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The Influence of Production Management Practices and Systems on Business Performance: From the Perspective of the Push-pull Production Systems

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Abstract

This study develops a conceptual model: Customer Output Process Integrated System (COPIS) with hybrid push-pull strategy. We seek to investigate the performance and critical success factors of a Taiwanese enterprise. The COPIS conceptual model provides managerial insights to enterprises to achieve their objectives as well as to improve customer relationship. Through an appropriate process design, the Taiwanese enterprise is able to control critical factors and performance indices to maintain flexibility and robustness. Enterprises should design and plan their process based on the characteristic of the business, the processing design, the flow design and the load leveling system.

Keywords: *push-pull system, pull system, COPIS, production management*

1. Introduction

The rapid globalization and booming technology have resulted in a challenging business environment (Toffler, 1990; Behrsin et al., 1994). Under this circumstance, business flexibility and adaptability become increasingly important (Ciborra, 1993). In order to gain competitive advantage over their competitors, organisations must be flexible, creative and innovative to adapt and response to changing external environments (Wee et al, 2004). Specifically, markets driven by mass customization and e-commerce are forcing retailers and manufacturers to shorten their planning cycles, compress manufacturing lead times, and expedite distribution (Tyan et al., 2003). A competitive enterprise should have the ability to adapt better and faster to satisfy their customers (Childerhouse et al., 2002).

Enterprises must satisfy their customers by improving the speed of service, business flexibility and response capability. The push or pull production system is identified by the mechanisms for controlling material flow (Teeravaraprug and Stapholdecha, 2004). Push production system control strategies are based on forecasted customer demands. Its objective is to maximize the throughput of the system so as to minimize cost. On the other hand, pull production system control strategies are based on actual customer demands. They are considered to be reactive-oriented (Geraghty and Heavey, 2005). Hoverver, most production systems in practice may consist of both push and pull systems. A push/pull integration strategy is denoted by a hybrid production system (Hodgson and Wang, 1991a; 1991b). This means that some parts of the system are push while the others are pull.

The advantages and disadvantages of push and pull production systems have been discussed in literatures (Lee, 1989; Deleersnyder et al., 1992; Spearman and Zazanis, 1992). The production lead time and batch sizes affect the inventory undulations under a pull production system, while the degree of forecasting errors are the main concern in the push production system (Kimura and Terada, 1981). Furthermore, pull systems reduce inventory costs but do not respond well to unexpected changes in demand (Browne et al., 1988). The performance of pull systems and their variations are better suited for original equipment manufacturers (OEMs) (Spearman and Zazanis, 1992). MRP-type (Material requirements planning) push strategies have better performance in inventories and service for multi-product system (Krishnamurthy et al., 2004). Hybrid strategy decreases inventory over the Kanban policy while maintaining the same service levels (Bonvik et al., 1997). Recently, several studies have compared the performances of push, pull and hybrid system by simulation (Bonvik et al., 1997; Bonney et al., 1999; Corry and Kozan, 2004; Teeravaraprug and Stapholdecha, 2004; Geraghty and Heavey, 2005). They concluded that the hybrid production system outperforms both the push and the pull strategies. This study uses an empirical method to investigate the condition and critical success factors of production management system. We construct a conceptual model and a set of questionnaire to investigate and compare the process design and control mechanisms among push, pull and hybrid production systems.

2. Literature Review

Production management systems are classified into push production systems (such as Material Requirement Planning, MRP) and pull production systems (such as Lean Production System, LPS) (Deleersnyder et al., 1992; Spearman and Zazanis, 1992; Bonney et al., 1999). The distinction between push and pull system is on how production orders are released to work stations in response to demands (Krishnamurthy et al., 2004). The push method is initiated based on the estimates of future demand and is controlled by a master production schedule. Most of the traditional management systems belong to the push process (Teeravaraprug and Stapholdecha, 2004). The main concern in the push system is the forecast errors (Kimura and Terada, 1981). In contrast, the pull method is initiated in response to current demand. The Just in time (JIT) manufacturing philosophy and Kanban-control system of the pull systems have been studied and implemented by many companies and academia around the world since Sugimori wrote the first article by on the Toyota production system in 1977 (Ou and Jiang, 1997).

