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A Structural Equation Model of Information Systems Development and Supply Chain Management

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ABSTRACT

This paper employs structural equation modeling to analyze the effects of information system development and supply chain management on manufacturing objective and organizational performance. Survey data of middle managers from Taiwan's computer and electronics industries was used to test the relationships between the constructs in the model. In general, the survey results supported the proposed structural equation model. It is observed that information system development facilitates supply chain management practice and manufacturing objective attainment. In addition, there are significant relationships between supply chain management and manufacturing objective, as well as between manufacturing objective and organizational performance. However, the impacts of information system development and supply chain management on organizational performance were not supported by the data. The study concludes that information system development and supply chain management does not lead to better organizational performance directly. Introducing supply chain management through information system development helps to achieve manufacturing objective, and finally improves organizational performance.

INTRODUCTION

In the past decades firms have been trying to be more competitive by practicing "total quality management". Recently, due to the increased international competition, the focus of quality-based paradigm has shifted from the traditional company-centered setting to complete supply chain systems. Managers can no longer effectively compete in isolation of other entities in the supply chain. They realize that maximizing performance of one function may lead to less
than optimal performance for the whole firm. On the other hand, they also see the benefits of collaborative relationships beyond their own organization. As John Gossman (1997) noted: “Competition is no longer company to company, but supply chain to supply chain.” Firms should look across the entire supply chain to evaluate the impact of any decision in any one area. The term “supply chain management (SCM)” is the concept of managing across typical organizational boundaries, which include interdepartmental boundaries within a company, such as manufacturing, marketing and purchasing department, and boundaries between companies, such as suppliers, carriers, manufacturing sites, distribution centers, retailers and consumers (Lummus & Vokurka, 1999).

Supply chain management includes managing the flow of information between partners in the chain (Lummus & Vokurka, 1999). The increasing popularity of Internet use and electronic commerce facilitates the construction of global supply chain. Hence, the introduction of information technology by a firm for integrated supply chain management can not only lead to better efficiency and effectiveness, but also eventually enhance the company’s competitiveness and position for further growth (Narasimhan & Kim, 2001).

Manufacturing objective is competitive priorities. It is the main objective of manufacturing activities after a firm scanning its own manufacturing capacity, product and market advantages as well as environmental threats and opportunities (Sharma, 1987; Leong et al., 1990). Many studies indicated that introducing supply chain management through well-constructed information system facilitates manufacturing objective attainment, and further improve organizational performance (King & Grover, 1991; Porter and Miller, 1985; Sokol, 1989; Fillipini & Raffo, 1991).

Taiwan is an exporting nation as well as an importing nation. Some 80 percent of the machines, tooling and accessories it produces are built for purchase by other countries. The United States is Taiwan’s No. 2 machine tool export market behind Mainland China. Meanwhile, the United States is the No.2 machine tool supplier to Taiwan. Demand for high value-added, automated equipment for Taiwan’s high technology and semi-conductor industries accounts for the high volume of imported U.S.made machine tools (Koepfer, G.C., 2001).

Taiwan is the home world’s biggest manufacturer for dozens of computer-related products such as notebooks, palm scanners, motherboards, and MODEMs. In terms of production values, it ranks third in computer manufacturing and fourth in semiconductor industries in the world. (Ministry of Economic Affairs, Republic of China homepage, MOEA, 2002). Taiwan’s electronics sector has grown from humble beginners in the 1970s to become the present supplier of half of the world’s computer hardware. Taiwan’s computer firms have been developing higher-mar gin services, like design, in-house (Young, 2000). The upper streams of computer/electronics industry in Taiwan include components, semiconductors; middle streams include card/board, and down streams include peripherals, communication products, systems and information services (Hsu, 1999).

Taiwan is also one of Asia’s most open and developed Internet communities (Trappey, 2001). In June of 1999, Taiwan launched a national Industrial Automation and Electronic Busi-
ness (IAEB) plan to build up the B2B e-business infrastructure (IAEB,1999). The five-and-a-half year plan will promote B2B e-business to 50,000 enterprises (with 200 supply chains) with the objective of increasing global competitiveness of manufacturing and distribution. Internet nodes in 2000 have been competed for the whole island of Taiwan as well as for four outlying islands while the coverage of ADSL service extends to 97% of the country (MOEA, 2002). Taiwan is fulfilling to become a leading Internet technology and computer technology provider for Asia and the world.

