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Multidimensional of Manufacturing Technology, Organizational Characteristics, and Performance

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1. Introduction

Over the last ten years manufacturing technology use has been studied in several countries and a stream of findings has been coming in. The purpose of this study is to investigate manufacturing technology use in the Thai automotive industry, and to (1) examine findings concerning certain manufacturing technology dimensions, (2) investigate the relationships among manufacturing technology use, organizational characteristics (i.e. size, ownership and unionization), and performance, and (4) use the findings to shape a concept of multidimensional view of manufacturing technology. In the past, many studies have used data from the US, Australia, and other developed countries (Boyer *et, al*., 1997; Sohal, 1999; Dean *et, al*, 2000: Park, 2000). The findings from this study using data of the Thai automotive industry are a useful contribution to international applicability of manufacturing technology.

This chapter is organized into five sections. The next section summarizes the literature and theoretical background. Research methodology and data analysis incorporating sample selection, questionnaire design, and reliability and validity of measurement instruments is described in Section 3. Research findings and conclusion is presented in Section 4 and 5 respectively.

2. Literature Review and Theoretical Background

2.1 Technology dimensions

Certain classes of manufacturing technology are appropriate for particular competitive manufacturing strategy. For example, computer numerical control (CNC), computer-aided design (CAD), computer-aided manufacturing (CAM) or computer-aided engineering (CAE) are appropriate for a strategy seeking

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flexibility. Manufacturing technologies have been grouped and classified in several different ways, some based on the level of integration, or the nature of the technology. (Rosenthal, 1984; Warner, 1987; Adler, 1988; Paul and Suresh, 1991; Small and Chen, 1997).
Swamidass and Kotha (1998), in an empirical study, found that nineteen technologies used in manufacturing could be classified into four groups based on the volume and variety considerations of the production process. Their empirical results indicate that manufacturing technology could be classified into four groups:

1) *Information exchange and planning technology*
2) *Product design technology*
3) *High-volume automation technology* and
4) *Low-volume flexible automation technology*.

A notable conclusion of their study being that *High-volume automation technology* could be used to serve the low variety and high volume production strategy, while *Product design technology* and *Low-volume flexible automation technology* could be used to serve the high variety and low volume production strategy. The implication is that technology dimensions have far reaching consequences for the manner in which companies use them. This study decides to use the empirically-established dimensions of manufacturing technology reported by some previous studies, as described in section 3, to guide this study.

2.2 Manufacturing technology use and organizational characteristics

A number of previous studies have indicated that organizational characteristics (i.e., firm size, ownership, year in operation, sales volume, and labor union membership) have an influence on the adoption and implementation of manufacturing technology (Ettlie, 1984; Chen *et al*, 1996; Millen and Sohal, 1998; Schroder and Sohal, 1999; Swamidass and Winch, 2002). Summary of these findings are explained as follow:

2.2.1 Size

Manufacturing and operations management researchers have found that large companies show a higher degree of manufacturing technology implementation than small and medium companies (Paul and Suresh, 1991; Mansfield, 1993;

Sohal, 1999; Swamidass and Kotha 1998). This is attributed in the literature to the fact that large companies have superior technological know-how because of their access to more human, financial and information resources compared to small to medium companies. Researchers have come to agree that size is an important variable when it comes to manufacturing technology use. For example, Small and Yasin (1997) recommend that future research in management of manufacturing technology should adopt a contingency approach to find out how organizational variables such as firm size, industry structure, and planning approach influence the relationship between adoption of manufacturing technology and overall plant performance.

2.2.2 The nationality of plant ownership

Although a number of studies to investigate the relationship between organizational variables and technology use have been conducted in developed countries, such studies are not common in developing countries. Peter *et al,* (1999) state that the nationality of ownership of companies reflects the differences in management practice in manufacturing technology implementation due to differences in national culture. Sohal (1994) reports a number of significant differences in manufacturing technology use (e.g. computer hardware, computer software, plant and equipment) and management effort (e.g. source of manufacturing technology information, financial appraisal techniques, training, and benefits) between Australia and the United Kingdom. Lefley and Sarkis (1997) studied appraisal/assessment of manufacturing technology capital projects in the USA and UK and found different degrees of success in manufacturing technology implementation. Kotha and Swamidass (1998) report a significant effect of the nationality of a company (Japan vs. USA) on manufacturing technology use.
Further, Schroder and Sohal (1999) found that Australian-owned companies rate the anticipated benefits of increased throughput, sales, and investment in manufacturing technology more highly than foreign-owned companies from South Korea, Taiwan, Japan, USA, and New Zealand operating in Australia.