According to Fiegenbaum and Thomas (1990), time is the real resource that enterprises should carefully utilize. Any enterprises that can response faster than the others will maintain certain advantages over its competitors. George (1994) suggested that all processes should be driven by customer requirements. Suri (1998) claimed that pull policies produce distinct demands in small batches. Most manufacturing systems improvements emphasize on achieving Lean Production System (LPS) (Duggan, 1998). The enterprise with the lowest lead time and highest quality will be the most competitive one. Based on the quantity of each order and shrinking variance, the LPS (also called Toyota Production System, TPS) have improved the processes of many enterprises. The essence of LPS is to eliminate unnecessary stock through a pull manufacture process design and shortened the cycle time of manufacturing. This will enable an enterprise to respond quickly. Automation (Jidoka) and JIT are crucial for efficient LPS (Womack and Jones, 2003). LPS contributes to reduce inventory, space requirements and costs through JIT techniques, shortening process distances and the elimination of non-value-added activities (Heizer and Render, 2001). It will also shorten the throughput time of manufacturing. Pull production control strategies are based on actual customer demands at the end of the line; they are considered to be reactive-oriented (Geraghty and Heavey, 2005). LPS produces the right products in the right time (Miltenburg, 1989).

More practical system may consist of both the push and the pull systems, commonly called a hybrid production system (Hodgson and Wang, 1991a; 1991b). A hybrid system implies that some parts of the system are push strategy while the others are pull strategy. Each production system has advantages and disadvantages (Spearman and Zazanis, 1992). Therefore, this research integrates the MRP-type push production system and the LPS-type pull production system to construct a conceptual hybrid push-pull model. Base on the conceptual hybrid push-pull model, we construct a set of questionnaire to investigate and compare production management issues and control mechanisms in Taiwanese enterprises. This comparative analysis can help enterprises find critical success factors in production management and design for achieving their business objectives.

3. Conceptual Model

This study applies empirical research results to compare the different control mechanisms and performance ascent among pull, push and hybrid push-pull production systems. Our aim is to identify those key factors and critical success factors which can elevate business performance.

3.1 Conceptual Hybrid Push-pull Model

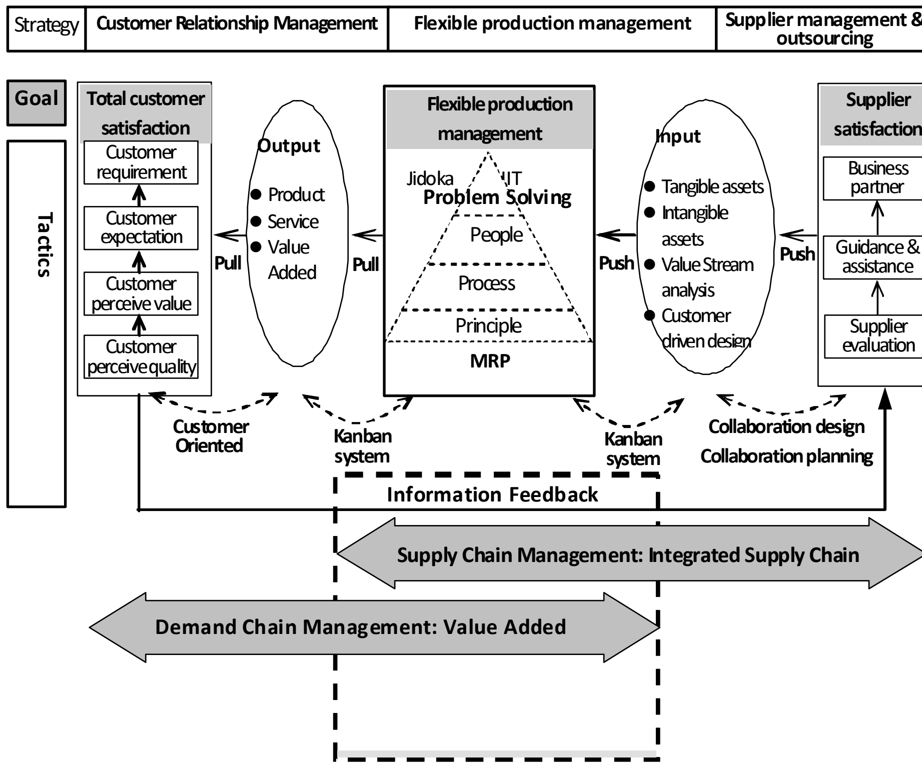
The hybrid production system outperforms both the push and the pull strategies (Corry and Kozan, 2004; Teeravaraprug and Stapholdecha, 2004; Geraghty and Heavey, 2005). This study integrates the "push" and "pull" production system to construct to construct a conceptual model of Hybrid push-pull COPIS (Customer Output Process Integrated System) as shown in Figure 1.

