



# An Empirical Model of the Relationship between Manufacturing Capabilities: Evidence from the Thai Automotive Industry

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## Abstract

*Regardless of the importance of manufacturing strategy and capability, the relationship between competitive capabilities has been recognized as an important element of operations strategy. However, there is still a lack of comprehension study and empirical evidence in justifying the precise relationships between different elements of manufacturing capability. Between the two suggested models from the literature, the cumulative (or sand-cone) model appears to be more sensible as opposed to the trade-off model. Therefore, the objectives of this research are to develop and test hypotheses based on the cumulative model of manufacturing capability relationships. Based on quantitative investigation of 151 firms from Thai automotive industry using structural equation models (SEM), we reveal interesting*

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*relationships especially in supporting the cumulative model. This study adds a new knowledge to the operations management by investigating the relationships and fills the gap in the literature on manufacturing capabilities, especially in Asian context. As a result, it takes the next step of trying to not only to examine but also to justify the relationships between manufacturing capabilities in the sand-cone model.*

**Keywords:** *Manufacturing Capability, Automotive Industry*

## โมเดลเชิงประจักษ์ความสัมพันธ์ระหว่างความสามารถ ด้านการผลิต: การศึกษาในอุตสาหกรรมรถยนต์ของประเทศไทย

ศากุน บุญอิต

### บทคัดย่อ

ในปัจจุบันความสำคัญของกลยุทธ์ความสามารถในการผลิตได้รับความสนใจมากขึ้นในวงการวิชาการโดยเฉพาะทางด้านการบริหารการปฏิบัติการสืบเนื่องจากกลยุทธ์ความสามารถในการผลิตเป็นองค์ประกอบสำคัญสำหรับกำหนดสร้างความสามารถในการแข่งขันขององค์กร อย่างไรก็ตาม งานวิจัยเชิงประจักษ์ยังมีไม่เพียงพอโดยเฉพาะอย่างยิ่งงานวิจัยที่มีวัตถุประสงค์เพื่อที่จะศึกษาความสัมพันธ์ระหว่างความสามารถในการผลิตในประเทศไทยที่จะทำให้เข้าใจการกำหนดกลยุทธ์ความสามารถในการแข่งขันได้ งานวิจัยที่เกี่ยวข้องกับกลยุทธ์การผลิตได้ถูกสรุปว่าโมเดลความสามารถในการผลิตที่เสริมกัน (Cumulative Model) มีความเหมาะสมมากกว่าโมเดลความสามารถในการผลิตที่ขัดแย้ง (Trade-off Model) ในการสร้างความสามารถในการแข่งขัน ดังนั้น งานวิจัยนี้มีวัตถุประสงค์ที่จะพัฒนาและทดสอบสมมติฐานที่เกี่ยวข้องกับความสัมพันธ์ของความสามารถในการผลิตในรูปแบบโมเดลแบบเสริมกัน การวิจัยเชิงสำรวจผ่านการใช้แบบสอบถามจำนวน 151 ชุดจากอุตสาหกรรมรถยนต์ในประเทศไทยโดยใช้การวิเคราะห์ข้อมูลแบบเทคนิควิธีการวิเคราะห์โมเดลโครงสร้าง ผลการวิจัยได้สนับสนุนรูปแบบโมเดลแบบเสริมกันสำหรับความสัมพันธ์ของความสามารถในการผลิต งานวิจัยนี้มีประโยชน์ในวงการวิชาการที่สร้างองค์ความรู้ใหม่ด้านการบริหารการปฏิบัติการที่เกี่ยวข้องกับการศึกษาความสัมพันธ์ของความสามารถในการผลิตโดยเฉพาะอย่างยิ่งสำหรับกลุ่มตัวอย่างในประเทศไทย อีกทั้งผลการวิจัยนี้ยังสามารถยืนยันได้ว่าความสัมพันธ์ของความสามารถในการผลิตโดยเฉพาะอุตสาหกรรมรถยนต์ในประเทศไทยเป็นไปในรูปแบบโมเดลเสริมกัน

**คำสำคัญ:** ความสามารถด้านการผลิต อุตสาหกรรมรถยนต์

## Introduction

In today's business, creating new forms of competitive capability has become a main concern for management, as the business environment continues to change rapidly and unpredictably. Based on this challenge, an effective manufacturing strategy must take into account the capabilities of the firms over their competitors. In practice, competitive capability is usually reflected in its superiority in production resources and performance outcomes (Day and Wensley, 1988). These competitive capabilities must also be first identified and evaluated in order to achieve a firm's strategic goals. In relation to operations management, Skinner (1985) stated that certain manufacturing capabilities, such as cost, quality, and time, can be used as competitive weapons. Based on the work of Skinner, many scholars have suggested that the relationship between manufacturing capabilities is an important element of operations strategy formation (Ferdows and Meyer, 1990).

However, there is still a lack of comprehension and empirical evidence in justifying the precise relationships between different elements in competitive capability. Unfortunately, various previous studies of these relationships have yielded different results (Größler and Grübner, 2006; Flynn and Flynn, 2004; Koufteros et al., 2002; and White, 1996). For example, Corbett and Van Wassenhove (1993), and Größler and Grübner (2006), suggest that the priority of competitive capability could be different, including quality, delivery, cost, flexibility (Schmenner and Swink, 1998); and quality, delivery (dependability), flexibility, cost (Swink and Way, 1995).