2.2.3 Unions

It has been widely suggested that effective implementing of manufacturing technology depends on the human factor or employees and their flexibility (Goldhar and Lei, 1994; Upton, 1995; Lefebvre *et al*, 1996). This often means that labor unions have to set aside their traditional work rules and job control strategies to allow team work and consultation (Osterman, 1994). Successful adoption of manufacturing technology also requires worker to attain new levels of operational skills and a higher level of commitment to improve product quality (Osterman, 1994). This can often be achieved through agreement with the union and management as in the case of Harley-Davidson Motor Company.

Chen *et al,* (1996) note that a company equipped with all the computerized or automated manufacturing technologies may be surprised to find that ultimate success is largely determined by the human factor. They also give the example of a plant, operated with the help of 300 robots, which had higher productivity and poorer quality performance than a more labor-intensive plant with a labor union.

Other major issue related to the adoption and implementation of manufacturing technology is employee commitment and cooperation (Krajewski and Ritzman, 1993; Chen and Gupta, 1993). Tchijov (1989) reports that plants with labor union membership exhibit the resistance to the adoption of manufacturing technologies. On the contrary, Dimnik and Richardson (1989) found that there was no relationship between union membership and adoption of manufacturing technology in a sample of auto-parts manufacturers in Canada.

Small and Yasin (2000) investigated human factors in the adoption and performance of manufacturing technology in unionized organizations. They found a union effect on the adoption of just-in-time production system only. For all other technologies investigated in their study, there was no significant union effect. Thus, given the above, there is no clear evidence of union effect on manufacturing technology use; it deserves more investigation.

2.3 Performance measures

Performance measures are multidimensional. Several researchers have investigated the relationship between manufacturing technology implementation and performance (Paul and Suresh, 1991; Chen and Small, 1994; Small and Yasin, 1997; Small, 1999; Swamidass and Kotha, 1998). This study classifies the wide range of performance measures in the literature into three groups:

(1) strategic measures
(2) organizational measures and
(3) business and market performance measures.

2.3.1 Strategic measures

Researchers suggest that the performance measures of manufacturing technology implementation should be strategically focused (Millen and Sohal, 1998; Sohal, 1999; Efstathiades *et al*, 2000; Sun, 2000). These measures include many dimensions including quality and flexibility.

Quality has surfaced in many performance measures. For example, Dimnik and Richardson (1989) note that the key performance measures in evaluating manufacturing technology in the automotive industry in Canada are cost, quality and flexibility. Other researchers recommend other two dimensions while investigating the auto industry; product quality, and service quality comprising both pre- and after-sale service (Curkovic *et al*, 2000). In the literature this study find that quality performance measure may incorporate percent defective, rejection rate, customer complaints, and product accuracy (Paul and Suresh, 1991; Laosirihongthong and Paul, 2000).

Flexibility is an important component of performance especially in the automotive industry (Zairi, 1992; Zammuto & O'Connor, 1992; Sohal, 1994; Boyer, 1996). Small and Chen (1997) define flexibility as the ability to respond quickly to changing customer needs. They also classify manufacturing flexibility into two dimensions, "time-based flexibility" which focuses on the speed of response to customer needs, and "range-based flexibility" which is concerned with the ability to meet varying customization and volume requirements in a cost-effective manner. In addition, time-based performance of automotive suppliers is critical, and manufacturing lead-time is especially critical in this industry (Jayaram et al, 1999).

2.3.2 Organizational performance

The specific measures of organizational performance include the degree to which manufacturing technology have improved work standard, skills of employees, image of the company, and coordination and communication within the company (Millen and Sohal, 1998; Sun, 2000; Efstahiades *et al*, 2000). Organizational measures are related to workflow, work standardization, communication, and management control (Dean et al, 2000).

