) Decision Support: providing assistance to managerial decisions (E-purchasing, ERP software).

In the context of the automotive supply chain, suppliers, especially tier-1, have been required by buyers (car assemblers) to adopt those e-purchasing technologies in order to reduce long-term cost of purchased components, increase the visibility of information flow, increase product customization, develop build-to-order capabilities, and manage their owned inventory [1].

In this paper, experiences in implementing web-based application technology to support VMI in the automotive supply chain in a selected emerging economy country, Thailand, are presented. This industry has been considered as a flagship sector frequently regarded as a barometer measuring the current wealth of the economy. The auto industry is an important sector because automobile production is a large and varied industry [17]. Achieving efficiency within the supply chain can be a competitive imperative in this industry. The following section reviews the literature. Subsequent sections describe the research methodology, followed by findings, and conclusions and implications of the study.

LITERATURE REVIEW

In this section, the current status of the Thai automotive industry is described. Next, literature on the implementation of web-based application in supply chain management, especially in purchasing function, is reviewed. Then, it is followed by web-based application diffusion in the automobile industry. Lastly, literature on web-based application technology in supporting VMI is summarized. It is important to note that greater efforts in adopting web-based application and enhancing data transaction capability achieved through the use of this technology could

enable significant customer responsiveness. E-purchasing, for example, will raise the professional practices of purchasing function through enhanced internal customer service and cost improvements [12] [36].

The Thai automotive industry: practices and policy

In an emerging economy country such as Thailand, the automotive industry has become one of the most important in the manufacturing sector in the country. This industry has contributed significantly to the rate of employment, GDP, and exports [3] [14] [37]. There are three levels of manufacturers in this industry: (a) passenger and commercial vehicle assemblers, (b) component manufacturers, and (c) supporting/equipment manufacturers (Board of Investment 1995; JICA 1995). The first level is dominated by sixteen assemblers including the Japanese big five (Toyota, Isuzu, Mitsubishi, Nissan, and Honda), the U.S. big three (Ford, General Motors, and Daimler-Chrysler), and few leading European automakers (BMW and Thai Swedish Assembly). Total production volume of cars in 2007, 2008, and 2009, was 1.28, 1.39, and 0.99 million units/vehicles respectively (www.thaiauto.or.th). For their tier suppliers, the second and third level, most companies are owned by foreigners through direct investment, joint venture, and technical licensing arrangements. Presently, there are 1,164 parts and component manufacturers, 850 of which manufacture parts and components in Thailand. Among these manufacturers, 358 are tier-1 suppliers, 272 are tier-2 suppliers, and 220 are tier-3 suppliers by www.thaiauto.co.th. The development of the automotive industry has also led to development in the upstream industries such as petrochemicals and plastics, automotive components, and metal and machinery.

Thailand is developing as a major offshore base for international automotive manufacturers especially Japanese and American. The Japanese Automobile Manufacturers' Association [14] reported that exports from Thailand led the automotive industry revival throughout Asian countries. The automobile industry has been chosen as one of the major strategic industries in Thailand's drive towards modern competitive manufacturing. However, the regional competitive situation in automobile manufacture and export is precarious. In order to respond to increasing demand from global customers and to attract more foreign investment, it is essential that the Thai automotive industry improve the cost, quality, and time-based flexibility in comparison to the same industry in the region. Most companies in this sector have implemented international quality management systems (ISO/TS16949), environmental management standard (ISO 14001), and international operations strategy including just-in-time production system, lean manufacturing, and supply chain management. In addition, these companies are able to enhance the competitive advantages of their supply chains by investing in e-purchasing through web-based order processing systems [16].

From the policy level point of view, new technology (production/manufacturing technology, ICT (including e-purchasing or web-based applications/web-based order processing system) and international operations strategy (as mentioned above) could be transferred from the parent company to the joint venture companies located in Thailand efficiently and effectively if financial and non-financial support has been well provided. The Thai Board of Investment (BOI) has an amended Skills, Technology & Innovation (STI) incentive package for projects which involve investing in research or design or developing Thai staff or supporting educational or research institutions. As a result, the rate of production/manufacturing technology, international operation strategy, and other organizational innovation/intervention diffusion has been increasing throughout the Thai automotive supply chains continuously.