In terms of the competitive capability model, there is also a contradiction between the results found by Flynn and Flynn (2004) and Größler and Grübner (2006). Größler and Grübner's (2006) results support the cumulative aspects (sand-cone model) of manufacturing capabilities, while another study conducted by Flynn and Flynn (2004) did not find support for this model (including an earlier study by Ferdows and Meyer (1990), who proposed the sand-cone model). According to Rosenzweig et al. (2003), an explanation of this argument might be the environmental factors such as country, product/industry maturity, and firm size that could favor or necessitate the manufacturing capabilities model. For

example, a study by Noble (1995) shows those European factories come closest to the cumulative model (sand-cone model). Differences in cultural perspectives have been offered as one of the reasons for obtaining different results. Factories in some countries may be more inclined to pursue a certain model of manufacturing capability. Flynn and Flynn (2004) have suggested further study of these differences. Thus, this study, using empirical data from an Asian context (Thai automotive industry), is more of a supplement to previous studies than a replication. This study provides empirical evidence for the relationships between competitive capabilities, similar to the previous study by Größler and Grübner (2006).

This paper contributes to the field of operations management by exploring an understanding of the relationships between these four competitive capabilities. The theoretical foundation of this paper employs a model similar to the one suggested by Ferdows and Meyer (1990) and Größler and Grübner (2006). This model is tested empirically. Another aim of this paper is to quantify the strength of the relationships between competitive capabilities for a survey from Thailand.

## **Theoretical Background**

In this section, the literature on the definitions and model of competitive capability is reviewed. In addition, special emphasis is placed on research findings concerning the nature of the relationships between manufacturing capabilities.

Intense global competition and dynamic markets are creating a complex and uncertain environment. These changes are causing customers to expect new, high-value, and high quality products and services. In order to remain competitive, a firm should focus on manufacturing capabilities that have an external-customer orientation and manifest the relative strength of the firm against its competitors (Koufteros et al., 2002). According to Porter (1980), competitive capability is the extent to which an organization is able to create a defensible position over its competitors. Moreover, Hayes and Pisano (1996) suggest that capabilities are activities that a firm can do better than its competitors. Flynn and Flynn (2004) point out that the selection of manufacturing capabilities should be a reflection of strategic business objectives and should be expressed

in terms of primary manufacturing tasks or order-winning attributes.

Various studies have suggested many different dimensions of manufacturing capabilities (White, 1996). For instance, Wood et al. (1990) examined the dimensions of manufacturing capabilities that focus on the following capabilities: low price, high product performance, high durability, high product reliability, short delivery time, delivery on due date, product customization, number of features, product cost, conformance to design specifications, improved manufacturing quality, cost, on-time delivery, product cost, quality consistency, quality perceived by customer, and product price. Likewise, Vickery et al. (1993) suggest a list of production competence characteristics including product flexibility, volume flexibility, process flexibility, low product cost, delivery speed, delivery dependability, production lead time, product reliability, product durability, quality, competitive pricing, and low price. In these studies, several items are very similar and they offer opportunity for combination (White, 1996). For instance, production lead time can be categorized as a sub-dimension of delivery. Also, it seems reasonable to combine product cost, low price, and competitive pricing under the dimension of cost.

Particularly, the notion of manufacturing capability is well-established in the manufacturing/operations management literature. Being a part of the strategic objective, manufacturing strategy has an impact on the development of competitive capabilities (Vickery et al., 1997; Tracey et al., 1999). Driven by its business strategies, a firm sets competitive priorities and develops action plans. As action plans are implemented, manufacturing competencies are developed and these competencies allow a firm to build manufacturing capabilities that enable them to compete in the market (Koufteros et al., 2002). Corbett and van Wassenhove (1993) point out that competitive capability represents, to a great extent, product, place, and price dimensions. Product refers to the physical dimension, such as quality. Place includes delivery issues and the availability of products. Price refers to the amount a customer pays for the product or service. Additionally, they state that these measures of capabilities have their counterpart in terms of competencies in the sense that capabilities are outward looking while competencies are inward looking. As an example, the counterpart of price is cost.

Based on the literature review, consensus on the dimensions of manufacturing capability exists within the empirical literature. Hayes and Wheelwright (1984) have defined this term as price (cost), quality, delivery dependability, and flexibility. Similarly, Ferdows and De Meyer (1990) identified four dimensions: cost, quality, dependability, and flexibility.

### **Product Quality**

The attainment of quality in products and services had increasingly become a major focus in the 1980s (Holcomb, 1994). Flynn et al. (1995) point out that quality performance is significantly related to competitive advantage. Moreover, among competitive capabilities, quality has often been cited as the highest competitive priority and a means of competitive performance (Buzzel et al., 1987).

According to Koufteros et al. (2002), product quality is defined as the extent to which the manufacturing enterprise is capable of offering products that will fulfill customers' expectations. With a similar concept, Vickery et al. (1997) view product quality as the ability to manufacture a product whose operating characteristics meet performance standards. Product quality is also defined as fitness for use and includes product performance, reliability, and durability (Tracey et al., 1999).

Indeed, quality performance is difficult to define precisely (Flyne et al., 1995; White, 1996). Garvin (1987) has proposed the notion that product quality is actually a multidimensional construct with a list of eight critical dimensions: 1) performance (characteristics of product); 2) features (characteristics that supplement the basic functioning of the product); 3) reliabilities (the probability of the product malfunctioning or failing within a specified time period); 4) conformance (the degree to which the product's design and operating characteristics meet standards); 5) durability (the amount of use the customer gets from the product before replacement is preferable to continued repair); 6) serviceability (the speed, courtesy, competence and ease of repair); 7) aesthetics (individual preference for how the product looks, feels, sounds, and smells); and 8) perceived quality (image, brand name and advertising that make inferences about quality).

Product quality may be measured according to two different definitions: 1) the manufacturing-based definition, or quality of conformance, and 2) the product-based definition, or quality of design (Maani and Sluti, 1990). Safizadeh et al. (1996) empirically measured quality by measuring four variables. Two of the four variables (product performance, number of features on the product) deal with quality level and the physical aspects of product. The two variables make up the manufacturing-based definition. The other two variables, including quality consistency and customer perception of quality, relate to the ability to conform to specifications, or the product-based definition. Flynn et al. (1994) further suggest that it is difficult to measure precisely the dimensions of the quality construct in an objective fashion. They propose that perceived quality market outcomes focus on management's perception of the plant's product quality and customer service, relative to its competition.