2.3.3 Business and market performance

A third set of measures is reported by Small and Yasin (1997), who suggest that business and market performance measures could be tied to revenue from manufacturing operation, return on investment, overhead cost, time-to-market

for a new product, and market share of existing/new products. Some of these measures are financial performance measures. Swamidass and Kotha (1998) investigated the relationship between manufacturing technology use and financial performance. They found that the relationship is not significant, and conclude that perhaps strategic rather than financial benefits might have been the primary reason for investing in manufacturing technology. Therefore, this study did not use financial performance measure.
In summary, performance measures used in manufacturing and operations management researches while investigating manufacturing technology use are varied. However, there is a common understanding that there are three important but broad dimensions of performance measures -- quality, flexibility, and organizational measures. This study uses these three dimensions for performance measurement reflecting the successful for manufacturing technology implementation.

2.4 Guiding Research Question

The discussion of key variables and their relationships above provide the basis for the guiding research question of the study based on the three technology types and three performance dimensions discussed above:

Whether High-volume automation technologies, data-interchange technologies, and low-volume automation technologies, either individually or collectively affect one or more of the performance measures, which are quality performance, flexibility and organizational performance.

3. Research Methodology and Data Analysis

3.1 Sample and data collection

This study selected only companies who are listed with Thailand Industrial Standard Institute and Thai Automotive Institute. The companies surveyed in this study all produce products classified in the automobile and parts/components industry sector. Questionnaire used in this study consists of three parts: the degree of manufacturing technology use, perceived manufacturing technology benefits/performances, and organizational characteristics. It includes fifteen manufacturing technology (Boyer et al., 1997; Burgess and

Gules, 1998; Efstahiades et al., 2000; Boyer and Pagell, 2000; Efstathiades et al., 2002), thirteen perceived performance measures (Small and Yasin, 1997; Park, 2000), and four organizational characteristics including size of the company (measured by a number of employees), type of ownership, and existence of labor union.

Characteristics	Description	%
Respondents	MD/VP/P	10.20
	Factory/Production Mgr.	37.80
	General Manager	14.50
	Engineering Mgr.	22.70
	QA/QC Mgr.	18.80
Company size (number of employees) [1]	Small to medium <= 200	58.40
	Large > 200	41.60
Ownership	Thai-owned	30.40
	Foreign-owned	14.30
	Joint-venture	55.30
Labor union	Labor union present	30.45
	No labor union	69.55
Main product classifications	Body parts	21.42
	Chassis parts	25.58
	Suspensions parts	12.25
	Electrical parts	8.20
	Accessories	11.45
	Trim parts	21.10
Existing quality management system	ISO/QS9000 certified	94.58
	None	5.42

Table 1. Characteristics of respondents [1] Size classification according to Ministry of Industry, Thailand

Totals of 480 questionnaires this study distributed to factory, general, engineering, and quality assurance managers who have a responsibility for manufacturing technology implementation in their own companies. Questionnaires were sent to the respondents by given directly (for return by mail) at the suppliers' monthly meeting of one Japanese assembler and one American assembler. One respondent per company was asked to indicate the degree of implementation for fifteen manufacturing technology and perceived performance after the implementation. The usage attributed to these technologies and performances was measured using Likert's five-point scale where 1 = not used or not satisfied and 5= extensively used or very satisfied. A total of 124 questionnaires were returned giving a response rate of 25.83 percent, comparable to the rates in previous such research (Sohal, 1996; Small and Chen, 1997). Table I exhibits the characteristics of respondents.

3.2 Non-Respondent Bias

A random sample of 30 companies from the 356 non-respondents was selected to compare the respondents with non-respondents. The following classificatory data this study are collected from the 30 non-respondents through the phone: (1) size (employment), (2) ownership, (3) ISO 9000 certification, and (4) unionization. All 30 non-respondents contacted by phone provided classificatory information requested by phone. In Table II, this study indicates the result of the comparison between responding and non-responding sample. The Chi-square values indicate that the two samples are statistically different. Major differences between respondents and non-respondents being that the sample of respondents have larger firms, foreign-owned firms, more ISO-certified firms, and more unionized forms.
If this study assume that the sample of 30 non-respondents is representative of all non-respondents, the findings of this study are pertinent to the 124 manufacturers who participated in this study.

