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AN EMPIRICAL ANALYSIS ON THE BENEFITS OF PRODUCTION INFORMATION SYSTEMS FOR JAPANESE MANUFACTURING COMPANIES

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ABSTRACT

We empirically analyzed the linkage from computer-based information technologies utilized for production activities to the perceived benefits of production information systems, further to the competitive performance of each manufacturing plant, after presenting our research framework and a series of hypotheses. A database used for the analysis includes forty-six manufacturing plants located in Japan from three industries (machinery, electrical & electronics, and automobile). Information technologies we took up include computer aided design (CAD), computer aided engineering (CAE), computer aided processes planning (CAPP), local area networks (LAN) linking design and engineering stations, computer or direct numerical control (CNC/DNC), flexible manufacturing systems (FMS), automated retrieval and storage, material requirement planning (MRP), just-in-time (JIT) software, simulation tools, statistical process control (SPC) software, database for quality information, and electronic data interchange (EDI) linkages among others. The benefits of production information systems were measured in terms of manufacturing cost reduction, decrease in inventories, quality improvement, lead time reduction, increase in flexibility to changing product mix and production volume, new product introduction time reduction and so on. We found that there were several information technologies which did not necessarily show the hypothesized effects, and there were considerable unexpected or secondary effects upon the benefits of production information systems. Furthermore, some important benefits of production information systems, particularly manufacturing cost reduction and increase in flexibility, didn't lead to the improvement in the corresponding competitive performance indexes.
Keywords: production information systems, information technology, empirical research

INTRODUCTION

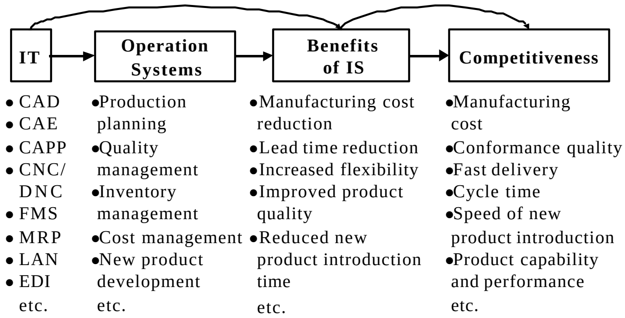
Most of the critical information flowing within plants has been quantitative: production volume, manufacturing cost, inventory turnover, percent defective, for example. Under the name of factory automation, numerical control techniques and computers were introduced into plants very early compared to other places in business enterprises, and production information systems have been implemented to support solving well-structured decision problems. There are numerous computer-based information technologies (ITs) or information system modules that have been used in the production function. They are computer aided design (CAD), computer aided engineering (CAE), computer aided processes planning (CAPP), computer or direct numerical control (CNC/DNC), computer aided manufacturing, flexible manufacturing systems (FMS), automated retrieval/storage, material requirements planning (MRP), JIT software, and statistical process control (SPC) software, to cite a few. More general are databases, local area networks (LAN) and electronic data interchange (EDI). These hardware and software have constituted main modules of the primary production information systems such as production planning and control system, quality management system, procurement/inventory control system, cost management system, new product development support system, and so on. [3] picked up famous examples of BPR from Ford's parts acquisition process and Kodak's new product development process. From a strategic perspective, information technologies are often seen as a source of the core competence suggested by [2].

The objective of this paper is to empirically examine the relationships among IT utilization, benefits of the aggregate production information systems and competitive performance by applying correlation and regression analyses to the plant survey data briefly mentioned below. A primary concern is whether IT utilization has ever produced the beneficial effects as expected. As [6][7] examined this research topic from comparative perspectives, in this paper we focus on the Japanese manufacturing plants where the most significant relationships was detected.

ANALYTICAL FRAMEWORK AND HYPOTHESES

To assess the real contribution of ITs and information system modules to competitive performance of manufacturing plants, we establish a simple analytical framework with four major characters: information technologies, production information systems, benefits of information systems, and competitiveness. The relationships among those characters are depicted in FIGURE 1.