Many studies have emphasized the interrelationships between information system development, supply chain management, manufacturing objective and organizational performance (Kuei, Madu & Lin, 2001; Narasimhan & Kim, 2001; Shin, Collier & Wilson, 2001; Lummus & Vokurka,1999; Narasimhan & Das, 1999; Porter and Miller, 1985; Sokol, 1989; Filippini & Raffo, 1991). However, rarely have them established a structural framework, or conducted an empirical study for all these concepts. Porter and Millar (1985) proposed the concept that information technology helps a firm alter the relationships among their suppliers and customers, as well as create sustainable competitive advantages. Filippini and Raffo (1991) held several case interviews, including with Olivetti and IBM in Italy, and concluded that information application has great impact on manufacturing function. Lummus and Vokurka (1999) pointed out the “moments of information” as critical elements necessary for a company to manage in its supply chain. The above studies are all qualitative and conceptual.

In empirical studies, Narasimhan and Das (1999) utilized discriminant analysis to test the relationship between supply chain management and manufacturing capability. Collier and Wilson (2001) used structural equation modeling approach to discuss the impact of supply management on suppliers’ operational performance and buyers’ competitive priorities. Nevertheless, information factor and organizational performance were not discussed in these two studies.

Meanwhile, Kuei, Madu and Lin (2001) presented an empirical study to examine the relationship between supply chain management and organizational performance. Narasimhan and Kim (2001) also employed a structural equation model and identified the relationship between information systems’ characteristics and supply chain management performance. This structural model didn’t put manufacturing objective and organizational performance into discussion.

Our study tries to explore the relationships among all these constructs – information system development, supply chain management, manufacturing objective and organizational performance- from an integrated point of view. Hopefully by employing structural equation modeling approach, the direct and indirect influences of information system development and supply chain management on manufacturing objective and organizational performance will be more clarified.

This paper is organized in an order of a research effort driven by three objectives. First, it tries to define and operationalize supply chain management, information system development, manufacturing objective and organizational performance based on the literature and statistical method, including factor analysis, reliability test and validity test. Secondly, it proposes a conceptual structural equation model to link the direct and indirect impacts of supply chain management, information system development, manufacturing objective and organizational performance.
Finally, this study surveys 155 middle managers from Taiwan’s high-tech manufacturing firms, and uses the data to test the relationships in the proposed model.

RESEARCH CONSTRUCTS

Supply Chain Management (SCM)

APIC (American Production and Inventory Control) dictionary describes the supply chain as “the processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier-use companies, and the functions within and outside a company that enable the value chain to make products and provide services to the customer” (Cox et al., 1995).

The Supply Chain Council (1997) defined supply chain as a term increasingly used by logistics professionals, and which encompasses every effort involved in producing and delivering a final product, from the supplier’s supplier to the customer’s customer. Four basic processes- plan, source, make, deliver- broadly define these efforts, which include managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer.

Lummus and Vokurka (1999) summarized the definitions of some literate and stated SCM as “all the activities involved in delivering a product from raw material to the customer. It coordinates and integrates all of the activities into a seamless process.

The academic and practitioner literature presents numerous dimensions to assess a firm’s effort of practicing supply chain management. Narasimhan and Das (1999) built up scales including volume flexibility, modification flexibility, delivery flexibility and strategic supply chain management practices as measurement constructs. Lummus and Vokurka (2000) presented a set of self-assessment guidelines to help companies assess their supply chain capability. The assessment model consists of following constructs: organizational structure, production capability, supplier relationships, customer service and information sharing.

For the purpose of this study, four dimensions cited SCM practices based on Lummus and Vokurka (2000) and Narasimhan and Das (1999) were used to assess this construct. Respondents were asked to indicate how they believe their firms practicing SCM on a 7-point Likert scale (1=strongly disagree, 7=strongly agree).

Information System Development (ISD)

Earl (1989) classified the scope of information technology into the following categories according to whether information technology is widely used in the value chain or selectively used for only information processing and whether it is applied for value creation or applied for the connection of value-adding activities: (1) Information technology that automates or improves
the physical aspect of every activity; (2) information technology used for physically connecting each value activity or controlling those activities at the connecting point; (3) information systems that facilitate the implementation, support, and management of value activities; and (4) information systems that optimize or adjust the connection of each value activity. Earl's classification is not only applicable to the internal value chain of a firm, but can also be extended to the company's supply chain, linking suppliers and customers (Narasimhan & Kim, 2001).

Robbins and Stylianou (1999) also presented a 13-scaled instrument to evaluate a firm's information system capability. The measurements include the capability to enhance a firm's competition position, to shape or enable critical business strategies, to integrate information system planning with organizational planning, to contribute to overall financial performance and so on.

Based on literature aforementioned, 16 information system development practices were selected to represent this construct. Respondents were asked to assess, on a 7-point Likert scale (1=strongly disagree, 7=strongly agree), how they believe their information systems developed.