A successful company has five important asset categories including: physical assets, financial assets, employee & supplier assets, customer assets, and organization assets. Furthermore, employee & supplier assets, customer assets and organization assets play a crucial part in creating value for businesses (Libert et al., 2000). All processes should be driven by customer requirements (George, 1994). Thus the COPIS model aims at "Customer Relationship Management" (C) which starts at identifying customer perceived quality to fulfill customer requirements. The companies then focus on customer value to clarify customer expectations and requirements. All the enterprise activities output (O) are designed and driven by customer requirements to satisfy customers. Enterprises have to improve the value-added and the design processes of products and services efficiently. Therefore flexible capabilities and outsourcing are seen as an important element to accomplish this (Kremic et al., 2006). The flexible production management (P) of COPIS model integrates MRP-type push production system and LPS-type pull production system. It utilizes Jidoka and JIT. Positive changes in employee behaviors lead to positive results in customer satisfaction. What happens to employees inside the firm should affect what happens to customers outside the company (Hallowell et al., 1996; Chien et al., 2002).

The working conception of COPIS is integrating SCM & DCM through suitable integrated information systems (Integrated System; IS) that share information with suppliers in the production planning. A way to reduce uncertainty in supply chain is to collaborate with the suppliers (Van der Vorst et al., 2002). The major issues of SCM implementation are outsourcing, logistics, partnerships and environment (Varma et al., 2006). Collaboration and outsourcing have become a mega trend in SCM (Feeney et al., 2005) which focuses on joint planning, coordination and process integration between the suppliers and the customers. Suitable outsourcing decisions can result in lower costs and competitive advantage (Cross, 1995). Therefore the upstream issue of COPIS is "supplier management" which includes three issues: supplier evaluation, supplier guidance & assistance, and business partner. Enterprises should carefully analyze the customer oriented value chain and deploy tangible/ intangible assets to design the process.

The conceptual model of Hybrid push-pull COPIS is a customer oriented design which can help manager draw a conceptual outline. All activities in this model are triggered by customer requirement in the push-pull system. This conceptual model aims

Figure 1. The conceptual model of Hybrid push-pull COPIS



Phase	Customer (Performance Upgrading)	Output (Performance Upgrading)	Process (Implementation)	Input-Supplier (Implementation)
Performance Index	• Fulfilling customer need • Customer satisfaction • Customer complain	• Fulfilling customer need • Quality relative • Cost relative • Delivery relative • Flexible capability relative • Sales relative • Speed relative • Security relative • Employee complain relative	• Principle • Process • People & Partners • Problem Solving • Supplier Management • Production management systems & techniques	• Supplier satisfaction • Supplier capability • Supplier management system • Supplier guidance & assistance • Supplier evaluation

to integrate the supply chain and the value-added in order to optimize the process management. Through the COPIS conceptual model and performance indicators which are linked to specific processes or activities, the enterprise is able to control critical factors and performance indices to maintain flexibility within each process. The COPIS conceptual model will help enterprises to achieve their objectives as well as improving the customer relationship.

