The Relationship between Quality Management Practices, Infrastructure and Fast Product Innovation

Barbara B. Flynn
Iowa State University, College of Business, Ames, Iowa, USA

Introduction

There is a substantial amount of anecdotal evidence that fast product innovation may be the next global challenge to face US manufacturers, particularly from Japanese competitors. It is becoming increasingly important in achieving a manufacturing-based competitive advantage, as the achievement of other goals, such as high quality and timely delivery, becomes more common. Although some US firms have used product innovation, with speed a competitive weapon for years, their potential market success has often been diluted by poor quality. In fact, the conventional wisdom has been that fast product innovation and quality represent a tradeoff which cannot be simultaneously achieved.

However, recent developments in the innovation process have begun to change this apparent tradeoff. Through the use of practices related to concurrent engineering and design for manufacturability, some firms have been able to achieve dramatic reductions in product innovation speed, while maintaining or even improving quality levels. In addition, there may be certain types of organizational infrastructure that provide an environment which best supports fast product innovation, combined with high quality.

Although there is some anecdotal evidence which supports these notions, there has been little empirical verification. The purpose of this article is to investigate empirically the relationship between fast product innovation, quality and organizational infrastructure, in order to learn more about the development of an environment which supports these approaches.

Fast Product Innovation as a Source of Competitive Advantage

In today's atmosphere of heightened global competition, manufacturers are striving to find better ways to attain and sustain a competitive advantage. Although many US manufacturers have recently focused their efforts on quality, those which are the most competitive are using a multifaceted approach, winning orders on cost, delivery speed, delivery reliability, design

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characteristics, volume flexibility and/or product line flexibility, in addition to quality. By competing simultaneously on several fronts manufacturers are able to create a competitive advantage which is difficult to copy, allowing it to be sustained[1-3].

The focus of this article is on the competitive dimension of product line flexibility, specifically on achieving product line flexibility through the approach known as fast product innovation. This approach is designed to lead to a competitive advantage through beating competitors to the market with new product developments[4]. There are numerous examples of companies whose fast innovation cycles have permitted them to take the leadership position in their industries[5,6].

Fast Product Innovation

Fast product innovation creates a competitive advantage by surprising competitors with modifications to existing products or by the introduction of new products[7]. When a firm introduces a new or modified product more quickly than a competitor, the competitor is faced with two alternatives, both distasteful[5]. On the one hand, it could proceed as planned, introducing an innovation to meet a market need which no longer exists. Alternatively, it could stop its development effort and redirect it, causing further delays and risking exposure to additional market and competitive change. Thus, skill in fast product innovation is a powerful means for establishing and sustaining a competitive advantage and satisfying customers.

Organizations which compete on product innovation speed often further insure their competitive advantage through the use of an incremental approach to product development and improvement, rather than searching for big breakthroughs[7,8]. They focus on improvements to existing products and the development of new products which represent small, incremental improvements over existing products. This continuous improvement philosophy leaves the firm even less vulnerable to pre-emption by competitors.

As Figure 1 illustrates, there are two main approaches to the achievement of fast product innovation. Concurrent engineering has reduced development time as its goal, while design for manufacturability has reduced time to ramp-up to full production as its goal. Both product development time and ramp-up time must be reduced in order to reduce product introduction time, which leads to achievement and sustainment of competitive advantage.

Concurrent Engineering

There are several key elements of concurrent engineering. Fast cycle innovators strive to eliminate the "heave it over the transom" phenomenon, where designers work in isolation from manufacturing, leading to designs which are difficult to manufacture, leading to the initial round of engineering change orders, etc.[9,10]. Rather, a design partnership is formed between marketing, design, manufacturing, quality assurance, customers and the supplier company's engineers[11]. The concept of "design without delay" seeks to