Manufacturing Objective (MO)

In an environment with fierce competition and limited resources, firms have to choose their priorities in achieving the multiple goals in order to compete in the market. Sharma (1987) and Leong et al. (1990) named manufacturing objective as "competitive priorities". Fine and Hax (1985) indicated that a firm is unable to attain the multiple objectives simultaneously; therefore it has to choose the priorities to achieve the goals.

Skinner (1969) defined manufacturing's objectives as cost, quality, delivery and flexibility and indicated that there were trade-offs between them. The interaction between objectives in the form of trade-offs has, however, become a contentious issue. In 1969 Skinner believed it impossible for manufacturing to make a wide range of high quality and low cost products quickly. Wheelwright (1981) questioned this assumption and noted that many Japanese managers seek to improve quality and reduce costs simultaneously. Slack (1991) entered the time dimension into the debate. He argued that while no manufacturer can double its product range tomorrow without increasing cost, high quality and low cost may well be possible over a longer period.

Based on this overview, five dimensions, including quality, cost, flexibility, delivery and service, about manufacturing objective were identified. Respondents were asked to indicate, on a 7-point Likert scale (1=strongly disagree, 7=strongly agree), how they think their firms attain their manufacturing objective.

Organizational Performance (PER)

Organizational performance can be measured on a variety of dimensions, and no single business approach can be expected to have the same effect on all dimensions (Walker and Ruekert 1987). Some of them have operationalized organizational performance with measures
of return on assets, sales growth, new product success (Narver and Slater 1990; Slater and Narver 1994), and market share and overall performance (Jaworski and Kohli 1993). Madu, Kuei and Jacob (1996), based on their empirical study about the relationship between quality management and organizational performance, presented the measures as productivity, cost, profitability, competitiveness, sales growth, profit growth and market share.

There is general agreement among organization scholars that objective measures of performance are preferable to those based on manager’s perceptions. However, objective data on the performance is usually not available because most firms are unwilling to reveal such information voluntarily to outsiders (Dess and Robinson 1984). Furthermore, when financial statements are available, they may be inaccurate because they are usually unaudited (Sapienza, Smith, and Gannon 1988). The study thus relies on perceptual measures of organizational performance. Beal (2000) performed perceptual measures from managers to gauge their satisfaction with organizational financial performance.

This study also adopted perceptual measures of organizational performances. Managers were asked to indicate, on a 7-point Likert scale, the extent of their satisfaction with their firms’ performance along each of the four performance indicators. The measures include productivity, sales growth, profit growth and market share.

RESEARCH MODEL & HYPOTHESES

Stock, Greis and Kasarda (2000) indicated the importance to coordinate information flow across the supply chain. The benefit of such supply chain management can be attained through electronic linkage among various supply chain activities utilizing information technology and the construction of integrated supply chain information systems (Bowersox and Daugherty 1995). Information systems were viewed as providing infrastructural support to the value chain and having an indirect impact on the competitiveness of a product (Narasimhan & Kim, 2001). Through the utilization of information systems, companies have been able to integrate similar functions spread over different areas as well as curtail unnecessary activities, thus enhancing their capability to cope with sophisticated needs of customers and to meet product quality standards (Bardi, Raghunathan, and Bagchi 1994).

Keen (1994) indicated that an enterprise that builds quality into its information technology development and service delivery is expected to experience superior performance. Porter and Millar (1985) asserted that the utilization of information technology has a significant influence on the relationships among value chain activities as well as on the physical aspects of individual value chain activities. They also believed that Information technology helps to create and maintain the competitiveness of a company. Earl (1989) supported the assertion of Porter and Millar (1985) and contended that information system must have the potential to be a strategic weapon in at least one of the following four ways: (1) to gain competitive advantage; (2) to improve productivity and performance; (3) to enable new ways of managing and organizing; and (4) to develop new businesses.
Based on literature aforementioned, we construct research hypothesis 1 to 3:

H1: Information system development has a direct influence on supply chain management capability.

H2: Information system development has a direct influence on manufacturing objective attainment.

H3: Information system development has a direct influence on organizational performance improvement.

In the digital age, supply chain quality management has been recognized as one of the most critical ways to respond rapidly, correctly, and profitably to market demands. Narasimhan and Das (1999) believed that SCM practices offer a strategic choice for achieving manufacturing capabilities without investments in capital equipment. Similarly, Harrison and Kelley (1993) observed that companies facing technology or capacity constraints often avoid fixed investments by accessing specialized skills, equipment and capacity from their supply chains.