Organizational characteristics	**Respondents**	**Non-respondents**	***Chi-sq.***	**Chi-Sq. table (.05 significance, 2-tail)***
Size =< 200 employees	72(58%)	12(40%)		4.89
Size > 200 employees	52(42%)	18(60%)	17.1	
Thai owned	37(30%)	6(20%)		7.57
Foreign owned	17(13.7%)	15(50%)		
Joint venture	70(56.3%)	9(30%)	52.8	
ISO/QS9000 certified	117(94.4%)	19(63.4%)		4.97
None	7(5.6%)	11(36.6%)	8.2	
Labor union present	37(30%)	10(33.4%)		5.14
No labor union	87(70%)	20(66.6%)	10.4	

Table 2. Comparison of Respondents with a Random Sample of Non-Respondents. * The Chi-squared values for size, ownership, ISO certification and union are all larger than the Chi-square table values for .05 significance (2-tail). Thus, the respondents are not similar to the random sample of non-respondents

Generalization of the findings to non-respondents must be done with care. Given that the sample of 124 firms participating in this study is substantial, the findings are valuable even if they are not representative of the entire Thai auto industry.

3.3 Data analysis

3.3.1 The reliability and validity of empirical measures

The internal consistency of our measures was verified using Cronbach's alpha (Cronbach, 1951); a value greater than 0.6 was treated acceptable (Chen and Small, 1994). Content validity was established from literature review, expert and practitioner opinions, and pre-testing with a small number of managers. Construct validity was ensured by factor identification through principal component factor analysis (Nunnally, 1967). Factors are selected using these three rules: (a) minimum Eigenvalue of 1, or cumulative factor variance explained in excess of 70 percent; (b) minimum factor loading of 0.4 for each item; and (c) the simplicity of factor structure. Factor analysis was used to find factors to explain dependent variables (performance measures) and independent variables (technology use). SPSS software was used to perform principal component analysis including an orthogonal transformation with Varimax rotation. The results are shown in Tables III (for technology factors) and VII (for performance factors).

In order to test the validity of perceptual performance measures, this study conducted a correlation analysis between selected objective external measures with self-reported perceptual data on performance for 20 per cent of the companies randomly selected (n = 30) from our sample of 124 respondents. Selected objective external measures were obtained from the Monthly Suppliers Evaluation Reports--MSER (Sriwatana, 2000; Vibulsilapa, 2000) concerning delivery, quality, cost, and organizational reputation. Correlation analysis between MSER data and survey data was conducted, specifically, the correlation analysis between MSER data and survey-based composite values of flexibility, quality performance, and organizational performance for a random sample of 30 companies. The resulting correlation coefficients are 0.77, 0.81, and 0.73 respectively. Therefore, this study considers the perceptual performance measures acceptable (Swamidass and Kotha, 1998; Lewis and Boyer, 2002).

4. Research Findings

4.1 Technology use (factors) confirm prior studies

Multi-item scales are developed for each construct (technology and performance) in this study. Before creating the final scales, the data are checked for normality and outliners. As shown in Table III and VII, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.887 (for technology factors) and 0.894 (for performance). A minimum Kaiser-Meyer-Olkin score of 0.5 is considered necessary to reliably use factor analysis for data analysis (Small, 1999). Score over 0.80 are considered very strong. Similarly, the Bartlett test of sphericity (the higher, the better) was 987.32 (technology factor) and 1322.t (performance) with significance value (Small, 1999).

The results of rotated principal component factor analysis show that three factors explain 63.25 per cent of the total variance (Table III). These technology factors are used in subsequent analysis to examine the relationships between technology use and organizational characteristics, as well as technology use and performance.