FIGURE 1
Analytical Framework for Production Information Systems



Being incorporated into primary production information systems, ITs play roles as drivers to promote the purposes of the information systems. Hence, characteristics of those

ITs have been examined in light of the objectives of the primary production information systems, and possible benefits of each IT after implementation could be estimated. For example, CAD is supposed to have a significant impact upon the period of new product development; CAE seems to improve reliability of parts and finished goods as well as hasten the new product development process; CAPP has a main effect on the reduction in cycle time; and the effect of LAN could be widespread from the automatic control of machine tools and robotics through various flows of production information. On the other hand, each benefit of aggregate production information systems can be regarded as a composite of the effects generated from every IT implemented. Reduction in manufacturing cost could be attained through implementations of NC machine tools, FMS, JIT software, simulation tools, computer-based production equipment control, etc. In general, certain IT has multiple benefits and certain benefit of the aggregate production information systems has multiple sources. In this research we do not explore the complicated relationships between ITs and production information systems and between production information systems and their benefits one by one. Instead, we bypass the path from ITs directly to the benefits of the aggregate production information systems.

Furthermore, the benefits of production information systems should contribute to competitive advantage in some fashion. MRP II, simulation tools, and JIT software are often regarded as key parts for inventory management systems, whose objectives are to reduce inventory and manufacturing cost and to smooth the flow of materials and the delivery to customers. When the objectives are met by implementing appropriate ITs, the plant becomes globally competitive in cost and delivery dimensions.

As shown in the next section, this paper deals with eighteen information technology variables concerning CAD, CAE, CAPP, NC machine tools, FMS, computer-based production equipment control, automated retrieval/storage, MRP I and II, simulation tools, JIT software, SPC software, database for quality information, LAN, and EDI. We pick up twelve benefits of production information systems and eleven competitive performance indexes, corresponding to basic objectives in production operations; manufacturing cost, product quality, quick delivery, and flexibility (product-mix, production volume, and new product development).

Then, we propose the hypotheses on the relationship between implementation of ITs and benefits of the production information systems as follows:

(B1) CNC/DNC, FMS, MRP I, MRP II, JIT software and computer-based production equipment control reduce manufacturing cost.

(B2) Automated retrieval/storage, MRP I, MRP II and JIT software decrease inventories.

(B3) CAPP, LAN, FMS, automated retrieval/storage, computer-based production equipment control and electronic linkage/EDI reduce overall lead-time.

(B4) Automated retrieval/storage and electronic linkage/EDI improve on-time deliveries.

(B5) FMS, automated retrieval/storage, MRP I, MRP II and computer-based production equipment control increase product-mix flexibility.

(B6) Computer-based production equipment control increases product-volume flexibility.

(B7) CAD, CAE and electronic linkage reduce new product introduction time.

(B8) There are no ITs that directly improve customer service. Secondary effects of ITs could be, however, expected concerning lead-time and deliveries.

(B9) Electronic linkage increases the level of cooperation with customers.

(B10) Electronic linkage increases the level of cooperation with suppliers.

(B11) CAD, CAE and electronic linkage improve product differentiation.

(B12) CAE, CNC/DNC, FMS, SPC software and database for quality information improve product quality.

TABLE 1 illustrates the hypothesized effects of ITs on the aggregate production information systems, (B1) to (B12), as primary effects. It also includes some cells which secondary or indirect effects of ITs.

Similarly, we have the hypotheses on the relationship between the benefits of production information systems and the competitive performance indexes.

(P1) - (P12) The Benefits of production information systems contribute to the corresponding competitive performance indexes.

In the hypotheses (P1) to (P12), increased level of cooperation with customers contributes to fast delivery and increased level of cooperation with suppliers shortens cycle time among others.

It should be noted that competitive performance of the plant is influenced by a lot of factors other than computer-based information systems, although they are not shown in FIGURE 1 for simplicity. One such factor should be information systems based on human communication. More influential to competitiveness are manufacturing strategy, technology development, quality management, Just-in-time production systems, human resource management, organizational behavior, and so on. Therefore, we can only expect the modest relationship between the benefits of production information systems and the competitive performance indexes.