There is evidence that firms are achieving volume, design and technology flexibilities through supply chain management (Tully, 1994). Kuei, Madu and Lin (2001) suggest that organizational performance could be enhanced through improved supply chain quality management. Tracey and Vonderembse (1998) also confirmed that better supplier performances such as timely delivery, reduced shipping damage, and higher inbound component quality did have positive impacts on manufacturing performances.

Narasimhan and Jauaram (1998) proposed a LISREL model and indicated that supplier capability has great impact on attaining manufacturing objective, and further improve organizational performances. Shin, Collier and Wilson (2001) also used structural equation modeling approach and revealed the direct impact of supply management on suppliers’ operational performance and buyers’ competitive priorities (cost, quality, delivery and flexibility).

Therefore, we construct the following hypotheses:

H4: Introducing supply chain management directly influences manufacturing objective attainment.

H5: Supply chain management capability has a direct influence on organizational performance.

H6: Manufacturing objective attainment has a direct influence on organizational performance improvement.

Based on prior studies and our research hypotheses, we construct the research model as figure 1 on the following page.
**Figure 1. Research Model**

```
  \begin{figure}
    \centering
    \includegraphics[width=\textwidth]{research_model.png}
    \caption{Research Model}
  \end{figure}
```

**METHODOLOGY**

**Sampling**

A survey instrument was developed based on the constructs described earlier. Respondents were asked to evaluate the extent, on a 7-point Likert scale, to how their firms practice the various constructs in this study. 15 academic and practical experts were interviewed to confirm the validity of the questionnaire. Data were then collected by mail to middle managers drawn from Taiwan’s top 500 manufacturing corporations, including 289 electronics and machinery firms and 211 computer firms. Follow-up calls were made to remind the participants to complete and return the questionnaires. Also, two repeat mailings were done to increase response rate. Of 500 corporations, 155 are replied and usable, including 84 from electronics and machinery industry, 71 from computer industry. Among the usable questionnaires, 103 were from first mailing, and 52 were from second mailing. The response rate of 31% is reasonable compared to recent studies in operations management (Narasimhan & Das, 1999; Suarez, et al., 1996).

**Non-response bias**

Respondents and non-respondent corporations were compared for industry and size to test for non-response bias. There were no difference between respondents and non-respondents for industry ($\chi^2=5.97, p>0.05$), for sales ($t=0.435, p>0.05$), and for assets ($t=0.079, p>0.05$). Table 1 summarizes the sample characteristics according to industry type and size.
In additions, data returned from first mailing and second mailing was compared mean scores by employing t-test. The result yields no differences among the questionnaire items, which strengthening the validity of our study.

Table 1 Summaries of the Sample Characteristics according to Type and Size

<table>
<thead>
<tr>
<th>Type of Industry</th>
<th>Total</th>
<th>Electronics &amp; Machinery</th>
<th>Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of firms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response</td>
<td>155</td>
<td>84</td>
<td>71</td>
</tr>
<tr>
<td>Non-response</td>
<td>345</td>
<td>205</td>
<td>140</td>
</tr>
<tr>
<td>Sales Mean</td>
<td>42.74</td>
<td>37.50</td>
<td>45.27</td>
</tr>
<tr>
<td>t-test</td>
<td>0.379, p&gt;0.05</td>
<td>0.339, p&gt;0.05</td>
<td>0.160, p&gt;0.05</td>
</tr>
<tr>
<td>Assets Mean</td>
<td>929.70</td>
<td>1044.44</td>
<td>877.25</td>
</tr>
<tr>
<td>t-test</td>
<td>0.326, p&gt;0.05</td>
<td>0.570, p&gt;0.05</td>
<td>0.340, p&gt;0.05</td>
</tr>
</tbody>
</table>

RESULTS

Factor Analysis

Due to lack of well-defined factors of information system development from literature, factor analysis was conducted to assess this construct. A Kaiser-Meyer-Olkin (KMO) of greater than 0.80 is considered adequate for factor analysis (Kaiser 1974). The KMO measure of our sample adequacy indicated that the 16-item sample was adequate for factor analysis (KMO measure = 0.881). Factor analysis by a varimax rotation was then used to assess the constructs of the 16 measured degrees of information system development. The results of factor loadings of item 5, 13 and 14 are lower than 0.6. Thus, we removed these items and performed factor analysis again. The final result is presented in Table 2. As shown in Table 2, 13 information system development indicators can be classified into two multivariate scale accounting for 65.174 percent of the variance of the items. Each of the two factors had eigenvalues greater than one (see Table 2). Factor 1 includes item 6, 7, 8, 9, 10, 11 and 12, and is named operational information system development; factor 2 is named managerial information system development, including item 1, 2, 3, 4, and 15.
Table 2. Factor Loadings of "Information System Development" After Varimax Rotation