3.2 Methodology

Based on the conceptual model of Hybrid push-pull COPIS, we construct a set of questionnaire. The critical perspectives come from literatures' inference and the specifics are according to the process with the "4P" principle of TPS as well as 14 management principles (Liker, 2004). Then we consider the performance indicators for the critical perspectives by interviewing 10 senior managers who are responsible to the production or supplier management. Then, we draw some inferences and performance indicators to design the questionnaire. The questionnaire consists of three sections:

(1) Production management principle (six questions), process (thirty four questions), people & partners (twelve questions), problem solving (twenty six questions) and supplier management (fourteen questions).
(2) Performance upgrading (twenty three questions)
(3) Information of enterprises (eleven questions)

The study analyses 203 subjects to compare the implementation of the production management. The questions use the 5-point Likert-scale ranging from 1 = "extremely low" to 5 = "extremely high". We investigate the application and compare the differences among push, pull and hybrid push-pull production systems using the above questions.

3.3 Background of Participants and Reliability

This empirical research collected data from non-Toyota system enterprises thorough the helping of three Science Park Administrations locating in northern, central and southern Taiwan. We focused on semiconductors, aviation, precision machinery, optoelectronics, and conventional industries. We send questionnaires by mail, e-mail followed by phone calls and interview. A total number of 700 questionnaires were sent. A total of 238 questionnaires were returned (a response rate of 34%). Out of the received mails, 85.3% was valid (203 out of 238). As shown in Figure 2, a quarter of the enterprises surveyed are electrical & electronic industrial, 18% (36) are machinery & metal industrial and 15% (31) are semiconductor industrial. The range of their capital varies from less than 3 million to more than 1,500 million US dollars, 25.6% of the enterprises has a capital less than 3 million US dollars. The numbers of hired personnel also varies from less than 100 to more than 5,000 employees and 21.2% of them has 200 to 500 employees. For more details, please see Appendix A. Since the sample units include not only the prime industries but other classes of market capitalization as well, the bias is less likely to exist.

Figure 2. Sample sizes of different industrial groups

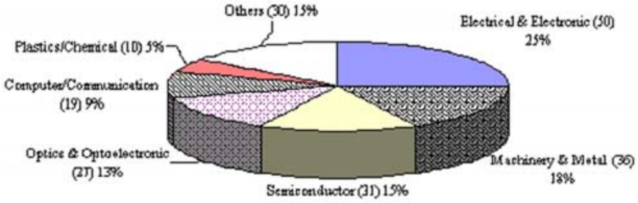


Table 1 shows the participants of different production system in different industrial groups. About 47.2% (17out of 36) of the machinery & metal industry applies hybrid push-pull production system and 33.3% (12 out of 36) of them applies pull production system (see Table 1). About 42.1% (8 out of 19) of the computer/communication industry applies hybrid push-pull or push production system, only 15.8% (3 out of 19) of them applies pull production system. The percentages of three type's production systems are approximated.

Cronbach's α coefficient is used to determine the consistency on the reliabilities analysis (Cronbach, 1951). Cuieford (1965) later applied Cronbach α coefficient to represent the reliability of instrument. A lower α coefficient means the survey doesn't have enough consistency. On the other hand, a higher α coefficient shows the information is consistent (Churchill, 1979). The value of Cronbach α should be greater than 0.7 (Cuieford, 1965; DeVellis, 1991). We calculate the Cronbach α coefficient in our study to check the consistency, correlation, homogeneous, and reliability of our questionnaires. The overall Cronbach±lies between 0.7853~0.9668 and therefore has acceptable reliability.

4. Comparison and Analysis of the Production Management

4.1 Implementation of Production Management

The implementation of production management was analyzed differently using a one-way analysis of variance (ANOVA) with the least-squares difference (LSD) method. All calculations and statistics were carried out using SPSS10.0.7C for Windows.

Table 1. Sample size of different production system in different industrial groups

Production System		Hybrid (n=72)	Pull (n=61)	Push (n=70)	Total
Electrical & Electronic	n	18	14	18	50
	%	36.0	28.0	36.0	100
Machinery & Metal	n	17	12	7	36
	%	47.2	33.3	19.4	100
Semiconductor	n	10	9	12	31
	%	32.3	29.0	38.7	100
Optics & Optoelectronic	n	8	8	11	27
	%	29.6	29.6	40.7	100
Computer/Communication	n	8	3	8	19
	%	42.1	15.8	42.1	100
Plastics/Chemical	n	3	4	3	10
	%	30.0	40.0	30.0	100
Others	n	8	11	11	30
	%	26.7	36.7	36.7	100
Total	**n**	**72**	**61**	**70**	**203**
	%	**35.5**	**30.0**	**34.5**	**100**