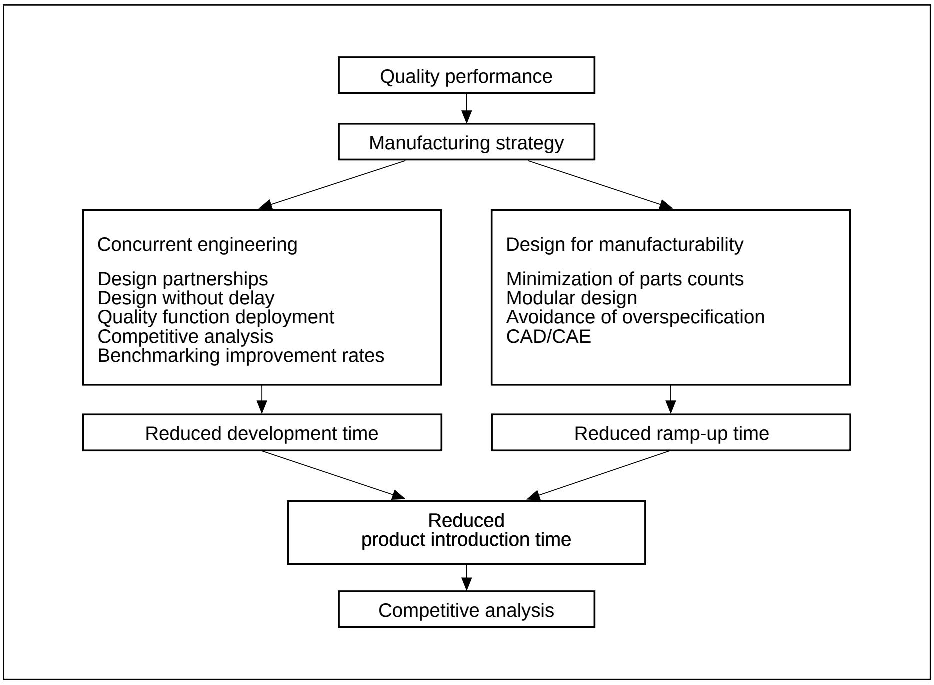

Figure 1.
Components of Fast Product Introduction

shorten design lead times by taking out unnecessary delays and developing product specifications which are fight for both the customer and the producer[12]. Tools such as quality function deployment help in achieving design without delay through translating the "voice of the customer" into detailed technical requirements, prioritized with competitive data[13]. Competitive analysis involves purchasing and trying competitors' products and surveying competitors' customers. It may also include activity in trade associations and speciality groups, hiring knowledgeable people from outside firms and benchmarking competitors' rate of improvement[13].

Design for Manufacturability

The ease of manufacture of a product design can be enhanced through a number of practices. Minimization of the parts count makes manufacturing more simple and products more reliable, while also often forcing product engineers and process engineers to work together[12]. Modular designs are useful in minimizing the disruptive effects of product-line flexibility. Each module is designed to be a "vanilla" design, which can be mixed to satisfy a variety of customers through the quick and easy addition of snap-on, bolt-on and plug-in modifications. Design for manufacturability also includes the avoidance of overspecification, focusing on loose tolerance tightly enforced, rather than tight tolerances loosely enforced[11]. CAD and CAE allow designs to be tapped by designers located at plants in different cities, permitting the use of company-standard parts, rather than constantly inventing new parts. The rationale is that standard parts are proven parts, and the use of fewer new components helps to speed time to market.

Quality Foundation

It has been suggested that quality performance forms the foundation for the development of lasting manufacturing capabilities[14]. Other strategies, such as speed, dependability and cost efficiency may be used to achieve a competitive advantage at a particular point in time, however, quality improvement is the base which supports these initiatives. Thus, Ferdows and DeMeyer postulate that quality performance is a precondition to other strategic thrusts.

Thus, it is suggested that effective implementation of fast product innovation can only be achieved in the context of quality management[15-19]. Many a manufacturer has rushed to market with a new product, only to find that quality considerations had not been fully developed and that it was unprepared for high volume production.

Quality management practices include the establishment of a managerial climate which clearly focuses on quality. Quality information systems provide feedback about quality performance[20] and monitor process flows[21]. Process management practices such as preventive maintenance, running at less than capacity and the development of proprietary equipment[22,23] facilitate the production of quality output. Product design improvements which stimulate improved quality include reliability engineering[24], trial runs[25] and life and stress testing[24]. Supplier management practices include supplier certification [25], the establishment of close, long-term supplier relationships[26] and development of a relationship of interdependence and co-operation[27].