RESEARCH VARIABLES

Information Technology Variables (Independent Variables)

In order to operationalize the analytical framework and the hypotheses in the preceding section, we introduce some research variables as below.

The first cluster of variables is concerned with the level of implementation and utilization of ITs or modules of production information system. They are put together to constitute independent variables explaining benefits of the aggregate production information systems. A simple description of each variable is given as below.

TABLE 1
Hypotheses: Effects of Information Technologies on Production Information Systems

ITs \ Benefits of PIS	RMFC	DINV	OLTR	IOTD	IPMF	IPVF	RNPI	ICSV	ILCC	ILCS	IPDF	IPQL
CAD							P				P	
CAE							P				P	P
CAPP			P					S				
LAN			P					S				
CNC/DNC	P											P
FMS	P		P		P			S				P
Automated R/S		P	P	P	P			S				
MRP I	P	P			P							
MRP II	P	P			P							
JIT software	P	P										
SPC software												P
Equipment control	P		P		P	P		S				
Quality database												P
Orders received by EDI			P	P				S				
Orders sent by EDI			P	P				S				
Suppliers linked by EDI			P	P				S				
Units electronically linked			P	P			P	S	P	P	P	

P: primary effect S: secondary effect

CAD: Implementation of computer aided design
CAE: Implementation of computer aided engineering
CAPP: Implementation of computer aided processes planning
LAN: Introduction of local area networks linking design and engineering stations
CDNC: Implementation of machine tools with computer or direct numerical control
FMS: Implementation of flexible manufacturing systems
ATRS: Implementation of automated retrieval/storage systems
MRP1: Implementation of material requirements planning I (type one MRP)
MRP2: Implementation of material requirements planning II (closed-loop MRP)
JITS: Utilization of just-in-time software
SIMT: Utilization of simulation tools
SPCS: Utilization of statistical process control software
CPEC: Implementation of computer-based production equipment control
DBQI: Utilization of database for quality information
PCOR: Percentage of customer orders received via electronic data interchange (%)
PPOS: Percentage of purchase orders sent to suppliers by electronic data interchange (%)
PSPL: Percentage of suppliers linked to the plant via electronic data interchange (%)
PELL: Percentage of external units (including suppliers, distributors, company plants, banks, etc.) that were electronically linked with the plant (%)

The last four variables are measured in percentage, like 30, or 75, for the penetration level of EDI or electronic linkage. The others are dummy variables, taking only two values, 1, if implemented, or otherwise 0.

Benefits of Production Information Systems (Intermediate Variables)

The second set of variables deal with perceived benefits of the aggregate production information systems. They become dependent variables of the regression analysis on ITs and in turn affect competitive performance indexes. The maximum value of each variable is 5, if every respondent in the plant strongly agree that the benefit could be directly attributed to the implementation of ITs and IS modules in the plant, and the minimum is 1, if they strongly disagree that. We use the following twelve benefits of the production information system as critical intermediate variable:

RMFC: Reduction in manufacturing cost
DINV: Decrease in inventories
OLTR: Overall lead time reduction
IOTD: Improvement in on-time deliveries
IPMF: Increased product-mix flexibility
IPVF: Increased production-volume flexibility
RNPI: Reduced new product introduction time
ICSV: Improved customer service
ILCC: Increased level of cooperation with customers
ILCS: Increased level of cooperation with suppliers
IPDF: Improved product differentiation
IPQL: Improved product quality

Competitive Performance Indexes (Dependent Variables)

The third category of variables is concerned with competitive performance indexes of the manufacturing plant, relative to global competitors in the industry. They are subjectively judged by each plant manager on a five-point Likert scale so that they take discrete integer values from 1 to 5. The following eleven performance indexes include basic objectives in the production function, that is, cost, quality, delivery, and flexibility:

MFCT: Manufacturing cost
IVTO: Inventory turnover
FDEL: Fast delivery
DELP: Delivery performance
FCPM: Flexibility to change product mix
FCVL: Flexibility to change volume
SNPI: Speed of new product introduction
CMSS: Customer support/service
CLTM: Cycle time
PCPF: Product capability/performance
CFQL: Conformance quality

Measurement Scales of Information Systems (Auxiliary Variables)

The last set of variables consists of measurement scales for the utilization of production information in the manufacturing plant. Actual production information systems are based on not only computers and digital networks but also human communication, which jointly determine the competitive performance of the plant. We use the following four measurement scales in order to partly capture the sophistication level of comprehensive production information systems (see next section for more details):

PFEE: *Performance feedback*
ACCT: *Accounting*
DPFM: *Dynamic performance measures*
EXQI: *External quality information -supplier quality control-*

DATA COLLECTION METHODS

Data used for the subsequent analyses were gathered through an international joint research on high performance manufacturing (HPM), some of whose results are shown in [9]. They are concerned with some important aspects of manufacturing plants: environment, human resources, quality, JIT production, IS/ITs, technology development, manufacturing strategy, improvement and performance. We could acquire the data from 164 plants located in five countries: Germany, Italy, Japan, the United Kingdom and the United States. Japan accounts for 46 plants, Italy for 40, Germany for 33, USA for 30, and UK for 21. Among Japanese plants 32 plants are subjectively judged to be world-class and the rest is randomly sampled from machinery, electrical & electronics, and automobile manufacturers. In any plant twenty-six individuals across levels responded to fifteen types of questionnaires that partly share the same questions. The respondents included plant manager, plant superintendent, plant research coordinator, plant accountant, human resource manager, inventory/purchasing manager, information systems manager, production control manager, process engineer, quality manager, supervisors and direct labor. Plant-level data were calculated as an average value of all the valid responses at the plant for each quantitative question item and each scale.

In order to identify which ITs and information system modules had been utilized in the plant, the information systems manager was asked whether or not the plant had implemented CAD, CAE, CAPP, LAN, CNC/DNC, FMS, automated retrieval/storage, MRP I and II, just-in-time software, simulation tools, SPC software, computer-based production equipment control and database for quality information, as well as the percentage of suppliers linked to the plant via EDI and the percentage of external units that were electronically linked with the plant. The inventory/purchasing manager also answered the percentage of purchase orders sent to suppliers by means of EDI and the percentage of customer orders received via EDI.

Benefits of the aggregate production information systems for each plant were measured by averaging those scores which plant manager, plant superintendent and information systems manager subjectively evaluated in terms of twelve possible items. They assessed whether those benefits could be directly attributed to the implementation of ITs and information system modules in the plant on a five-point Likert scale (1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree). In the subsequent analysis we pick up the following twelve benefits of the information systems: reduction in manufacturing cost, decrease in inventories, overall lead-time reduction, improvement in on-time deliveries, increased product-mix flexibility, increased product-volume flexibility, reduced new product introduction time, improved customer service, increased level of cooperation with customers, increased level of cooperation with suppliers, improved product differentiation, and improved product quality.

In addition, we established measurement scales for the utilization of information systems including human-based communication systems. In this paper we take up four scales as follows: *Performance feedback* (responded by plant research coordinator, information systems manager and two supervisors), *Accounting* (responded by plant accountant, information systems manager and process engineer), *Dynamic performance measures* (responded by information systems manager and two supervisors), and *External quality information -supplier quality control* (responded by inventory/purchasing manager, quality manager and information systems manager). [8] pointed out that process accounting, assigning burden by lead-time and direct costing were important purposes of information systems, besides scheduling and tracking workflows, in world class manufacturing companies. Each measurement scale was constructed by five to seven question items evaluated on a five-point Likert scale (1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree). See an appendix at the last part of this paper for the question items. Reliability of those measurement scales was tested according to Cronbach's alpha coefficient, and construct validity was examined through factor analysis. [1] discussed the methodological issues on empirical research in operations management. [4][5] showed the details of measurement analysis for the Japanese plants.