<table>
<thead>
<tr>
<th>Construct</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A10 Identify and assimilate new technologies</td>
<td>.863</td>
<td>.101</td>
</tr>
<tr>
<td>A7 Provide good quality information</td>
<td>.815</td>
<td>.320</td>
</tr>
<tr>
<td>A11 Develop systems efficiently and effectively</td>
<td>.809</td>
<td>.286</td>
</tr>
<tr>
<td>A9 Operate systems efficiently by ensuring system availability, reliability and responsiveness</td>
<td>.786</td>
<td>.183</td>
</tr>
<tr>
<td>A6 Provide corporate-wide information accessibility</td>
<td>.763</td>
<td>.339</td>
</tr>
<tr>
<td>A8 Provide corporate-wide information accessibility</td>
<td>.763</td>
<td>.339</td>
</tr>
<tr>
<td>A12 Provide adequate end-user support</td>
<td>.733</td>
<td>8.445E-02</td>
</tr>
<tr>
<td>A2 Shape or enable critical business strategies</td>
<td>3.666E-02</td>
<td>.848</td>
</tr>
<tr>
<td>A16 React to customers' demand by internet</td>
<td>.120</td>
<td>.751</td>
</tr>
<tr>
<td>A15 Communicate with suppliers by internet</td>
<td>.216</td>
<td>.742</td>
</tr>
<tr>
<td>A4 Contribute to overall organizational performance</td>
<td>.276</td>
<td>.726</td>
</tr>
<tr>
<td>A3 Integrate IS planning with organizational planning</td>
<td>.398</td>
<td>.724</td>
</tr>
<tr>
<td>A1 Enhance the organization's competitive position</td>
<td>.301</td>
<td>.618</td>
</tr>
</tbody>
</table>

To confirm that there are no other independent factors in every construct of supply chain management, factor analysis was also conducted respectively on this literature-defined factor. The result of factor analysis shows there are not other factors in this construct, revealing the reliability of the survey instrument. The final results are presented in Table 3.

Table 3. Factor Analysis Results of Information System Development and Supply Chain Management

<table>
<thead>
<tr>
<th>Construct</th>
<th>Factor</th>
<th>Eigenvalue</th>
<th>Accumulative Percentage of Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information System Development</td>
<td>Operational information system development</td>
<td>6.529</td>
<td>50.224%</td>
</tr>
<tr>
<td>ISD</td>
<td>Managerial information system development</td>
<td>1.944</td>
<td>65.174%</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>Organizational structure (Scm1)</td>
<td>3.545</td>
<td>70.904%</td>
</tr>
<tr>
<td>SCM</td>
<td>Production capability (Scm2)</td>
<td>2.771</td>
<td>69.278%</td>
</tr>
<tr>
<td></td>
<td>Supplier relationships (Scm3)</td>
<td>3.316</td>
<td>62.272%</td>
</tr>
<tr>
<td></td>
<td>Customer service (Scm4)</td>
<td>2.732</td>
<td>68.296%</td>
</tr>
</tbody>
</table>
Reliability & Validity Test

Reliability and validity tests were then conducted on the constructs with multivariate measures. Cronbach’s alpha reliability estimate was used to measure the internal consistency of these multivariate scales (Nunnally, 1967). Cudeford (1965) believed that scales with Cronbach α greater than 0.7 are highly reliable, between 0.7 and 0.35 are acceptable, and those smaller than 0.35 are low reliable. If an indicator has low correlation with a given scale, it is removed from that scale. A new Cronbach’s alpha is then obtained. Usually, the value of Cronbach’s alpha will increase due to this. In this study, Cronbach’s alpha of all the constructs are greater than 0.8, which reveals good reliability of our survey instrument.

According to Kerlinger (1986), item-to-total correlation is an appropriate measurement for testing criterion validity. The criterion validity of each scale in this study was satisfactory according to Kerlinger (1986), with all the item-total correlations at least 0.5, and most of which are greater than 0.6.

Cronbach’s alpha values for each construct are presented in Table 4.