In Table III, the result indicates that seven technologies load on the first factor. This factor consists of technologies that can be used to reduce direct labor costs in repetitive operations and high-volume production with low variety of products. Therefore, the study names this factor as *"High-volume automation technologies."*

The second factor consists of five technologies that relate to planning and data interchange. Therefore, the study names this factor as "*Data-interchange technologies*," which parallels the "information exchange and planning technologies" reported by Swamidass and Kotha (1998) using US data. The third factor includes technologies that provide low-volume manufacturing flexibility that permits low-volume high variety production. This study, therefore, calls this factor, *"Low-volume flexible automation technologies."*

The three factors that emerged from data of the Thai automotive industry are similar to technology factors that determined from factor analysis of some previous studies.

Thus, it is important to note that manufacturing technology factors that were identified in this study are robust and are stable across time and national boundaries.

Technology Factors	Mean	S.D.	orsExtracted fact		
			1	2	3
High-volume automation technologies					
Automated material handling	2.15	1.21	0.774		
Automated assembly system	2.38	1.35	0.732		
Automated storage/retrieval system	1.74	1.02	0.715		
Automated inspection system	2.42	1.01	0.701		
Computer-aided manufacturing	3.15	1.04	0.554		
Barcode system	2.88	1.33	0.568		
Pick and place robots	2.04	1.41	0.520		
Average mean score	*2.39*				
Data interchange technologies					
Material resources planning	2.54	1.11		0.726	
cturing centerFlexible manufa	1.98	1.06		0.711	
Computer-aided process planning	2.22	1.21		0.702	
Computerized statistical process control	2.16	1.05		0.566	
Electronic data interchange	2.53	1.02		0.511	
Average mean score	*2.28*				
Low-volume flexible automation technologies					
Computer numerical control	3.88	1.44			0.818
Pneumatic and hydraulic equipment	3.72	1.32			0.735
Computer-aided design	3.25	1.51			0.598
Average mean score	*3.62*				
Kaiser-Meyer Olkin adequacy(KMO)			0.887		
ericityBartlett's test of sph			987.32		
Significance			0.00000		
Cronbach's Alpha			0.875	0.902	0.821
Eigenvalues			3.488	2.876	2.034
Varience explained			24.45	22.62	16.18
Total variance explained			24.45	47.04	63.25

Table 3. Technology Facts (Rotated Comonent Matrix). Note: 1 – Lowest, 5 - Highest

4.2 Technology factors and organizational characteristics

4.2.1 Size

In Table IV, this study compares the use of three different technology dimensions (factors) in large versus small/medium firms. The table shows that there is a significant difference between large and small-to-medium companies in the use of *High-volume automation technologies* (p=.025) and *Low-volume flexible automation technologies* (p=.002). There is no significant difference in the use of *Data-interchange technologies* (p=.103). *Data-interchange technologies* form the backbone of manufacturing systems now and these technologies have been around longer the other technologies. *The implication is that all manufacturers, regardless of size, equally depend on Data-interchange technologies.* One reason being, these technologies are easily implementable on PCs, which are affordable by even small manufacturers. For example, MRP and Electronic Data Interchange (EDI) (see Table III) that are included in this dimension could be implemented using ordinary PCs. *The findings reveal that plant size has differential effect on the various technology factors*.

Technology Factors	**Sig.**	*Small-to-medium* **Composite mean**	*Large* **Composite mean**
High-volume automation technologies	0.025*	2.87	2.74
Data-interchange technologies	0.103	2.01	2.23
Low-volume flexible automation technologies	0.002**	2.66	3.37

* Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level.

Table 4. Technology Factors and Size of Company. * (Employees <= 200 = small-to-medium; employees > 200 = large.)

4.2.2 Ownership

Table V reports the use of the three different dimensions of manufacturing technologies in Thai-owned, foreign-owned and jointly-owned firms. According to the table, the following is revealed:

- In foreign-owned plants, *High-volume automation technology* use is significantly higher than its use in either Thai-owned (p=.001) or joint-venture plants (p=.001).
- In Thai-owned plants, *Low-volume flexible automation technology* use is higher than the use of this technology in either joint ventures (p=.001) or foreign-owned (p=.001) plants. Apparently, Thai plants produce more low volume components.
- Plant ownership has no effect on *Data-interchange technologies.* In an earlier section, this study reported that plant size has no effect on *Data-interchange technology* use. Taken together with this finding, it is important to note that *Data-interchange technologies* are relatively more mature technologies, easily implementable without much capital or resources, and is immune to size and ownership.