E-purchasing and Order Fulfillment

Many companies are making more strategic purchasing through electronic channels and consequently, the supply chain is increasingly becoming a two-way, communications-rich medium. The shift to an online environment is reducing the “paper trail” of purchasing for organizations, as evidenced by the fast-growth across the board in the use of the internet for communicating with their supply base [24]. Purchasing and order-fulfillment are key processes in supply chain operations and with the growth of the internet these processes have had to be redesigned and reorganized [21]. The new forms of purchasing and order-fulfillment, which take advantage of ICT in order to digitize certain stages of these processes, are called e-purchasing and e-fulfillment. Purchasing includes all of the activities involved in acquiring goods or services and managing its flow from the supplier to the company where those will be transformed to the semi-finished products. [19] [41]. The stages of the purchasing process can be ranged from identifying the need to purchase particular goods/services to receive the purchased goods/services on-site [23]. It is important to note that e-purchasing can be defined as all of those

activities required for the purchasing of goods or services which are supported by the internet system, or in general by ICT [15] [20]. More importantly, as e-purchasing is fully integrated with both internal and external systems, this allows for communication to grow into greater collaboration between buyers and suppliers. Both immediately and further on, this development will provide mutual benefit for both parties, as it facilitates partnerships and cooperation in supply chain management [38]. The concept of order-fulfillment is an important aspect of supply chain operations also.

Order-fulfillment involves managing through receiving the order, managing the transaction, warehouse management, managing transportation, customer response, and reverse logistics management [35]. Hence, an efficient e-fulfillment is the management of all interrelated processes/sub-process by using ICT. Recent trends indicate that companies are placing orders more frequent and often to manage smaller lots/batches. The consequence of this phenomenon is an intensified exchange of information among the players in the process in order to increase the flexibility and customer responsiveness [18].

The quarterly Report on Technology in Supply Management, conducted through a joint effort of the Institute for Supply Management (ISM) (formerly the National Association of Purchasing Managers) and Forrester Research provides the best snapshot of the growth of e-purchasing in the United States. The adoption rates of e-purchasing tools, techniques and protocols in the American marketplace, for example, are high [40]. Both in manufacturing and service-oriented firms and in large and small organizations, the adoption of e-purchasing methods is increasing and reaching "critical mass" in most areas. The adoption of e-purchasing systems can be considered from three perspectives, which are all organizations/industries, by comparing between manufacturing and non-manufacturing firms; and by comparing between large and small purchasers respectively. The overall trend in using internet systems for the procurement process could be considered at the usage of online methods for purchasing of direct and indirect goods and services, making use of the internet systems to communicate and collaborate with suppliers, usage of online auctions, and adoption of enterprise-wide e-procurement tools [39]. In addition, web-based application/web-based order processing is a rapidly evolving area of e-purchasing, which is attractive to many firms because of the potential payback and improving their supply chain integration.

Diffusion of web-based application technology in the automobile industry

According to Childerhouse et al. [7], the schedules of OEMs in the automobile industry are extremely volatile and are liable to cause disruption further upstream the supply chain. This will negatively affect the efficiency of supply chains operation. In an effort to improve the efficiency of inter-organizational supply chains operation, much emphasis has been placed on the implementation of e-business tools and techniques such as web-based applications and/or Electronic data interchange (EDI). It is observed that most organizations have invested in EDI technology to share the information among supply chain stakeholders. In a discussion of EDI deployment in the supply chain, Leonard & Davis [26] suggested that EDI enables better information flow in the supply chain. In particular, they suggested that EDI can reduce errors and improve the accuracy of information exchanged in the supply chain. EDI also allows order entry to become faster and cheaper while eliminating the need for manual re-entry of data. Thus, this technology helps to reduce inventory in the supply chain while improving customer satisfaction as well as the level of customer responsiveness.