Finally, competitive performance was subjectively judged by the plant manager in terms of the following eleven indexes: manufacturing cost, inventory turnover, fast delivery, delivery performance (on-time delivery), flexibility to change product mix, flexibility to change volume, speed of new product introduction, customer support/service, cycle time (from receipt of raw materials to shipment), product capability and performance, and conformance quality. Each plant manager was asked to indicate his/her opinion about how the plant compared to its competitors in the industry on a global basis on a five-point Likert scale (1=Poor or low end of the industry, 2=Below average, 3=Average, 4=Better than average, 5=Superior or top of the industry).

RESULTS OF ANALYSIS

IT Utilization and Benefits of Production Information Systems

We shall regress each benefit of the aggregate production information systems on IT variables for the sample of Japanese manufacturing plants. We start with a regression model including all IT variables as independent variables, and then continue to drop some independent variable to improve significance and fitness of the model. We can use the data for only nineteen Japanese plants whose IT utilization data appearing in the final runs are completely available.

TABLE 2A
Results of Stepwise Regression Analyses

	RMFC	DINV	OLTR	IOTD	IPMF	IPVF
Intercept	2.179201 (9.109)**	3.532766 (12.175)**	3.667000 (24.911)**	3.794971 (33.404)**	2.489811 (6.791)**	2.348547 (7.728)**
CAD	0.331054 (1.740)					
CAPP	0.303096 (2.275)*		0.786429 (2.107)*	0.547388 (1.963)*		
LAN			0.381571 (1.663)		0.461195 (1.920)*	
CDNC	0.243411 (2.301)*					
FMS					0.348742 (1.479)	0.304144 (2.006)*
ATRS					0.849748 (2.363)*	0.718507 (3.199)**
MRP1						0.347696 (2.270)*
MRP2	0.209417 (2.151)*					
JITS					0.550440 (2.020)*	
SPCS	0.284766 (3.136)**			0.298332 (1.686)		
CPEC	0.828896 (9.274)**					
DBQI		0.366179 (1.413)				0.288876 (1.892)*
PCOR		0.005447 (1.661)				0.003422 (1.983)*
PPOS	0.003311 (3.142)**					
PSPL				0.006189 (2.114)*		
PELL	0.002265 (2.003)*					
R^2	0.9578	0.2294	0.4119	0.5409	0.6289	0.7292
Adjusted R^2	0.9241	0.1331	0.3384	0.4491	0.5228	0.6251
F-value	28.376**	2.382	5.603*	5.891**	5.931**	7.002**

Values in the parentheses are t-values.
** significant at the 1% level by one-tailed test * significant at the 5% level by one-tailed test

TABLE 2B
Results of Stepwise Regression Analyses

	RNPI	ICSV	ILCC	ILCS	IPDF	IPQL
Intercept	-0.163616 (-0.246)	0.681441 (0.997)	0.605680 (1.288)	2.498129 (5.576)**	-0.584632 (-0.696)	1.767615 (5.433)**
CAD	0.571212 (1.322)	1.022662 (2.441)*	1.225392 (3.312)**		1.806741 (3.265)**	
FMS			0.700880 (4.077)**			
ATRS	2.163389 (6.896)**	0.857662 (2.631)*		0.600631 (1.626)	1.863695 (4.652)**	1.320860 (4.948)**
MRP1	0.329041 (1.672)	0.703650 (3.634)**				
JITS	0.475647 (2.152)*		0.534217 (2.896)**	0.436511 (1.929)*	0.556091 (2.097)*	0.283001 (1.632)
CPEC		0.755407 (3.732)**		0.330334 (1.388)		
DBQI						0.600504 (3.812)**
PCOR			0.006238 (3.324)**			
PPOS	0.012076 (5.007)**	0.005069 (1.997)*	0.004944 (2.444)*	0.006267 (2.324)*	0.006716 (2.201)*	0.007986 (3.857)**
PSPL				0.005687 (1.594)		
PELL			0.009099 (4.308)**			
R^2	0.8255	0.7396	0.8563	0.6159	0.6465	0.7447
Adjusted R^2	0.7584	0.6394	0.7845	0.4682	0.5455	0.6718
F-value	12.298**	7.384**	11.919**	4.169*	6.401**	10.211**