### **Production cost**

Competing in the marketplace requires low-cost production. Specifically, inventories have been the focus of cost reduction for manufacturers and are one of the justifications for the just-in-time (JIT) system. In order to keep manufacturing competitive, firms also have to emphasize materials, labor, overhead, and other costs (Li, 2000). Noble (1997) suggests that cost-efficiency is associated with low-cost product, low work-in-process inventories, production flow, reduction overhead, and so forth. Swink and Hegarty (1998) focus on production and transfer cost, and define them as the cost to a manufacturer to make and deliver the product, including the cost to return or replace the item if necessary. Moreover, cost capability can emphasize reducing production costs, reducing inventory, increasing equipment utilization, and increasing capacity utilization (Ward and Duray, 2000).

### **Production Flexibility**

An increasing number of manufacturing managers recognize that achieving low cost and high quality is no longer enough to improve or sustain their firms' competitive advantages. The ability to respond quickly and profitably to the customer and to market demand is critical for success in business. Flexibility has



received much attention from both research and managers as a source of competitive advantage. Gupta and Somers (1996) found an interrelationship between production flexibility and organizational performance based on the empirical study of manufacturing firms. The result indicated that production flexibility contributed to organizational performance. In addition, Yusuf et al. (2003) suggest that having the ability to vary capacity, respond to rapid changes in demand, and mass customize at the cost of mass production is critical in today's business. Narasimhan and Das (1999) point out that there are four changes that have occurred in the competitive market environment: 1) rapid technological shift, 2) higher risk level, 3) increased globalization, and 4) greater customization pressures. These changes are causing an increase in the level of flexibility required by a company.

In general, extensive studies have defined the concept of flexibility. For example, flexibility is described as the ability of a manufacturing system to cope with environmental uncertainties (Narasimhan and Das, 1999). Flexibility is also considered to be the ability to respond to changes and to accommodate the unique needs of each customer. It can typically imply that the production operating system must be flexible in handling specific customer needs and changes in design.) In the narrow sense, Zhang et al. (2003) provide a definition of manufacturing flexibility as the ability of an organization to manage production resources and uncertainty to meet various customer requests.

Similar to quality, flexibility is recognized as a multi-dimensional construct. However, extensive reviews of manufacturing flexibility, such as operational flexibility, product and process flexibility, volume flexibility, and market flexibility, can be found in the study of Hyun and Ahn (1992), who in their review focus mostly on the taxonomies of flexibility. In an attempt to clarify, Upton (1994) has contended that according to the ambiguity of definition, flexibility can be categorized by three attributes: dimensions, time horizon, and elements. Consequently, the definition of flexibility can be extended and become practical for business.

Based on the previous discussion, this research study will concentrate on production flexibility (plant level flexibility). There is primary evidence that

production flexibility can be influenced by sourcing strategy and the amount or type of uncertainty that a firm needs to focus. For example, supplier responsiveness to uncertainties in demand and supplier involvement in production processes can enhance volume and modification flexibilities. In addition, sourcing strategy cannot contribute to operational flexibilities, which mainly depend on setup times or machine capacities and workers (Koste and Malhorta, 1999; Narasimhan and Das, 1999). In sum, it is reasonable to state that different levels and dimensions of flexibility are influenced by different strategies.

### **Delivery**

In recent years, even as cost and quality have become baselines by which competitiveness is measured, time and delivery performance have turned out to be increasingly important as a vital differentiator. Indeed, delivery performance has become the focal point of many firms' competitive strategies (Fawcett et al., 1997). Kumar and Sharman (1992) also point out that on-time delivery performance can reduce pretax profits by as much as 30 percent, depending on order size and the number of changes per order. In an attempt to explain the benefits of delivery time, there are three reasons why the strategic value of time can affect the firm's performance: 1) faster response time commands a price premium; 2) faster delivery of customized products attracts more customers and increases brand loyalty; and 3) accelerated pace of activities in production and logistics processes results in higher profitability.

By definition, time refers to the totality of time required to perform all activities on a critical path, which commences from the identification of a market need and ends with the delivery of a matching product to the customer (Kumar and Motwani, 1995). It has been pointed out that the definitions of time-based performance and delivery performance are somewhat different, and that these dimension should not be used interchangeably. In order to clarify this confusion, Kumar and Motwani (1995) suggest that delivery has somewhat narrower connotations than time, since it includes only the post-manufacturing segment of the critical path.

Delivery is defined as competition on the basis of quick and reliable deliveries (Nobel, 1997). When considering the dimensions of delivery performance, Li (2000) suggests that delivery is a time issue, and is usually defined in the following aspects: 1) how quickly a product is delivered, 2) how reliably the products are developed and brought to the market, and 3) the rate at which improvements in products and processes are made. Similarly, Wacker (1996) proposes that delivery has three meanings: 1) delivery reliability or delivery dependability, 2) speed of delivery for current products, and 3) new product delivery. However, recent conceptual work suggests that delivery performance should emphasize customer service, as indicated by delivery reliability and delivery speed (Ward and Duray, 2000). The delivery time for a new product should be discussed under innovation and new product design flexibility performance because a new product must be delivered within a short time span (Wacker, 1996).

By developing a measurement for delivery speed, Vickery et al. (1997) and Jayaram et al. (1999) define delivery speed as the ability to reduce the time frame between order taking and customer delivery. Nobel (1997) also measures delivery speed as the ability to delivery a product quickly or with a short lead time. Moreover, Milgate (2001) evaluates delivery speed by two factors: 1) the average actual time that elapses from the placement of an order until its shipment to the customer, and 2) the time to complete an order from the start of its production to its completion.