Web-based application technology (as the EDI system) in supporting VMI

Organizations are now shifting to web-based information transfer systems [13]. There is increasing number of web-based applications to support the entire supply chain's operations, e.g., inventory management, vendor managed inventory (VMI), order management/fulfillment, and warehouse management. The benefits include linkage of ordering and accounts payable, automation of the approval process, improved business intelligence for better decision-making, and reduction of "maverick" (unauthorized) buying. Further advantages of e-purchasing and e-fulfillment through web-based application technology were identified by Muffatto & Payaro [29]. Their study found that this application leads firms to be better management of the information and knowledge exchange with supply chain partners, better understanding of weaknesses, better control of supply-based operations, more accurate procurement, improves control of sales; warehouse stock optimization, better control of market trends and an increase in the number of products supplied by the main suppliers. It is also important to note that many of the costs associated with poor scheduling and inventory management can be eliminated by improving the flow of order and demand information upstream

of the supply chain [8]. In addition, web-application technology enables internet-based supply chain activities to operate fast and inexpensive. As the result, customers can instantly monitor the status of their orders while the suppliers or vendor can manage their owned inventory level calling Vendor Managed Inventory or VMI.

VMI is a collaboration technique that allows suppliers to take responsibility for a range of contracts and to manage inventories of agreed-upon items. [10] VMI has been widely used in the retail industry, e.g., Procter and Gamble (P&G) and Wal-Mart have successfully implemented VMI systems. Adopting full-functioned VMI systems requires a huge capital investment [5]. Lee et al. [25] investigated a web-based enterprise collaborative platform for networked enterprises. Research work with regard to implementing web-based application to support VMI is still limited.

After reviewing literature, this study found that web-based application is able to enhance inter-organizational coordination, resulting in transaction cost savings and competitive sourcing opportunities for both supplier and the buyer organization. However, organizations need to be certain that this technology has been implemented efficiently and effectively. Hence, research question was established and explored as below:

As required by major customers in the Thai automotive supply chain, what enabling factors influence the web-based application implementation to support the adoption of VMI for tier-1 suppliers?

In the next section, research methodology including survey instrument development, data collection, non-respondent bias, and reliability and exploratory factor analysis are described.

RESEARCH METHODOLOGY

Survey instrument development

This study used pre-tested scales from past empirical studies to ensure their validity and reliability. The scales of enabling factors, expected operational outcomes, in implementing web-based application used in this study were adapted from previous studies by Childerhouse et al. [8], Lyons et al. [28], Lauer [24], Leonard & Davis [26],. The content and rationale of the scales is briefly described below.

The scales representing enabling factors were derived from the study of Lyons et al. [28]. The content captures technology competence, leadership, and systems integration. These scales not only reflect the technical aspect of adopted technology, but also the firm's commitment to adapt the organizational culture, which is strongly connected with system integration within and between organizations.

Expected operational outcomes in implementing web-based application technology include increasing the degree of customer satisfaction, increasing the ability to share information between company and customers, reducing the loss of purchasing documents, increasing accuracy in purchasing and production planning, increasing the customer (assemblers) responsiveness, reducing the cost of manufacturing, and reducing inventory level of raw materials and work-in-process (WIP). Therefore, the scale represents the focus on customer responsiveness [24] [26]. All items in the four constructs used a six-point Likert scale. The scales for enabling factors ranged from (1) not at all to (6) a great extent. For expected outcomes from implementing web-based application technology, the scale ranged from (1) worst industry to (6) best in industry as compared with competitors. The questionnaire was then pretested through interviews with procurement/purchasing managers, production planning and control department managers, academics, and system vendors who assessed its overall quality and level of understanding. Based on the results of the pretesting, the questionnaire was slightly modified in order to improve the data validity and reliability.

Data collection and profile of respondents

In this study, the questionnaires were sent to 230 tier-1 suppliers of two automobile assemblers (Japanese and American) located in Thailand. These two assemblers are top two companies in term of annual production volume. These suppliers cover the manufacturers of key parts/components including engine, frame and body, suspensions components, and electrical components. In addition, these suppliers have been required to adopt web-based application in supporting the vendor-managed inventory (VMI) system by those two major assemblers (customers) since 2006. Their experiences in implementing this technology ensure a relatively high level of maturity of obtained data. Middle to top management staff working in production planning and control function was the target respondents.

A total of 74 completed responses were received, implying a 32.17 per cent response rate. Compared with previous studies, this returned rate is acceptable [16]. There were 4 questionnaires that were discarded due to excessive missing responses, thus resulting in 70 usable cases. Table 1 presents the key characteristics of respondents involved in this study.