Table 4. Cronbach’s Alpha for All Constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>Factor</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information System</td>
<td>operational information system development</td>
<td>0.9211</td>
</tr>
<tr>
<td>Development (ISD)</td>
<td>managerial information system development</td>
<td>0.8635</td>
</tr>
<tr>
<td>Supply Chain Management (SCM)</td>
<td>organizational structure (Scm1)</td>
<td>0.8967</td>
</tr>
<tr>
<td></td>
<td>production capability (Scm2)</td>
<td>0.8520</td>
</tr>
<tr>
<td></td>
<td>supplier relationships (Scm3)</td>
<td>0.8499</td>
</tr>
<tr>
<td></td>
<td>customer service (Scm4)</td>
<td>0.8443</td>
</tr>
<tr>
<td>Manufacturing Objective (MO)</td>
<td>Cost advantage (E1)</td>
<td>0.8425</td>
</tr>
<tr>
<td></td>
<td>Quality advantage (E2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility advantage (E3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service advantage (E4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delivery advantage (E5)</td>
<td></td>
</tr>
<tr>
<td>Organizational Performance (PER)</td>
<td>Productivity (G1)</td>
<td>0.8995</td>
</tr>
<tr>
<td></td>
<td>Market growth (G2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Profit growth (G3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sales growth (G4)</td>
<td></td>
</tr>
</tbody>
</table>
Structural Equation Modeling Approach

Structural equation modeling is a multivariate statistical technique for testing structural theory (Tan, 2001). It incorporates both observed and latent variables, and is usually separated into measurement models and a structural model. The measurement models address the reliability and validity of the variables in measuring the latent variables, while the structural model specifies the direct and indirect relations among the latent variables (Byrne, 1998; Schumacker & Lomax, 1996) and further provides insights into the direction of influence between research constructs (Judge and Ferris, 1993).

Schumacker and Lomax (1996), citing the work of James, Mulaik, and Brett (1982), Anderson and Gerbing (1988), and Joreskog and Sorbom (1993), recommended a two-step modeling approach to assessing the fit of the structural model independently of the measurement models. They contended that the measurement models provide an assessment of convergent and discriminant validity while the structural model provides an assessment of predictive validity. Maruyama (1998) stressed that to ensure model identification, one can separate the measurement and structural models. If each measurement model is identified independently, and then the structural model is identified.

Based on this overview, a two-step modeling approach was conducted. The measurement models (or confirmatory factor models) were tested prior to the structural model. The maximum likelihood (ML) estimation method was employed. According to Bagozzi and Yi (1989), maximum likelihood is superior since it has desirable asymptotic properties and is scale-free.

Schumacker & Lomax (1996) indicated that no single index is generally accepted for evaluating the model fit although a number of criteria have been proposed and. In this study, seven measures of goodness of fit were used, including GFI, AGFI, RMSR, CFI, NFI, NNFI, and chi-square value.

Analysis of the Measurement Models

Despite the cronbach’s alpha and item-to-total correlations have shown satisfactory reliability and validity of each construct, the independency among factors of each construct, except information system development, which has been factor analyzed, has not been proved yet. Confirmatory factor analysis was hence performed, suggested by Byrne (1998), to assess the measurement model of supply chain management, manufacturing objective and organizational performance. To establish the scale for each latent variable in the model, the first regression path in each measurement model was fixed at 1 (Hoyle, 1995; Maruyama, 1998).

Measurement Model of Supply Chain Management Supply chain management construct was the first measurement model tested. Tan (2001) indicted that high modification index reveals high correlation between two factors. The modification indices of this model suggested that organizational structure (SCM1) and supplier relationship (SCM3) influenced each other. Since supplier relationship is likely to be part of a firm’s organizational structure, an error covariance between the two factors was included, and the supply chain management model was modified...
accordingly. Parameter estimate describes the ability of the observed variables to measure the corresponding latent variable (Shumacker and Lomax, 1996). All parameter estimates in this model are rather large and statistically significant, with t-value greater than 1.96. Results indicate the model fits the sample data well, with GFI = 0.994, AGFI = 0.941, RMSR = 0.006, CFI = 0.997, NFI = 0.994, and NNFI = 0.997. Standardized parameter estimates are shown in figure 2 (see figure 2).

**Figure 2. Measure Model of Supply Chain Management**

![Diagram of Supply Chain Model]

**Measurement Model of Manufacturing Objective.** Manufacturing objective is the next measurement model to be tested. Results indicate the model fits the sample data well, with GFI = 0.982, AGFI = 0.941 and RMSR = 0.02. Baggozi and Yi (1988) proposed that squared multiple correlation (SMC) of observed variables should be greater than 0.5, and which of latent variables greater than 0.6 to be able to measure its construct. Nevertheless, the squared multiple correlation (SMC) of the first measure, cost advantage, is 0.434, less than 0.5 suggested by Baggozi and Yi (1988). Since manufacturing objective refers to the "competitive priorities" pursued by firms, Taiwanese firms may have shifted their competitive priorities from cost to other advantages such as quality and flexibility. According to prior studies, Taiwan's domestic production was affected by an appreciating NTS, wage increases, employee shortages, ecological concerns, and competition from other developing countries. Together these factors increased production costs (Woodcock and Chen, 2000). In additions, overall model fit of structural equation is much better with cost advantage removed from this construct (GFI = 0.871 with cost advantage, and GFI = 0.891 after deleting cost advantage). Consequently, cost advantage is removed and the revised measurement model of manufacturing objective is tested again. The final result shows that the model fits the sample data very well, with GFI, AGFI, CFI, NFI and NNFI
close to 1, and RMSR equaling 0.001. All parameter estimates are statistically significant. Standardized estimates are shown in figure 3 (see figure 3).