## **The Models of Manufacturing Capabilities**

After having reviewed the literature on operations strategy and manufacturing capabilities, two opposing concepts emerge: (1) the Trade-off model and (2) the Cumulative or Sand-cone model. First, the trade-off model argues that one manufacturing capability can only be improved at the expense of other capabilities (Skinner, 1974). For example, producing at a lower cost would only be possible with a decrease in quality. This is because a plant that is supposed to provide a high level of all capabilities will suffer from a high level of complexity and confusion (Skinner, 1985). As discussed from the cumulative

model perspective, modern manufacturing systems allow for improvement in more than one manufacturing capability, which in a general way states that improvement in certain capabilities can amplify certain other capabilities (Schmenner and Swink, 1998). From this perspective, the Sand-cone model suggested by Ferdows and DeMeyer (1990) provides a distinct approach to explaining the relationships among manufacturing capabilities. The capability to produce at a low cost could be supported by achieving good performance on other capabilities. Thus, depending on the competitive priority and the emphasis placed on the improvement of different capabilities, successful sequences of supportive strategic capabilities are so-called “performance improvement paths” (Hayes and Pisano, 1996).

### **Conceptual Framework and Hypotheses**

Based on the definitions shown in the previous section, a number of researchers have suggested that addressing capabilities in a particular sequence enables improvements to be made more easily in other capabilities (Ferdows and DeMeyer, 1990; Swink and Way, 1995; and Schmenner and Swink, 1998). In fact, manufacturing capabilities are layered upon each other. The best known sequence of manufacturing capabilities is the “cumulative model” or the “sand-cone model” (Ferdow and DeMeyer, 1990). Quality conformance is described as the base of the sand-cone. Delivery performance is build upon the quality foundation because products become more reliable and less time and cost is required for rework. Therefore, the following hypothesis has been developed:

H1: Increased product quality has a direct positive impact on delivery performance.

Built upon product quality and delivery is speed, then production flexibility and cost efficiency are achieved. It can be assumed that improvements in product quality performance serve as the base for all other capabilities. In line with the sand-cone model, the conceptual framework proposed in this study suggests that quality performance is the basis of other capabilities. Thus, the following hypotheses indicating the direct effects of product quality are tested:

H2: Increased product quality has a direct positive impact on production flexibility performance.

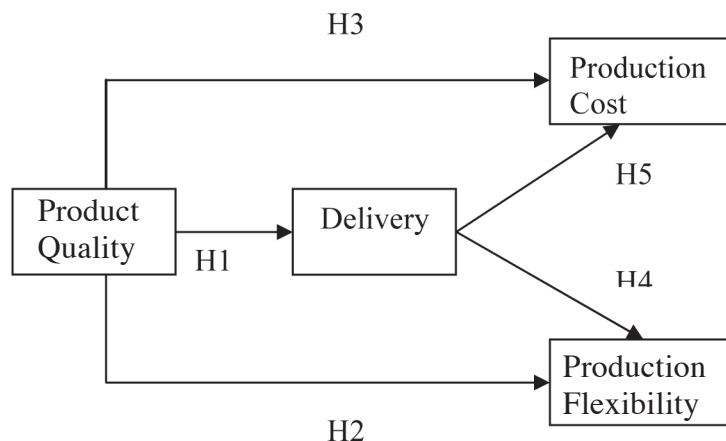
H3: Increased product quality has a direct positive impact on production cost performance.

The capabilities with regard to delivery are supposed to serve as the next level in the sand-cone model of cumulative manufacturing capabilities. As suggested by Sakakibara et al. (1997) and Funk (1995), manufacturing at high speed improves the flexibility of the operation because less time is required to respond to different influences or factors and to adjust to changed requirements. Furthermore, reducing times in the operations process helps in reducing costs through higher productivity and lower inventory costs. In addition, a relationship between delivery and cost has been found in the literature by Rondeau et al. (2000). Therefore, the following hypotheses have been developed:

H4: Improvements in delivery performance have a direct positive impact on production flexibility.

H5: Improvements in delivery performance have a direct positive impact on production cost.

**Figure 1:** shows the conceptual framework presented and incorporates the hypotheses stated above.



**Figure 1:** Conceptual Framework

## Methodology

### Sample and Data Collection

The automotive industry in Thailand was chosen as the target for this study because it has been a Thai industry leader in developing the competitive capability model (Narasimhan and Das, 1999). Moreover, by using a single industry, this study can ensure a high level of internal validity for testing the relationships between factors. The selection of respondents is crucial when designing a large-scale survey. The respondents in this study were expected to have detailed knowledge of the firm's competitive capability. Each respondent on a mailing list was asked to complete the questionnaire from the perspective of his or her primary on each dimension on competitive capability. In terms of the unit of analysis, this study was predominately conducted using a population at the plant level. Flynn et al. (1994) pointed out that most empirical research on operations management occurs at the corporation or individual level. The independent variables of supply chain management practices usually reflect corporate level practices. Similarly, the dependent variable of firm capability also reflects corporate level results.

A mailing list was obtained from two sources: (1) the Directory of the Society of Automotive Engineering of Thailand, and (2) the Thailand Automotive Industry Directory. The list was limited to automakers and first-tier suppliers in eight sectors of the automotive industry: (1) engine parts, (2) electrical parts, (3) drive transmission and steering parts, (4) suspension and brake parts, (5) body parts, (6) accessories, (7) molds and dies, and (8) other parts. Respondents were purchasing/material managers as well as CEOs, presidents, vice presidents, and directors. Potential respondents were contacted first by telephone to confirm the contact information for mail delivery. Surveys were sent to 724 respondents and follow-up telephone calls were made to the late responses at two-month intervals. The final number of complete and usable responses was 151, indicating a response rate of 20.85% (151/724). This is close to the recommended minimum of 20% for empirical studies in operations management (Malhotra and Grover, 1998).