Technology Factors		**Thai-owned**	**Joint-venture**	**Foreign-owned**
High-volume automation technologies	Mean score →	2.35	2.22	2.61
Significance of Joint venture and column	Joint venture	p=0.182 (ns)		
Significance of Foreign-owned and column	Foreign-owned	p=0.001***	p=0.001***	
Data-interchange technologies	Mean score →	2.53	2.72	2.45
Significance of Joint venture and column	Joint venture	p=0.225 (ns)		
Significance of Foreign-owned and column	Foreign-owned	p=0.743 (ns)	p=0.351 (ns)	
Low-volume flexible automation technologies	Mean score →	3.47	3.18	3.01
Significance of Joint venture and column	Joint venture	p=0.001***		
Significance of Foreign-owned and column	Foreign-owned	p=0.001***	p=0.423 (ns)	

Table 5. Technology Factors and Ownership. * Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level. ns = not significant

4.2.3 Unionization

Very few studies have investigated the effect of unionization on manufacturing technology use. Tchijov (1989)'s found that plants with labor union membership exhibit the resistance to adoption of new technologies. This study does not measure union membership of employees, if measures if the plant is unionized or not. As shown in Table VI, the use of *Data interchange technologies* is significantly higher (p=.013) in plants with labor unions, and the use of *High-volume automation technologies* is higher in non-union plants (p=.011). It is a notable finding that unionization does have an effect in the use of at least a certain technology.

Technology Factors	**Sig.**	**Labor union** Composite mean	**Non-union** Composite mean
High-volume automation technologies	p=0.011*	2.53	2.62
Data-interchange technologies	p=.013**	2.77	2.32
Low-volume flexible automation technologies	p=0.644	3.32	3.15

Table 6. Technology Factors and Labor Unionization. * Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level.

4.2.4 Performance measures

A principal component factor analysis is used to reduce and group the thirteen individual performance items in the survey into three performance factors, "*Flexibility performance*", "*Quality performance*", and "*Organizational performance*". The three performance factors together explain 71.55 percent of the total variance (Table VII).

4.3 Technology factors and performance

As a rule, this study finds that there is little association between technology use and performance factors (Table VIII), the one exception being *High-volume automation technology*, which is associated with *Quality Performance* (Pearson r =

0.236; p = 0.000). Three multiple regression models to estimate performance using technology use dimensions are reported in Table IV. According to the table, only quality performance is explained by one of the technology dimensions (*High-volume automation technologies).*
An inference from this study is that, for the auto industry, high-volume automation is an essential ingredient for quality. This inference may be limited to the auto industry because of the sample.

Performance measures	***Mean**	**S.D.**	**Extracted Factors**		
			1	**2**	**3**
Flexibility performance					
Delivery lead time	3.87	0.84	0.720		
Responsiveness to customer needs	3.65	0.78	0.815		
Production change overtime	3.42	0.92	0.736		
Set-up time	3.33	0.76	0.884		
Average mean score	*3.57*				
Quality performance					
Defective ratio along the process	3.66	0.88		0.833	
Rejection ratio within the process	3.47	0.91		0.784	
Customer complain	4.22	1.02		0.746	
Frequency of inspection	3.85	0.77		0.626	
Accuracy of product	4.01	0.98		0.689	
Average mean score	*3.84*				
Organizational performance					
Upgrading human skills	3.72	0.74			0.843
Company's image	3.88	0.83			0.744
Work standardization	4.21	0,98			0.832
Reducing bargaining of skilled labor	3.18	0.86			0.675
Average mean score	*3.75*				
Kaiser-Meyer Olkin adequacy(KMO)			0.894		
Bartlett's test of sphericity			1322.7		
Significance			0.00000		
Cronbach's Alpha			0.922	0.916	0.842
Eigenvalues			2.133	3.411	2.756
Varience explained			24.22	28.72	18.61
Total varience explained			24.22	52.94	71.55

Table 7. Performance Factors (Rotated Component Matrix
Note: 1 – Lowest, 5 – Highest