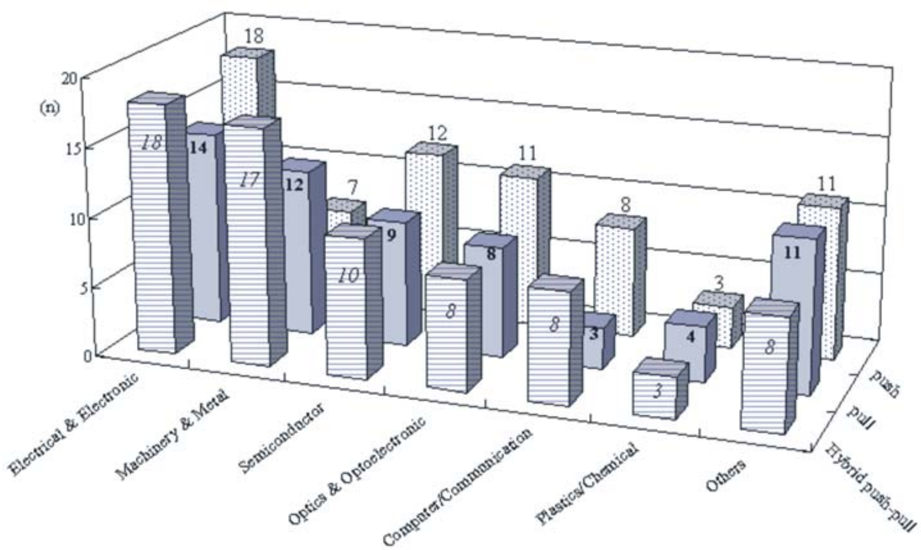


Table 2(a). Implementation ANOVA of production management

Construct Variable	Hybrid (n=72)		Pull (n=61)		Push (n=70)		F	P
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		
I. Production Management	3.947	0.462	3.989	0.515	3.813	0.505	2.339	0.099
(1) Principle	4.005	0.649	3.959	0.606	3.898	0.643	0.508	0.603
(2) Process	3.981	0.508	3.954	0.543	3.853	0.533	1.146	0.32
(3) People & partners	3.993	0.595	4.007	0.654	3.951	0.664	0.139	0.870
(4) Problem solving	3.862	0.600	3.996	0.567	3.707	0.640	3.734	**0.026***
(5) Supplier management	3.893	0.495	4.029	0.585	3.654	0.703	6.634	**0.002***

Table 2(b). LSD post-hoc test results of production management

Construct Variable	Problem Solving		Supplier Management	
	Hybrid	Pull	Hybrid	Pull
Push	0.129	(Push < Pull) p = 0.007*	(Push < Hybrid) p =0.000**	(Push < Pull) p = 0.019*
Pull	0.205	-	0.193	-

The production management has no significant differences (F=2.339; p=0.099) among push, pull and hybrid push-pull production systems. As for construct variables, significant differences have been found in the problem solving (F=3.734; p=0.026) and supplier management (F=6.634; p=0.002) as shown in Table 2(a). But there are no significant differences in principle (F=0.508; p=0.603), process (F=1.146; p=0.32) and people & partners (F=0.139; p=0.87). Table 2(b) shows LSD post-hoc test results of significant variables.

Significant differences have been found in the problem solving between "push" and "pull" production system (p=0.007), but no significant differences have been found between "hybrid" and "pull" production system (p=0.205). Those enterprises which apply a pull production system implement "problem solving" better than the enterprise applying push production system. This implies that pull production system will pay more attention to problem solving. Significant differences have been found in the supplier management between "hybrid" and "push" production system (p=0.000), as well as between "pull" and "push" production system (p=0.019). Those enterprises which apply a pull/ hybrid pull production system have higher administration of supplier management than with a push production system. But no significant differences have been found in the supplier management between "hybrid" and "pull" production system (p=0.193). This implies that the

Table 3. Process management application (1)