## Non-Respondent Bias

The non-response bias was evaluated in two ways. First, early responses were compared with late responses (Armstrong and Overton, 1977). Although this method does not investigate non-response directly (Larson and Poist, 2004), a comparison was made between early and late responses. The  $\chi^2$  test results indicated no significant difference in any criterion with a significant level below 0.1 ( $\chi^2 = 8.156$  for number of employees,  $p = 0.158$ ;  $\chi^2 = 1.559$  for respondent's position,  $p = 0.919$ ;  $\chi^2 = 1.387$  for number of years in business,  $p = 0.943$ ; and  $\chi^2 = 6.052$  for plant ownership,  $p = 0.119$ ).

Second, another  $\chi^2$  test was applied to check whether there was any significant difference between respondents and non-respondents. We contacted non-respondents and asked them to return the questionnaires; they were considered as non-respondents. One demographic variable (e.g. their sector in the automotive industry) was tested. The result indicated no significant difference between the respondents and "non-respondents" ( $\chi^2 = 3.135$ ,  $p = 0.792$ ). Therefore, non-response bias did not appear to be a problem.

## Questionnaire and Measures

The survey instrument was developed in three stages. In the first stage, all the items from the literature review were identified and used to draft the questionnaire, along with questions where respondents were asked to provide demographic information relating to their firms. For most items, a five-point Likert scale, ranging from strongly disagrees to strongly agree, was used. An English version of the questionnaire was developed and tested to determine content validity. The second stage was to translate the questionnaire into Thai. A bilingual Thai native proofread the English version and noted ambiguities that could cause confusion in translation. Following these revisions, the questionnaire was translated into Thai and then reviewed by several Thai practitioners and academics with expertise in supply chain management in the automotive industry. This group was asked to examine the questionnaire for clarity and determine whether it conveyed the adequate meaning of each item. The comments primarily focused upon clarification of the instructions and refinement of item wording.

There were no major problems detected; minor modifications were made to the instructions and wording of some items.

In the final stage, the revised questionnaire was pre-tested on a small scale, using 21 potential respondents, in order to further assess its validity and overall readability. Although this survey size was not sufficient to perform any statistically significant tests, it did provide information necessary to the overall research. Comments offered by the respondents helped with question wording and with identifying how long the survey took to fill out. A final benefit provided by this survey was an estimation of the variability of the responses to the questions.

### **The Measurement Properties**

As suggested by Anderson and Gerbing (1988), this study adopted a two-stage approach to test the structural equation models. The first stage determined the adequacy of the measurement model. Restated, the measurement model was estimated separately before estimating the structural model. The structural equation model was constructed in the second stage. The focus of confirmatory factor analysis (CFA) is to assess measurement properties and to test a hypothesized structural model. A systematic process was used to determine whether items should be eliminated from the measurement considering weak loading, cross loading. Evaluation of the proposed model was made using structural equation model (SEM). All SEM analyses were run using the AMOS program. Table 2 presents the goodness of fit statistics for the hypothesized model. Multiple fit criteria were considered in order to rule out measurement biases. Based on Table 2, the fit indices considered are those most commonly recommended (Acceptable value) for this type of analysis (Bagozzi and Yi, 1998). For instance, the goodness-of-fit index (GFI) values are above 0.95, and the RMSEA value is below 0.06, suggesting a good fit between the implied covariance in the model and the observed covariance from the data. In this case, all the indices were within the recommendation range, suggesting that the model has a satisfactory model fit.



To assess reliability, one common measure of construct reliability is Cronbach's  $\alpha$ , which tests indicators on their general suitability to be represented by a single factor. There is no absolute threshold value for Cronbach's  $\alpha$ ; however, it is well established in the literature to assume construct reliability if a value is above 0.6 (Sakakibara et al., 1997). The factors in Table 3 show construct reliability that is above the limit.

**Table 2:** The goodness of fit statistics

Fit Statistic	Notation	Model value	Acceptable value
Chi-square to degree of freedom	$\chi^2/\text{d.f}$	1.13	$\leq 2.0$
Root mean square error of approximation	RMSEA	0.03	$\leq 0.06$
Root mean square residual	RMR	0.04	$\leq 0.05$
Goodness of fit index	GFI	0.96	$\geq 0.95$
Normed fit index	NFI	0.96	$\geq 0.95$
Comparative fit index	CFI	0.99	$\geq 0.95$
Incremental fit index	IFI	0.99	$\geq 0.95$

In order to perform a meaningful analysis of the causal model, the measures used need to display certain empirical properties of convergent validity, which illustrates the degree to which individual items measure the same underlying construct. To test convergent validity, researchers can evaluate whether the individual item's standardized coefficient from the measurement model is significant and greater than twice its standard error (Anderson and Gerbing, 1988). Table 3 shows that the coefficients for all items greatly exceed twice their standard error. In addition, coefficient for all variables are large and significant provides evidence of convergent validity.

**Table 3:** Measure model analysis

Factor and Scale items	Standardized Coefficient	Standard Error	t-value
<b>Product Quality</b> (Cronbach's $\alpha = 0.74$ )			
High performance products that meet customer needs	0.86	__a	__a
Produce consistent quality products with low defects	0.79	0.09	10.9*
Offer highly reliable products that meet customer needs	0.64	0.12	8.14*
High quality products that meet our customer needs	0.66	0.12	8.48*
<b>Delivery</b> (Cronbach's $\alpha = 0.89$ )			
Correct quantity with the right kind of products	0.76	__a	__a
Delivery products quickly or short lead-time	0.79	0.10	10.09*
Provide on-time delivery to our customers	0.76	0.12	9.45*
Provide reliable delivery to our customers	0.90	0.09	11.28*
Reduce customer order-taking time	0.67	0.12	8.23*
<b>Production Cost</b> (Cronbach's $\alpha = 0.68$ )			
Produce products at low costs	0.56	__a	__a
Produce products at low inventory costs	0.72	0.19	6.46*
Produce products at low overhead costs	0.86	0.20	6.73*
Offer price as low or lower than our competitors	0.51	0.19	5.01*
<b>Production Flexibility</b> (Cronbach's $\alpha = 0.77$ )			
Able to rapidly change production volume	0.56	__a	__a
Produce customized product features	0.63	0.19	5.06*
Produce broad product specifications within same facility	0.70	0.20	6.55*
The capability to make rapid product mix changes	0.80	0.25	5.97*