Values in the parentheses are t-values.
** significant at the 1% level by one-tailed test * significant at the 5% level by one-tailed test

Results of the final runs are summarized in TABLE 2A and B. Hypothesized effects on the reduction in manufacturing cost are found significant of CNC/DNC, MRP II and computer-based production equipment control. FMS and JIT software, however, have no significant effects on the costs. On the other hand, unexpectedly, SPC software, EDI and electronic linkage contribute to the manufacturing cost reduction. The final run shows both the highest significance and the best fitness among twelve benefits.

Any hypothesized effects on the decrease in inventories are not shown, regarding automated retrieval/storage, MRP and JIT software. Although quality database and the percentage of customer orders received via EDI have marginally significant effects on inventory levels, the regression model explaining the inventory reduction is the poorest in significance and fitness.

We can find that CAPP has a significant effect and LAN has a marginal effect on the overall lead-time, while FMS, automated retrieval/storage, computer-based production equipment control, EDI and electronic linkage have no hypothesized effects.

The percentage of suppliers linked to the plant via EDI influences on-time deliveries, while automated retrieval/storage has no hypothesized effect on the delivery performance. Unexpectedly significant effects on the improvement in on-time deliveries are found in CAPP. Marginal effects are also found of SPC software.

Significant effects on the improved flexibility to change product-mix are found in automated retrieval/storage and marginally FMS. MRP and Computer-based production equipment have no significant effects on the product-mix flexibility. On the other hand, unexpected impacts on the product-mix flexibility are detected in LAN and JIT.

The result is contrary to the hypothesis that computer-based production equipment control improves the flexibility to change production-volume. Rather, there are some unexpected influences on the product-volume flexibility. They are FMS, automated retrieval/storage, MRP I, quality database, and the percentage of customer orders received via EDI.

We can find that upon the reduction in new product introduction time CAD has a marginally significant effect, but CAE has no such effect. Although the percentage of external units electronically linked with the plant has no hypothesized impact on the new product introduction time, the percentage of purchase orders sent to suppliers by means of EDI has a highly significant effect. On this benefit there are many unexpected effects of ITs. They are automated retrieval/storage, JIT software and marginally MRP I.

Several secondary effects on the improvement in customer service are found in automated retrieval/storage, computer-based production equipment control, and the percentage of purchase orders sent to suppliers by means of EDI. While CAPP, LAN, FMS show no secondary effects for Japan, CAD and MRP are supposed to contribute to the improvement in customer service.

Hypothesized effect on the increase in the level of cooperation with customers is detected in the percentage of the external units that are electronically linked with the plant, along with the percentages of customer orders received and purchase orders sent by means of EDI. The other unexpected effects of ITs on the cooperation with customers are found in CAD, FMS and JIT software.

Upon the increase in the level of cooperation with suppliers, the percentage of purchase orders sent to suppliers by means of EDI has a significant effect and also the percentage of suppliers linked to the plant via EDI has a marginal impact, but the percentage of the external units that are electronically linked with the plant show no hypothesized effect. Unexpected effects on the cooperation with suppliers are found of just-in-time software and marginally automated retrieval/storage and computer-based production equipment control.

We can find that CAD shows highly significant impacts on the improvement in product differentiation, while CAE and the percentage of the external units that are electronically linked with the plant have no hypothesized effects. Unexpectedly automated retrieval/storage, just-in-time software and the percentage of purchase orders sent to suppliers by means of EDI improve the product differentiation.

Upon the improvement of product quality quality database shows a highly significant effect, but other hypothesized impacts of CAE, CNC/DNC, FMS and SPC software cannot be detected. Unexpected effects on the product quality are automated retrieval/storage, the percentage of purchase orders sent to suppliers by means of EDI, and marginally just-in-time software.