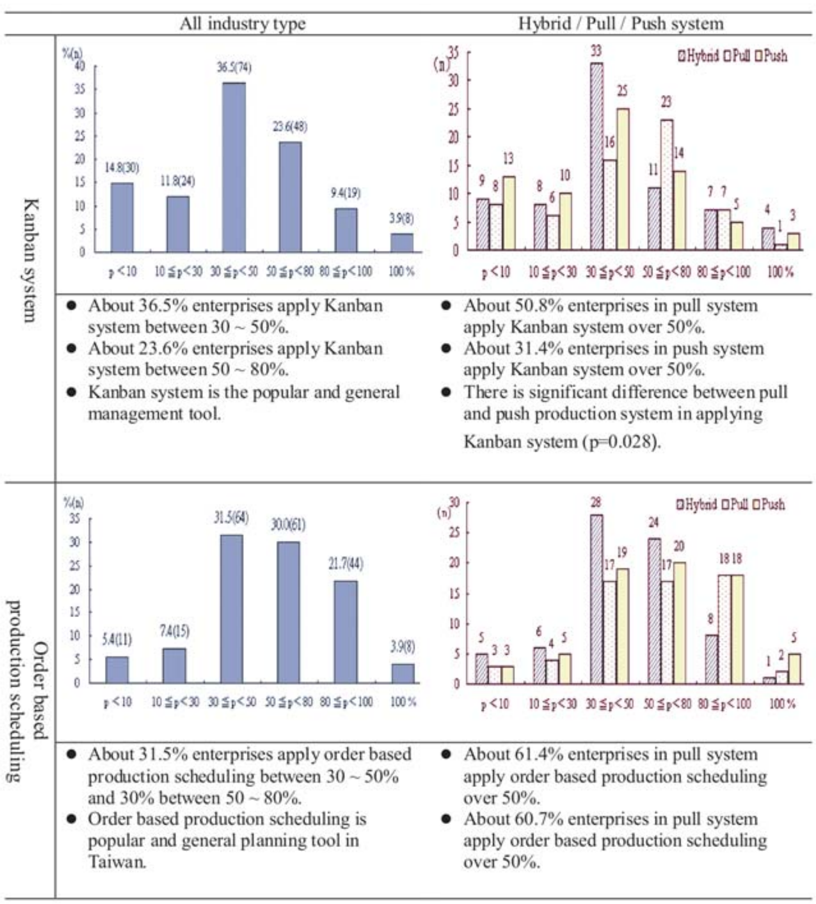
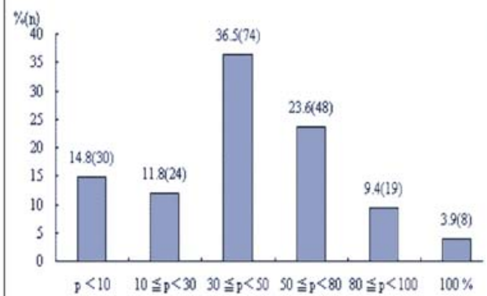
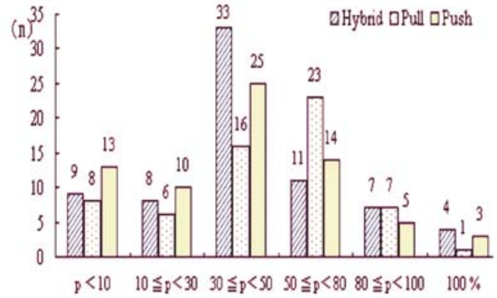
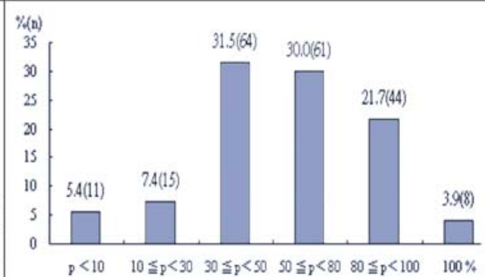
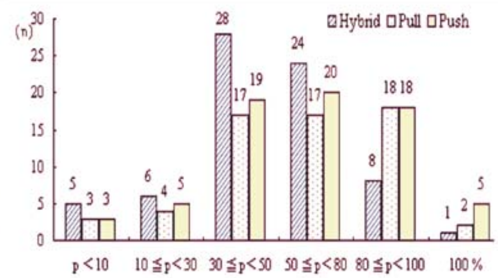