\* Significance at the  $p \leq 0.01$  level

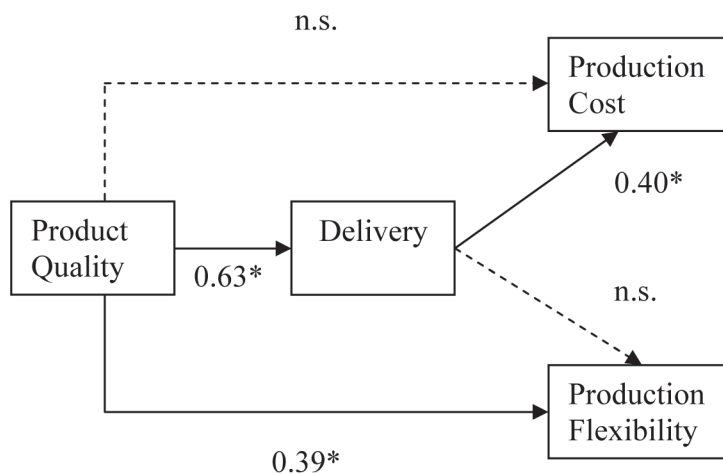
a Indicates a parameter fixed at 1.0 in the original solution

## Results

### Assessment of the Hypothesized Relationship

In order to test the hypothesized relationship, the Structural equation model (SEM) is a technique to specify and evaluate the models of linear relationships among variables (Shah and Goldstein, 2006). SEM allows for the

analysis of variables as causal factors in a structural equation system (Hershberger, 1994; and Kline, 1998). Before reporting on these relationships, some parameters have to be evaluated in order to assess overall model quality. Based on the results shown in Table 2, the overall model fit indices are acceptable (Hu and Plant, 2001). As shown in Figure 2, the standardized regression weights ( $r$ ) and  $p$ -value in the structural model between the manufacturing capabilities are presented. H1 is supported by the empirical data shown: that product quality is associated ( $r = 0.63$ ,  $p = 0.009$ ) with delivery performance. Along with H1, product quality is also found to be directly associated with production flexibility ( $r = 0.39$ ,  $p = 0.008$ ). Thus, H2 is supported. However, product quality is not directly related with production cost ( $r = 0.053$ ,  $p = 0.501$ ). Thus, H3 is not supported. H4 is also not supported because the parameter estimate is not significant, meaning that delivery performance is not directly associated with production flexibility ( $r = 0.078$ ,  $p = 0.323$ ). H5 is supported by the empirical data analyzed in this study. Delivery performance has a significant relationship ( $r = 0.40$ ,  $p = 0.010$ ) with production cost.



\* Significance at the  $p \leq 0.01$  level

**Figure 2:** Structural Model

## Discussion and Conclusion

Based on the path analysis shown above, there are no negative relationships indicating that cumulative capabilities exist within the Thai automotive context. The cumulative nature and supportive relationships among different competitive capabilities can be supported. According to the interpretation, our findings are consistent with the studies by Amoako-Gyampah and Meredith (2007), Größler and Grübner (2006), Flynn and Flynn (2004), and Ferdows and De Mayer (1990), who also found partial support for the structure of the cumulative model in their studies. In addition, in terms of cumulative capability, it explains that product quality has to be considered as the base capability that supports other capabilities. When a firm has a high quality product, it may provide better delivery to its customers. According to Phusavat and Kanchana (2007), manufacturers in the automotive industry in Thailand still emphasize quality management, especially quality control, to help develop superior product quality. In other words, an overall direction among Thai manufacturers is to use quality as a foundation for formulating other manufacturing strategies. The firms are therefore developing delivery performance and reducing production cost. However, product quality did not have a direct significant effect on production cost. This finding may be true because this study conceptualizes product quality as an external measure, not an internal measure, so that the effect of product quality on production cost may be negligible (Koufteros et al., 2002). This finding also complements the findings observed by Prajogo (2007). It is possible that the nature of the link between product quality and production cost, while holding the inverse links, solely emphasizing low cost production, will lead to firms producing poor quality. However, it seems that via delivery performance, product quality has a significant relationship with production cost.

In the study reported here, the relationship between delivery and production flexibility remains ambiguous. The path analysis in SEM does not support the original hypothesis. This result implies that the improvement in one of these capabilities has no significant effect on the other. Although this finding leads to the assumption that there is an exclusive relationship between both capabilities, in most cases delivery and production flexibility should have a direct

effect on each other. However, a question that needs clarification is whether plants that have only been successful in building up delivery performance have ever intended, or tried to improve, production flexibility at all and vice versa. Further research will be required to examine this issue and to discover efficient paths to strengthen the overall capability of the plant.