These results partially support the hypotheses (P1) to (P12). There are several ITs which do not show the hypothesized effects. For instance, CAE has no significant effect on new product introduction time and product quality; FMS and automated retrieval/storage neither shorten overall lead-time nor improve on-time deliveries. JIT software does not directly decrease inventories. On the other hand, there found many unexpected or secondary effects of IT utilization. LAN, EDI or electronic linkage has been recognized as a source of almost every benefit of production information systems. Some examples of the unexpected effects are CAD, FMS just-in-time software upon cooperation with customers, automated retrieval/storage upon product-volume flexibility and product quality, MRP upon customer service, and SPC software upon manufacturing costs.

Benefits of Production Information Systems and Competitive Performance

Next we shall examine the relationships between the benefits of production information systems and competitive performance indexes by using a simple correlation analysis. The results are shown at the upper part of TABLE 3. It has 132 cells, each corresponding to a pair of one benefit and one competitive performance index. Asterisks in the cells represent the level of significance for correlations between the benefits and the performance indexes. They are judged to support the hypotheses (P3), (P4), and (P8) through (P12). What is the most surprising is that reduction in manufacturing cost, decrease in inventories, reduced new product introduction time, improvement in product-mix flexibility and production-volume flexibility do not significantly correlate with the corresponding competitive performance indexes for the Japanese plants. At least for these areas, the benefits of production information systems do not necessarily connect with the improvement in competitive performance directly. Competitive performance depends on many factors other than computer-based information systems: for instance, human-based communication systems, human resource management, quality management, JIT production, technology development, manufacturing strategy and so forth. Production information systems are only one source of core competence.

Another puzzle is that the benefits of production information systems sometimes have multiple effects on the competitive performance indexes. One reason is that those competitive performance indexes are closely correlated. Another possible explanation can be given by the intermediary influence of comprehensive information systems based on both electronic and human communication. The lower part of TABLE 3 includes the correlation coefficients between the benefits of production information systems and four measurement scales concerning information systems in a broad sense. Most of the benefits of production information systems are significantly correlated with the measurement scales. Only exception is for the decrease in inventories. In addition, we could find that the benefits of production information systems are closely related with the measurement scales concerning human resource management, quality management, JIT production, and manufacturing strategy for the Japanese sample, as shown in [5]. This possibility should be explored further along with investigations into determining the competitive performance of manufacturing companies from global perspectives.

CONCLUSIONS

In this paper we made an analytical framework and hypotheses concerning the relationships among IT utilization, benefits of production information systems and competitive performance indexes, (B1) to (B12) and (P1) to (P12). Main results we can derive from the regression and correlation analyses applied for Japanese nineteen manufacturing plants are as follows:

a) The hypotheses concerning the relationships between IT utilization and benefits of production information systems, (B1) to (B12), are only partially supported. There are several ITs which do not necessarily show the hypothesized effects: CAE, FMS, automated retrieval/storage and JIT software.

TABLE 3
Correlation Analysis on the Benefits of Production Information Systems

Benefits of PIS	RMFC	DINV	OLTR	IOTD	IPMF	IPVF	RNPI	ICSV	ILCC	ILCS	IPDF	IPQL
(Competitiveness)												
MFCT				*	*					*		*
IVTO				*					*	**		*
FDEL	**	*	*	**				*	**	*		**
DELP	*			**		**						**
FCPM												
FCVL	*											
SNPI										*	*	*
CMSS								**			*	
CLTM		*	*	**	**	**			*	**		**
PCPF											*	
CFQL	*					*	*			**		*
(IS scales)												
PFEE	*		**	*		*	*		*	**	**	**
ACCT			*	**		*	*			*		*
DPFM	*		**	**	**	**	**		*	**	*	**
EXQI	**		**	**	**	**	*	**	**	**	**	**

** significant at the 1% level by two-tailed test * significant at the 5% level by two-tailed test

b) There are many unexpected effects of IT utilization. LAN, EDI or electronic linkage has been recognized as a source of almost every benefit of production information systems.
c) The benefits of production information systems do not necessarily connect with the improvement in competitive performance indexes, particularly manufacturing costs, inventory turnover and flexibility indexes.