Table 4. Process management application (2)

<table>
<tr><th></th><th>All industry type</th><th>Hybrid / Pull / Push system</th></tr>
<tr><td rowspan="2">Kanban system</td><td>
</td><td>
</td></tr>
<tr><td>● About 36.5% enterprises apply Kanban system between 30 ~ 50%.
● About 23.6% enterprises apply Kanban system between 50 ~ 80%.
● Kanban system is the popular and general management tool.</td><td>● About 50.8% enterprises in pull system apply Kanban system over 50%.
● About 31.4% enterprises in push system apply Kanban system over 50%.
● There is significant difference between pull and push production system in applying Kanban system (p=0.028).</td></tr>
<tr><td rowspan="2">Order based production scheduling</td><td>
</td><td>
</td></tr>
<tr><td>● About 31.5% enterprises apply order based production scheduling between 30 ~ 50% and 30% between 50 ~ 80%.
● Order based production scheduling is popular and general planning tool in Taiwan.</td><td>● About 61.4% enterprises in pull system apply order based production scheduling over 50%.
● About 60.7% enterprises in pull system apply order based production scheduling over 50%.</td></tr>
</table>

enterprises which formally introduce LPS will place more emphasis on supplier management for production management.

4.2 Process Management Application

The study analyses 203 of the process management application in four perspectives: "Kanban system", "Order based production scheduling", "One-piece flow design" and "Load leveling system". The result is shown in Table 3, Table 4 and listed in more detail in Appendix B.

No significant difference is found in applying order based production scheduling. Since most Taiwanese enterprises are OEM/ODM, they fulfill orders by ordering based production scheduling.

The survey shows that these two LPS-style manufacturing process designs are highly practical. The enterprises which apply pull production system have better application range than those of push production system. This also implies that the enterprises which formally introduce LPS emphasize more on the importance of load leveling schedule for process management application.

5. Critical Success Factors in Production Management

5.1 Performance Upgrading

Sixteen questions have been found significant in production management. They are classified into five phase in this section. This analysis tests the significant improvement between hybrid push-pull, pull and push production system. Table 5 shows the significant results of each pair.

There are significant differences between push and pull production system in quality improvement (t=3.065, p = 0.003), cost improvement (t=2.505, p = 0.013) and flexibly (t=2.626, p = 0.010). Significant differences are found between either pull and hybrid push-pull production system (t=2.341, p = 0.021) or push and pull production system (t=3.276, p = 0.001).

As regards the customer satisfaction, both integrated and pull production systems are better than push production system. We can conclude that those companies applying pull and hybrid push-pull production systems result in better performance than push production system.

5.2 The Regression Analysis of Key Factors

Based on how management performances influences the customer satisfaction, we assume a linear relation between customer satisfaction and the nine factors (on time delivery, X_1; quality improvement, X_2; fulfilling customer need, X_3; product changing flexibly, X_4; lower stock cost, X_5; shorten delivery time, X_6; quick R&D, X_7; flexible capability, X_8 and shorten R&D lead time, X_9). After

Table 5. Significant differences of performance upgrading

Significant performance	Hybrid (n=72)		Pull (n=61)		Push (n=70)		t	p-value	significant difference
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD			
1. Quality	3.83	0.52	4.01	0.61	3.65	0.70	3.065	0.003**	Pull Push
2. Cost	3.70	0.59	3.88	0.65	3.58	0.72	2.505	0.013*	Pull Push
3. Flexiblycapability	3.84	0.54	4.02	0.65	3.70	0.74	2.626	0.010*	Pull Push
4. Delivery	3.84	0.63	4.11	0.68			2.341	0.021*	Pull Hybrid
					3.70	0.73	3.276	0.001**	Pull Push
5. Customer satisfaction	3.88	0.60			3.63	0.77	2.084	0.039*	Hybrid Push
			4.09	0.64			3.655	0.000**	Pull Push
Comprehensive	3.79	0.50			3.60	0.66	1.993	0.048*	Hybrid Push
			3.97	0.55			3.435	0.001**	Pull Push