Although this study has similar objectives and similar methods as Größler and Grübner's study (2006), it still yielded some different results. The differences can be concluded in the following issues. First, our finding shows the insignificant relationship between delivery and production flexibility. This is also consistent with results from Korean factories, as suggested by Noble (1995). A possible explanation is that firms, especially 1<sup>st</sup> tier suppliers in the automotive industry, competing on the basis of delivery, carry a higher total inventory, leading to a larger inventory which may cause the firms in terms of inflexibility (Sarmiento et al., 2007). Indeed, there are differences in the database used that might bias the results in one direction. The data used in Größler and Grübner's study might slightly be biased in the sense that it contains data involving 17 countries from the International Manufacturing Strategy Survey (IMSS) database, and our study included only data from Thailand. However, their study found all positive relationships for the same model, while our study could not find all positive relationships. Therefore, our findings provide additional empirical evidence indicating that the model is not universal. There must be some other contingent factors affecting these relationships, and further research should focus more on these differences. Second, there are also differences in the manufacturing capability investigated. In our study, we focus specifically on product quality, production cost, and production flexibility. These differences are the result of slightly different definitions of capabilities. Generally, our study is not just a replication of the previous studies by Amoako-Gyampah and Meredith (2007), Größler and Grübner (2006), Flynn and Flynn (2004), and Ferdows and De Mayer (1990), but is more an addition to their papers so that the theoretical testing of the cumulative model in the Asian context could be extended.

This study could be furthered in several ways. First, future research can investigate each capability in different definition. For example, one must

understand the relationship between process flexibility and delivery. Second, future research can be done to investigate the impact of the fit between contingency factors, competitive capability, and the structure of the capability model. Finally, further study with a larger sample from different industries is required in order to gain more understanding of manufacturing capabilities.

As a practical implication, this study provides information for managers on what kinds of capabilities are mostly found in the automotive industry, especially in Thailand. From the strategic point of view, the benefits may lay a specific set of competitive capability and understand what competitors do in managing competitive capabilities to remain competitive in the highly competitive global marketplace.

## References

- Amoako-Gyampah, K. & Meredith, J.R. (2007). Examining cumulative capabilities in a developing economy. *International Journal of Operations and Production Management*, 27(9), 928-950.
- Anderson, J.C. & Gerbing, D.W. (1988). Structural equation modeling in practice: a review and recommendation two-step approach. *Psychological Bulletin*, 103 (3), 411-423.
- Armstrong, J.S. & Overton, T.S. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14, 396-402.
- Bagozzi, R.P. & Yi, Y. (1998). On the evaluation of structural equation models. *Academy of Management Science*, 6(1), 74-93.
- Buzzel, R.D. (1987). *The PIMS principles*. Free Press, NY.
- Corbett, C. & van Wassehnove, L. (1993). Trade-offs? What trade-offs? Competence and competitiveness in manufacturing strategy. *California Management Review*, Summer, 107-122.
- Day, S.G. & Wensley, R. (1988). Assessing advantage: A framework for diagnosing competitive superiority. *Journal of Marketing*, 52(2), 1-20.
- Fawcett, S.E., Calantone, R., & Smith, S.R. (1997). Delivery capability and firm performance in international operations. *International Journal of Production Economics*, 51, 191-204.

- Ferdows, K. & De Meyer, A. (1990). Lasting improvements in manufacturing performance of strategic group memberships and organizational performance. *Journal of Operations Management*. 9(2), 168-184.
- Flynn, B.B. & Flynn, E.J. (2004). An exploratory study of the nature of cumulative capabilities. *Journal of Operations Management*. 22, 439-457.
- Flynn, B.B., Sakakibara, S., Schroeder, R.G., & Bates, K.A. (1995). Relationship between JIT and TQM: practices and performance. *Academy of Management Journal*. 38(5), 1325-1360.
- Flynn, B.B., Schroeder, R.G., & Sakakibara. (1994). A framework for quality management practices on performance and competitive advantage. *Decision Science*. 26(5), 659-691.
- Funk, J.L. (1995). Just-in-time manufacturing and logistical complexity: a contingency model. *International Journal of Operations and Production Management*. 15(5), 60-71.
- Garvin, D. (1987). Competing on the eight dimensions of quality. *Harvard Business Review*. 65(6), 101-109.
- Größler, A. & Grübner, A. (2006). An empirical model of the relationships between manufacturing capabilities. *International Journal of Operations and Production Management*. 26(5), 458-485.
- Gupta, Y. & Somers, T. (1996). Business strategy, manufacturing flexibility, and organizational performance relationships: a path analysis approach. *Production and Operations Management*. 5(3), 204-233.
- Hayes, R. & Pisano, G.P. (1996). Manufacturing strategy: at the intersection of two paradigm shifts. *Production and Operations Management*, 5(1), 25-41.
- Hayes, R. & Wheelwright, S. (1984), *Restoring our competitive edge*, John Wiley & Son, New York, NY.
- Hershberger, S.L. (1994). *The specification of equivalent models before the collection of data*. in: von Eye, A., Clogg, C.C. (Eds.), *Latent variables analysis*. Sage Publication, Thousand Oak, CA.
- Holcomb, M.C. (1994). Customer service measurement: a methodology for increasing customer value through utilization of the Taguchi strategy," *Journal of Business Logistics*, 15(1), 29-52.

- Hu, Q. & Plant, R.T. (2001). An empirical study of the causal relationship between IT investment and firm performance. *Information Resources Management Journal*, 14(3), 15-26.
- Hyun, J. & Ahn, B. (1992). A unifying framework for manufacturing flexibility. *Manufacturing Review*, December, 251-260.
- Jayaram, J., Vickery, S.K. & Droge, C. (1999). An empirical study of the time-based competition in the North American automotive supplier industry. *International Journal of Operations and Production Management*, 19(10), 1010-1033.
- Kline, R.B. (1998). *Principle and Practices of Structural Equation Modeling*. The Guildford Press, New York.
- Koste, L.L. & Malhotra, M.K. (1999). A theoretical framework for analyzing the dimensions of manufacturing flexibility. *Journal of Operations Management*, 18, 75-93.
- Koufteros, X.A., Vonderembsa, M.A., & Doll, W.J. (2002). Examine the competitive capabilities of manufacturing firms. *Structural Equation Modeling*, 9(2). 256-282.
- Kumar, A. & Motwani, J. (1995). A methodology for assessing time-based competitive advantage of manufacturing firms. *International Journal of Operations and Production Management*, 15(2), 36-53.
- Kumar, A. & Sharman, G. (1992). We love your product, but where is it?. *Sloan Management Review*, Winter, 93-99.
- Larson, P.D. & Poist, R.F. (2004). Improving response rates to mail surveys: a research note. *Transportation Journal*, 42(4), 67-75.
- Li, L.L. (2000). Manufacturing capability development in a changing business environment. *Industrial Management and Data Systems*. 100(6), 261-270.
- Maani, I.E. & Sluti, D.G. (1990). A conformance-performance model: linking quality strategies to business units' performance. in J.E. Ettlie, M.C. Burstein and A. Fiegenbaum (Eds), *Manufacturing Strategy: the research agenda for the next decade*. Kluwer, Boston, MA.
- Malhotra, M.K. & Grover, V. (1998), An assessment of survey research in POM: from constructs to theory. *Journal of Operations Management*. 16(4), 407-425.