Table 1 Respondents' Characteristics

Characteristics of Respondents (n = 70)	**Frequency**	**Percent**
Number of Employees		
200 or more	45	64.3
Less than 200	25	35.7
Ownership		
Thai-owned	13	18.6
Foreign-owned	20	28.6
Joint-venture	37	52.8
Manufactured Parts/Components		
Accessories Parts	6	8.6
Stamping Parts	6	8.6
Suspensions Parts	6	8.6
Frame and Body Parts	11	15.6
Power Transmission Parts	13	18.6
Electrical Parts	14	20.0
Engine	14	20.0
Years of Experience in Production Planning and Control Function		
More than 10	14	20.0
6 – 10	22	31.4
2 – 5	25	35.7
Less than 2	9	12.9
Management System Certification		
ISO9001/14001 and ISO/TS-16949	42	60.0
ISO9001	7	11.4
ISO14001	14	20.0
ISO/TS-16949	7	8.6

The result shows that the majority of respondents are electrical components, engine power transmission components, frame and body manufacturing firms respectively. Approximately sixty five per cent of the respondents are large companies with 200 employees or more. The working experience of respondents is at least 2 years in production planning and control function, which helps to ensure the accuracy of the information they provided for this study. With respect to the type of ownership of firm, 80 per cent (approximately) of respondents are foreign-owned through joint venture (53 per cent) and direct investment (28 per cent). Only 20 per cent are Thai-owned. Finally, all firms have adopted at least one international standard of management systems/standards including ISO9001:2000, ISO 14001:1996, and ISO/TS-16949: 2002.

In order to examine non-response bias in the survey data [22], the collected data was tested for statistical differences in responses and three firm characteristics (number of employees, ownership, and management system certifications) between the early and late waves of returned surveys. The last wave of returned surveys was considered to be good representative of non-respondents. Independent samples t-tests did not yield any statistical significant difference between the two groups, suggesting that non-response bias was not an issue in this study.

Reliability and exploratory factor analysis

Validity and reliability examination were carried out for the all constructs (Tables 2–3). Reliability analysis was conducted by examining the value of Cronbach's α [11] for each extracted construct. Results showed that in each case, values of α exceeded the suggested threshold value of 0.6 [32]. Since Cronbach's α may under-estimate error caused by external factors such as differences in testing situations and respondents over time, composite reliability and average variance extracted were also examined since they are more parsimonious measure of reliability [34]. Statistics for composite reliabilities for the each extracted constructs exceeded the required threshold value of 0.70, providing further evidence of scale reliability [9].

In order to answer the research question, exploratory factor analysis with principal components analysis was then employed to investigate the uni-dimensionality of the scales/variables. Factor loadings of all items within each scale were above 0.50, providing support for the validity of measuring the latent variables using the respective sets of indicators. Values of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in excess of 0.50 indicated that the use of factor analysis was appropriate, and that extracted factors were distinct and reliable. This is reaffirmed by the fact that for each scale, Bartlett's sphericity test for the null hypothesis that the correlation matrix is an identity matrix, was rejected (α = 5%). Table 2-3 present the results of exploratory factor

analysis with the Varimax rotated component matrix.

Table 2 Enabling Factors (Rotated Component Matrix)

	Avg. (S.D.)	1	2	3
Technology Readiness (Composite mean = 4.912)				
Knowledge and expertise of web-based technology's user	4.97 (0.74)	0.8154		
Continuous training and education for all interested parties	5.01 (0.92)	0.7955		
Ability to use electronic media in communicating with customers	4.93 (0.76)	0.7645		
Technological infrastructure (computer hardware/software, networks) of users	4.94 (0.88)	0.6263		
Feature of web-based technology	4.71 (1.02)	0.5420		
Leadership (Composite mean = 4.855)				
Top management commitment and financial support	5.14 (1.03)		0.8793	
Establishing the long-term plan	4.69 (1.02)		0.7940	
Frequency of data transactions among users	4.76 (1.01)		0.7237	
Operational ability among interested parties using the web-based technology	4.83 (0.93)		0.7083	
System Integration (Composite mean = 4.770)				
Scope of system implementation (inter-organization and intra-organization)	4.61 (0.91)			0.8159
Technological capability of systems vendors	4.86 (0.87)			0.7690
Coordination & communication among interested parties	4.84 (0.93)			0.7345
Total variance explained		26.091	51.556	72.688
Reliability coefficient		0.8710	0.8360	0.8260
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.830			
Bartlett's Test of Sphericity: Approx. Chi-Square	491.920			
Df	66			
Sig.	0.000			

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser

FINDING

Enabling factors in implementing web-based application

Table 2 presents the findings relating to the enabling factors in three different constructs – technology readiness, leadership, and systems integration. The composite mean among those three constructs show that technology readiness (4.912) is the most important enabler in implementing web-based application technology follow by leadership (4.855), and systems integration (4.770). This finding confirms the study of Zhu et al. [42], which indicated that the web functionalities, technology competence, and technology integration were significant facilitators in internet-based e-commerce implementation in European countries, and US and Canada respectively.