Technology Factors	***Flexibility***	***Quality***	***Organizational***
High-volume automation technologies	0.005 p = 0.843	0.236 p = 0.000***	0.054 p = 0.331
Data-interchange technologies	0.054 p = 0.466	0.082 p = 0.342	0.037 p = 0.693
High-flexible automation technologies	0.993 p = 0.215	0.051 p = 0.442	0.027 p = 0.578

Table 8. Correlation Analysis between Technology Factors and Performance Factors. * Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level

Technology Factors		***Small-to-medium***	***Large***
	Sig.	**Composite mean**	**Composite mean**
High-volume automation technologies	0.025*	2.87	2.74
Data-interchange technologies	0.103	2.01	2.23
Low-volume flexible automation technologies	0.002*	2.66	3.37

Table 9. Technology Factors and Size of Company* * Employees <= 200 = small-to-medium; employees > 200 = large. * Significant at 0.10 level. ** Significant at 0.05 level. *** Significant at 0.01 level.

5. Conclusions and Future Studies

The most notable theme here is that findings from this study confirm several findings reported in the literature based on data from other nations. First, the study concurs with previous studies that show the size of companies influences the use of manufacturing technology. The reasoning is now this study known; large companies can afford the higher cost of adopting these technologies. Also, managerial resources necessary in planning and implementing such technologies are available in larger companies (Ariss *et al*, 2000).
Second, this study found that technology use is a function of the nationality of the plant ownership. For example, finding indicates that *High-volume automation technologies* such as automated material handling, automated assembly

system and robots are more likely to be adopted in foreign-owned companies than in Thai-owned and joint-venture companies. Foreign-owned companies perhaps tend to adopt more technologies because of their superior financial, technical and managerial resources, technological capabilities, and abilities to transfer those technologies. Further, foreign-owned plants may replicate the use of technology in plants back home, which is invariably a more developed nation compared to Thailand. The findings concerning the effect of the nationality of ownership on technology use concurs with studies on technology implementation in Australia (Sohal *et al*, 1991), in the UK (Sohal, 1994), and the USA (Kotha and Swamidass, 1998).
Third, The multidimensional view of technology reported by Swamidass and Kotha (1998) using a US sample holds up this study in the sample of firms from Thai auto industry; further, the two samples are several years apart.

5.1 Some Directions for Future Studies

5.1.1 The need for more investigations of the unionization-technology link

A notable finding of this study is that the use of Data interchange technologies, at least, is significantly higher in plants with labor unions. Could it be that these technologies reduce the influence or soften the effect of unionization? Do they reduce the need for employees in functions affected by unionization? Is it possible that unions do not resist the adoption of Data-interchange technologies? The search for answering to these questions is a worthy line of investigation for the future.

5.1.2 A proposed concept of manufacturing technology use

This study, confirms the emerging multi-dimensional view of technology use with collected data in Thailand with a specific industry. Further, the multiple technology factors that this study found in Thailand are similar to those found in the USA. This is a testimony to the robustness of the technology factors, which transcend national borders. Additionally, in an earlier study by Swamidass and Kotha (1998), which reported the multiple dimensions of technology, the data came from a survey nearly 10 years earlier than the Thai survey reported here. Therefore, it appears that the technology dimensions/factors are stable across time.

In addition, this study confirms findings concerning the effect of plant size, and the nationality of ownership. Taken together, empirical research to this point encourages the following Theory of manufacturing technology use for testing and retesting in the future for its confirmation and establishment: “ *In the complex manufacturing environment made of people, technology and procedures, manufacturing technology is not homogenous but has consistently distinct dimensions. These technology dimensions are robust and exist across national boundaries and time. However, technology use is a function of plant size, and the nationality of plant ownership”.*

5.2 Limitations

While this study is based on responses from nearly 150 firms, our non-response bias test shows that the responding firms are larger, more foreign-owned, more ISO-certified, and more unionized, compared to non-respondents. In the future, a more representative sample may be investigated. Boyer et al (1997) found that companies benefit from manufacturing technology investments when there is adequate and matching investments in the infrastructure. This study did not investigate this aspect of technology use in more details. Therefore, this study would encourage studies that test the above concept in order to expand it to cover the role of infrastructure investments.

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