- Milgate, M. (2001). Antecedents of delivery performance: an international exploratory study of supply chain complexity. *Irish Marketing Review*. 13(2), 42-54.
- Narasimhan, R. & Das, A. (1999). An empirical investigation of the contribution of strategic sourcing to manufacturing flexibilities and performance. *Decision Science*. 30(3), 683-718.
- Noble, M.A. (1997). Manufacturing competitive priorities and productivity: an empirical study. *International Journal of Operations and Production Management*. 17(1), 85-99.
- Noble, M.A. (1995). Manufacturing strategy: Testing the cumulative model in a multiple country context. *Decision Sciences*. 26(5), 693-721.
- Phusavat, K. & Kanchana, R. (2007). Competitive priorities of manufacturing firms in Thailand. *Industrial Management and Data Systems*. 107(7), 979-996.
- Porter, M.E. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, New York: Free Press.
- Prajago, D.I. (2007). The relationship between competitive strategies and product quality. *Industrial Management and Data Systems*. 107(1), 69-83.
- Rondeau, P.J., Vonderembsa, M.A., & Ragu-Nathan, T.S. (2000). Exploring work system practices for time-based manufacturers. *Journal of Operations Management*. 18, 509-529.
- Rosenzweig, E.D., Roth, A.V., & Dean, J.W. (2003). The influence of an integrative strategy on competitive capabilities and business performance: An exploratory study of consumer products manufacturers. *Journal of Operations Management*. 21, 437-456.
- Safizdeh, M.H., Ritzman, L.P., Sharma, D., & Wood, C. (1996). An empirical analysis of the product-process matrix. *Management Science*. 42(11), 1576-1591.
- Sakakibara, S., Flynn, B.B., Schroeder, R.G., & Morris, W.T. (1997). The impact of just-in-time manufacturing and its infrastructure on manufacturing performance. *Management Science*. 43(9), 1246-1257.
- Sarmiento, R., Byrne, M., Contreras, L.R., & Rich, N. (2007). Delivery reliability manufacturing capabilities and new models of manufacturing efficiency. *Journal of Manufacturing Technology Management*. 18(4), 367-386.

- Schmenner, R.W. & Swink, M.L. (1998). On theory in operations management. *Journal of Operations Management*. 17(1), 97-113.
- Shah, R. & Goldstein, S.M. (2006). Use of structural equation modeling in operations management research: Looking back and forward. *Journal of Operations Management*. 24, 148-169.
- Skinner, W., (1974). The focused factory. *Harvard Business Review*. 52(3), 113-121.
- Skinner, W., (1985). *Manufacturing: The Formidable Competitive Weapon*, Wiley, New York, NY.
- Swink, M. & Hegarty, W.H. (1998). Core manufacturing capabilities and their links to product differentiation. *International Journal of Operations and Production Management*. 18(4), 374-396.
- Swink, M. & Way, M.H. (1995). Manufacturing strategy: propositions, current research, renewed directions. *International Journal of Production and Operations Management*. 15(7), 4-26.
- Tracey, M., Vonderembse, M.A., & Lim, J. (1999). Manufacturing technology and strategy formulation: keys to enhancing competitiveness and improving performance. *Journal of Operations Management*. 17, 411-428.
- Upton, D.M. (1994). The management of manufacturing flexibility. *California Management Review*. 36(2), 72-89.
- Vickery, S.K., Droge, C., & Markland, R.E (1993). Production competence and business strategy: do they affect business performance?. *Decision Sciences*. 24(2), 435-455.
- Vickery, S.K., Droge, C., & Markland, R.E. (1997). Dimensions of manufacturing strength in the furniture industry. *Journal of Operations Management*. 15, 317-330.
- Wacker, J.G. (1996). A theoretical model of manufacturing lead times and their relationship to a manufacturing goal hierarchy. *Decision Science*. 27(3), 483-517.
- Ward, P.T. & Duray, R. (2000). Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy. *Journal of Operations Management*, 18, 123-138.
- White, G.P. (1996). A meta-analysis model of manufacturing capabilities. *Journal of Operations Management*. 14, 315-331.

- Wood, C.H., Ritzman, L.P., & Sharman, D. (1990). Intended and achieved competitive advantage: measures, frequencies, and financial impact". in J.E. Ettlie, M.C. Burstein and A. Fiegenbaum (Eds), *Manufacturing Strategy: the research agenda for the next decade*. Kluwer, Boston, MA.
- Yusuf, Y.Y., Adeleye, E.O., & Sivayoganathan, K. (2003). Volume flexibility: the agile manufacturing conundrum. *Management Decision*. 41(7), 613-624.
- Zhang, Q., Vonderembse, M.A., & Lim, J. (2003). Manufacturing flexibility: defining and analyzing relationships among competence, capability, and customer satisfaction. *Journal of Operations Management*. 21, 173-191.