For the technology readiness construct, continuous training and education (average score = 5.01) was seen as requiring most emphasis followed in order by knowledge and expertise of users (average score = 4.97), technological infrastructure (average score = 4.94), ability to use technology to communicate with customers (average score = 4.93), and finally the features of the technology being used (average score = 4.71). With respect to leadership, top management commitment and financial support (average score = 5.14) was seen to be most important followed by operational abilities of users (average score = 4.83), frequency of data transactions (average score = 4.76), and finally long-term planning (average score = 4.69). For systems integration, the technological capability of the systems vendors was most important (average score = 4.86), followed by co-ordination and communication among users (average score = 4.84), and the scope of system implementation (average score = 4.61).

Table 3 shows the results with respect to the expected outcomes of web-based application with customer responsiveness being the singular classification. Increasing the degree of customer satisfaction (average score = 5.11) was the most important outcome, followed in order by reduction in loss of purchase order documents (average score = 5.04), increase in accuracy of purchasing and production planning (average score = 5.04), increased ability to share data with customers (average score = 4.94), reduction in manufacturing cost (average score = 4.86), increasing customer responsiveness (average score = 4.73), and reduction in inventory levels of raw materials and Work-in-process (WIP) (average score = 4.27).

Table 3 Expected Outcomes (Rotated Component Matrix)

	Avg. (S.D.)	1	2
Customer Responsiveness (Composite mean = 4.856)			
Increasing the degree of customer satisfaction	5.11 (0.93)	0.8930	

Increasing the ability to share data between company and customers	4.94 (0.99)	0.8547	
Reducing the loss of purchased order documents	5.04 (1.00)	0.7717	
Increasing accuracy in purchasing and production planning	5.04 (0.89)	0.7669	
Increasing the customer (assemblers) responsiveness	4.73 (0.91)	0.7587	
Reducing the cost of manufacturing of your company	4.86 (0.90)	0.7540	
Reducing inventory level of raw materials and WIP	4.27 (1.05)	0.6320	
Total variance explained		45.259	71.773
Reliability coefficient		0.9190	0.8260
Kaiser-Meyer-Olkin Measure of Sampling Adequacy			0.833
Bartlett's Test of Sphericity: Approx. Chi-Square			391.678
Df			45
Sig.			0.000

CONCLUSIONS AND IMPLICATIONS

This study has presented the experiences of tier-1 suppliers of automobile manufacturing industry that have implemented web-based application technology in an emerging economy country. Overall, the study has shown that the enabling factors for web-based application technology implementation by the respondents were technology readiness, leadership, and systems integration. With respect to the enabling factors for adopting this technology, three important extracted factors were top management commitment and financial support, continuous education and training, and knowledge and expertise of the users. This suggests that some of the skills and support issues are as important as the technological issues. With respect to the expected outcomes of implementing this technology, increasing the degree of customer satisfaction, reducing loss of documents and increasing the accuracy of production planning were the most important issues under the extracted factor of customer responsiveness. These issues which relate to process efficiency and customer focus were seen to be more important than the cost-based measures – reducing the cost of manufacturing and reducing inventory levels.

This study has important implications for practitioners and academics. For practitioners, there is the need to clearly understand the reasons for implementing web-based application technology. In this regard, the satisfaction of customers and the improved efficiency of internal operations should be paramount. It is also important to note that the roles of management support and the development of appropriate technical skills are crucial to successful deployment of technology. Well-designed action agenda in implementing this technology among suppliers, customers (assemblers), and IT system vendors leads to enhancement in absorptive capability of users. For academia, this study indicates the need for continuing research into how technology be deployed and enables the efficiency of supply chains operations by considering the resource-based view theory. While much of the benefits of technology deployment are recognized, the factors and processes that underpin successful implementation of new technology along the supply chain should be the focus of future research.

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