REFERENCES

[1] Flynn, B. B., Sakakibara, S., Schroeder, R. G., Bates, K. A., and E.J. Flynn, E. J. "Empirical Research Methods in Operations Management," *Journal of Operations Management*, Vol. 9, No. 2, pp. 250-284, 1990.
[2] Hamel, G., and Prahalad, C. K. *Competing for the Future*, Harvard Business School Press, Boston, MA, 1994.
[3] Hammer, M., and Champy, J. *Reengineering the Corporation*, HarperBusiness, New York, NY, 1993.
[4] Matsui, Y. "Contribution of Manufacturing Department to Technology Development: An Empirical Analysis for Mechanical, Electric & Electronics, and Automobile Plants in Japan," in J. A. D. Machuca and T. Mandakovic (eds.), *POM Facing the New Millennium: Evaluating the past, leading with the present and planning the future of Operations, Selected Papers from the First World Conference on Production and Operations Management*, DEFDO, Seville, pp. 247-256, 2000.
[5] Matsui, Y. "Role of Information Systems in Manufacturing Firms: An Empirical Analysis for Machinery, Electrical & Electronics, and Automobile Plants in Japan," *Proceedings of the Thirtieth Annual Meeting of the Western Decision Science Institute* (*WDSI2001*), Vancouver, pp. 614-616, 2001.
[6] Matsui, Y. and Sato, O., "An International Comparison Study on the Benefits of Production Information Systems," in O. K. Gupta and R. Seethamraju, (eds.), *Information Technology and Operations Management: Relationships and Synergies*, *Proceedings of the Third International Conference on Operations and Quantitative Management*, Tata McGraw-Hill, New Delhi, pp. 156-166, 2000
[7] Matsui, Y. and O. Sato, "An Inter-industrial Comparison Study on the Benefits of Production Information Systems," *Proceedings of the Pacific Asia Conference on Information Systems* (*PACIS2001*), Seoul, Korea, pp. 197-211, 2001.
[8] Schonberger, R.J. *World Class Manufacturing: The Lessons of Simplicity Applied*, Free Press, New York, 1986.
[9] Schroeder, R. G., and Flynn, B. B. (eds.) *High Performance Manufacturing: Global Perspectives*, John Wiley & Sons, New York, 2001.

APPENDIX: MEASUREMENT SCALES ON INFORMATION SYSTEMS

Performance feedback intends to collect information on the kind of feedback used and who receives what. The question to the respondents is that
I receive the following information which helps me to adequately do my job:
1. Quality performance
2. Dependability performance3. Waste reduction
4. New product introduction
5. Financial performance
6. Cost variances
7. Cost of activities

Accounting measures whether or not the plant has adopted accounting systems based on activity and direct costing.
The question items are
1. Some burden/overhead costs have been converted to direct costs.
2. Our cost accounting system guides us to eliminate non-value added activities.
3. We use activity based costing.
4. We have good traceability of costs to their cost drivers.

Dynamic performance measures intends to assess the performance measurement system in terms of changing detail and object of measures and consider whether the feedback is timely. The question items are

1. The performance indicators which we use are strongly related to the planned objectives of the plant.
2. The performance indicators we use change whenever the planned objectives or programs are changed.
3. The detail of the performance indicators we use changes with the situation being addressed.
4. We receive performance measurement in time to perform improvement actions.
5. Our performance measures clearly show objectives and trends.

External quality information -supplier quality control- measures the availability and the easy use of external quality information regarding suppliers and tests the quality information exchange from suppliers to plant. The question items are

1. Data about quality of parts and components under purchasing consideration are at our disposal.
2. We can easily use data from tests (of quality) conducted by a supplier or by an independent laboratory.
3. We have a system for supplier certification.
4. We require evidence of statistical process control from suppliers of critical parts.
5. Our suppliers have to send us information (documents) certifying the results of specified tests and inspections on materials.