Table 6. Regression analysis of customer satisfaction

Model	SS	df	MS	F	p-value
Regression	2150.519	5	430.104	2003.298	0.000**
Residual	27.481	128	0.215		
Total	2178.00	133			
R=0.994, R^2=0.987, Adj R^2=0.987					

Variable	Coefficients β	Std. Error	t	p-value
On time delivery, X_1	0.232	0.233	3.648	0.000**
Quality improvement, X_2	0.209	0.207	3.181	0.002**
Fulfilling customer need, X_3	0.202	0.203	2.800	0.006**
Product changing flexibly, X_4	0.194	0.192	2.623	0.010**
Lower stock cost, X_5	0.174	0.165	2.855	0.005**

the first and the second regression analysis and eliminating the insignificant factors, we keep five significant performances, as shown in Table 6.

Since R^2=0.987, the formula below shows 98.7% of the customer satisfaction (Y):

$$Y = 0.232 \times X_1 + 0.209 \times X_2 + 0.202 X_3 + 0.194 \times X_4 + 0.174 \times X_5 \quad (1)$$

On time delivery and quality are the key factors that effect customer satisfaction. Other crucial factors are fulfilling customer need, flexibly and lower stock cost. These results provide managerial insights to industry in production management.

6. Discussion and Conclusions

In order to test and verify the conceptual model of the hybrid push-pull COPIS system, our study selected only those non-Toyota system enterprises. Based on our analysis of 203 valid questionnaires, we show that hybrid push-pull and pull production system perform better. The significant factors in the production management include: quality improvement, cost improvement, flexibly and on time delivery. Both hybrid push-pull and pull production systems result in a higher customer satisfaction than the push production system. Spearman and Zazanis (1992) concluded that the performance of pull systems is better suited for OEMs. According to our investigated, no significant difference is found in applying orders based on production scheduling among push, pull and hybrid production systems, since most Taiwanese enterprises are OEM/ODM.

We also show that a good customer relationship is very important in the hybrid push-pull or pull production systems. "On time delivery" and "quality" are the top 2 key factors affecting customer satisfaction. The customer satisfaction regression equation [1] shows that in order to achieve a better customer relationship, an enterprise must provide delivery on time, offer good quality products, product flexibly and efficient stock control. This gives managerial insights to enterprises in what to focus. Future researches can be done to compare the relationship between the Toyota system enterprises and the non- Toyota system enterprises.

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Appendix A: Background of Participants

INDUSTRIAL			CAPITAL (US)			EMPLOYEE		
	No.	%		No.	%		No.	%
Electrical & Electronic	50	24.4	< 3	52	25.6	p < 100	41	20.2
Machinery & Metal	36	17.3	3 ≤ $ < 15	40	19.7	100 ≤ p < 200	29	14.3
Semiconductor	31	14.2	15 ≤ $ < 30	30	14.8	200 ≤ p < 500	43	21.2
Optics & Optoelectronic	27	13.4	30 ≤ $ < 150	37	18.2	500 ≤ p < 1,000	27	13.3
Computer/Communication	19	12.6	150 ≤ $ < 300	12	5.9	1,000 ≤ p < 5,000	40	19.7
Plastics/Chemical	10	3.1	300 ≤ $ < 1,500	16	7.9	pg ≥ 5,000	23	11.3
Others	30	15.0	$ ≥ 1,500	16	7.9			
Total	**203**	**100**	**Total**	**203**	**100**	**Total**	**203**	**100**

Appendix B: Process management & manufacturing process design application

	Kanban System		Order based production scheduling		One-piece flow design		Load leveling system	
	No.	%	No.	%	No.	%	No.	%
< 10%	30	14.8	44	21.7	34	16.7	30	14.8
10 ≤ p < 30%	24	11.8	29	14.3	22	10.8	31	15.3
30 ≤ p < 50%	74	36.5	39	19.2	59	29.1	63	31.0
50 ≤ p < 80%	48	23.6	23	11.3	27	13.3	37	18.2
80 ≤ p < 100%	19	9.4	16	7.9	19	9.4	21	10.3
100%	8	3.9	52	25.6	42	20.7	21	10.3
Total	**203**	**100**	**203**	**100**	**203**	**100**	**203**	**100**