Figure 3. Measurement Model of Manufacturing Objective

![Diagram of Manufacturing Objective](image)

Measurement Model of Organizational Performance Finally, organizational performance model was evaluated. The result shows that the model fit is good, with GFI=0.983, AGFI=0.917, RMSR=0.018, CFI=0.992, NFI=0.987 and NNFI=0.993. All parameter estimates are rather large and statistically significant (t-value>1.96). Standardized estimates are shown in figure 4 (see figure 4).

Figure 4. Measurement Model of Organizational Performance

![Diagram of Organizational Performance](image)
Analysis of the Structural Model

The structural model was analyzed after incorporating modifications based on the results of the measurement models. The results of the structural model reveal a satisfactory model fit of our sample data (GFI=0.891, AGFI=0.836, RMSR=0.043, CFI=0.936, NFI=0.89, NNFI=0.93). Although the chi-square p-value (<0.05) implies the sample data do not fit the model well, many studies have proposed that chi-square statistics are very sensitive to large sample size, thus producing significant results (Bryenm & Maruyama, 1998; Shumacker & Lomax, 1996). In general, most of the fit measures reveal the sample data fit the hypothesized model well.

Parameter estimates in the structural equation model indicate the relationships between the latent measures. The results show that information system development directly influences supply chain management ($\gamma=0.646$, $p<0.05$) and manufacturing objective ($\gamma=0.427$, $p<0.05$), supply chain management influences manufacturing objective ($\beta=0.435$, $p<0.05$), and manufacturing objective significantly influences organizational performance ($\beta=0.581$, $p<0.05$). The hypotheses that information system development and supply chain management have direct effects on organizational performance, with $p$ value greater than 0.05, are not supported by the sample data. The results are summarized in Table 5.

### Table 5. Results of Structural Equation Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\frac{\beta}{\gamma}$</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information System Development $\rightarrow$ Supply Chain Management</td>
<td>0.646</td>
<td>5.274*</td>
</tr>
<tr>
<td>Information System Development $\rightarrow$ Manufacturing Objective</td>
<td>0.427</td>
<td>3.210**</td>
</tr>
<tr>
<td>Information System Development $\rightarrow$ Organizational Performance</td>
<td>0.054</td>
<td>0.386</td>
</tr>
<tr>
<td>Supply Chain Management $\rightarrow$ Manufacturing Objective</td>
<td>0.435</td>
<td>3.549**</td>
</tr>
<tr>
<td>Supply Chain Management $\rightarrow$ Organizational Performance</td>
<td>0.119</td>
<td>0.974</td>
</tr>
<tr>
<td>Manufacturing Objective $\rightarrow$ Organizational Performance</td>
<td>0.581</td>
<td>3.746**</td>
</tr>
<tr>
<td>GFI</td>
<td>0.891</td>
<td></td>
</tr>
<tr>
<td>AGFI</td>
<td>0.836</td>
<td></td>
</tr>
<tr>
<td>RMSR</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td>CFI</td>
<td>0.936</td>
<td></td>
</tr>
<tr>
<td>NFI</td>
<td>0.889</td>
<td></td>
</tr>
<tr>
<td>NNFI</td>
<td>0.931</td>
<td></td>
</tr>
</tbody>
</table>

** refers to p value <0.01, * refers to p value <0.05
DISCUSSION

The results support the structural equation model and the following research hypotheses: Information system development has direct influence on supply chain management practice (H1) and manufacturing objective attainment (H2). Besides, the practice of supply chain management has direct impact on achieving manufacturing objective (H4). At last, attaining manufacturing objective significantly improves organizational performance (H6).

However, the results do not support the hypothesis that supply chain management has a direct influence on improving organizational performance (H5). On the other hand, the hypothesis that information system development has a direct effect on improving organizational performance (H3) is not supported either.

Based on the study results, we draw the following conclusions. First, the statistically unsupported results of H3 and H5 reveal that either information system development or supply chain management alone does not guarantee better organizational performance immediately. Both of them should be observed for the long-term effects. This result is different from previous studies (Kuei, Madu & Lin, 2001; Narasimhan and Jauaram, 1998), which indicated the significant association between supply chain management and organizational performance. However, the prior studies put only two factors - supply chain management and organizational performance into examined. The significant association between supply chain management and organizational performance is perhaps owing to a precondition. That is, attaining manufacturing objective through well-developed information system and supply chain management. The effects of practicing information system and supply chain management will ultimately influence organizational performance indirectly through attaining manufacturing objective.

Secondly, since H1, H2 and H4 are supported by the study results, we should notice that the simultaneous development of information system and supply chain management as well as adequate interactions between them maybe able to enhance the outcome of manufacturing objective and organizational performance. This result coincides with Narasimhan and Kim’s (2001) study, which suggested that information system must be coordinated with the requirements of supply chain integration in order to be implemented successfully. For example, a software company “SeeCommerce” develops an information system, which collects data from the units on the supply chain and posts them on the Internet. It allows all the firms of the supply chain to check and monitor the supply chain operations in a real time (The Economist Newspaper Limited, London, 2002).

The validity of H1, H2 and H4 can be confirmed by many existing studies (Shin, Collier, & Wilson, 2000; Lummus & Vokurka, 1999; Narasimhan & Das, 1999; Filippini & Raffo, 1991; Porter & Millar, 1985). Similar to H1, Lummus and Vokurka (1999) proposed a concept that information flow is a crucial factor for supply chain management and decision making. Porter and Millar (1985) as well as Filippini and Raffo (1991) have expressed the same opinion with H2. Porter and Millar (1985) pointed out how information technology as a key to lowering cost and enhancing differentiation. They also suggested five steps for firms to take advantage of
opportunities that information revolution has created. Filippini and Raffo (1991) also indicated the great impact of information application on manufacturing functions after several case interviews. Related to H4, Narasimhan and Das (1999) used discriminant analysis and verified that supply chain management does affect manufacturing capabilities. In addition, Shin, Collier and Wilson (2001) used structural equation modeling approach and revealed the direct impact of supply management on manufacturing objectives (cost, quality, delivery and flexibility).

Thirdly, since the cost advantage indicator has been dropped from the manufacturing objective construct, the relationship between supply chain management and cost advantage is worth being discussed. Shin, Collier, and Wilson (2001) found the similar result in their study where the influence of supply management on delivery and quality related performance is more statistically significant than on cost or flexibility performance. Supply Chain Management used to be regarded as a useful concept for cost containment (Lumus & Vokurka, 1999; Narasimhan & Das, 1999). However, the transaction costs of externalizing capabilities may become manifest in reduced managerial control and fewer learning opportunities, as compared to in-house investments (William, 1975). Hence, it is critical for businesses to control the transaction costs in order to really obtain cost advantages when implementing supply chain management.

The other reason for deleting cost advantage from the manufacturing objective construct is that Taiwan seems to losing this competitive advantage gradually. Taiwan’s production cost has been increasing rapidly due to high labor costs and energy costs. On the other hand, developing countries such as Mainland China and Eastern-south Asian counties are attracting investment from all over the world because of their relatively low production costs (Woodcock and Chen, 2000). Therefore, except shifting the competitive priorities to quality, delivery, flexibility and service, Taiwan should make efforts on developing high value-added manufacturing objective such as knowledge-economic industry. In the past decade, Taiwan government strives to upgrade the level of technological research development in order to sustain the motive force for economic growth. Meanwhile, the government is constructing the national information and communications infrastructure and believes that they will improve business environment and enhance operational efficiency (MOEA, 2002).

CONCLUSION

The research results show that information system development facilitates supply chain management practice and manufacturing objective attainment. In addition, introducing supply chain management through information system development helps to achieve manufacturing objective, and finally improves organizational performance.

The study contribution for practice is to suggest that firms develop information systems effectively and efficiently to enhance the performance of supply chain management. Further, managers should notice that information system development and supply chain management cannot enhance organizational performance in a short time. Instead, long-term planning and investment are required for practicing both measures. Adequate interaction between information system development and supply chain management helps to attain firms’ manufacturing
objective, and ultimately, organizational performance improvement will be seen.

The implication for research is that it brings information system development into the structural model of supply chain, and combines them with manufacturing objective and organizational performance. Although many studies have proposed the relationships among the study constructs, rarely of them have discussed them as an integrated framework. This structural equation model helps researchers figure out the direct and indirect relationships among these constructs.

Further researches are suggested to discuss the relationships among the measures of these constructs. Advanced studies of these measures will provide more information for businesses when making strategic planning.

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