Infrastructure for Quality and Fast Product Innovation

Practices related to fast product innovation and high quality may be facilitated by certain infrastructure characteristics. These organizational characteristics, human resource management practices and JIT approaches create an environment which is supportive of fast product innovation.

Organizational characteristics. Decentralization of decision making facilitates the establishment of a quick response system through handling uncertainty at the source, improving the efficiency of the development process[28-31]. A decentralized environment facilitates cross-functional communication and teamwork, which are important to concurrent engineering. Integrating mechanisms, such as cross-functional teams and task forces, also play a key role in concurrent engineering. Standardization and formalization of procedures encourages flexible labour assignments, aiding in a smooth ramp-up to full production.

Human resource management. Human resource management practices which lead to improved quality include selection of a reliable, loyal and creative workforce[32], quality-oriented training, as well as general training[22] and egalitarian approaches which minimize status differentials between workers at different levels in the organizational hierarchy. Compensation approaches which set the stage for high quality include group compensation plans, which encourage teamwork and creativity, and pay-for-skill/pay-for-knowledge plans, which encourage flexibility[33]. Teamwork facilitates process improvement and the fast introduction of new products and product enhancements. Suggestions from teams can also result in innovative enhancements to existing products and ideas for new products.

Just-in-time. Another important component of the infrastructure for fast product innovation and quality may be the approach known as Just-in-time (JIT). Effective implementation of JIT requires detailed understanding and analysis of the production process. The innovation pioneers of the 1970s and 1980s demonstrated that product enhancement is better managed as a series of many small improvements rather than large major enhancements (new "model years"). However, in order to make a large number of small improvements, the production process must be under control, pilot production must be able to be introduced effectively and improvements must be slotted into production schedules with a minimum of disruption[34]. In contrast, large releases have been traditionally preferred by organizations which do not have effective control of their production processes and are, therefore, not able to manage a large number of small releases effectively[7]. JIT provides a simple approach to production planning and control which is flexible and understandable by the entire organization. In addition, JIT's emphasis on inventory reduction means that there is a reduced need to delay introductions while excess inventories of old components and subassemblies are depleted[7].

Thus, we suggest that fast product innovation must be built upon a foundation of quality, in order to be effective in achieving and sustaining a competitive advantage. We further suggest that there will be certain infrastructure characteristics, in terms of organizational characteristics, human resource management practices and JIT approaches, which will facilitate both fast product innovation and quality.

Hypotheses

This article focuses on the investigation of several assertions. First, in order to sustain a competitive advantage, fast product innovation can be pursued only while remaining competitive in terms of quality. Rushing to market with a new product, characterized by poor quality, can do more harm than good in today's competitive environment. Second, in order to support the simultaneous achievement of fast product innovation and high quality output, a total organizational commitment is necessary. This includes changes in organizational characteristics, human resource management practices and shopfloor control systems.

Thus, the overall intent of this article is to articulate the key dimensions of organizational infrastructure and quality management necessary to support the simultaneous pursuit of fast product innovation and high quality output. Specifically, two hypotheses were tested:

H_1: Plants which use strong quality management practices will achieve shorter new product introduction cycles than plants which use weak quality management practices.

H_2: Plants with strong infrastructure characteristics will achieve shorter new product introduction cycles than plants with weak infrastructure characteristics.

Method

Sample

An existing database, collected to support a project dealing with various aspects of world class manufacturing, was used. The database contains data from 712 respondents at 42 plants in the US, in the electronics, transportation components and machinery industries. Within each industry, there are Japanese transplants, US-owned plants with a world class reputation and traditional US-owned plants. Initial contact was made via a telephone conversation with the plant manager. Those who agreed to participate appointed a plant research co-ordinator, who functioned as primary liaison with the project. Sixty per cent of the plants contacted ultimately participated in the study. Participating plants received a detailed profile of their performance and an industry profile for comparison.

Instrument

The instrument used for data collection contained 50 reliable and valid perceptual scales and 200 items which requested objective data about plant performance. Included in the data collected was information about new product development speed, quality performance and infrastructure strength. The items were divided into a total of nine questionnaires, which were distributed by the plant research co-ordinator to the plant manager, supervisors, direct labourers, human resource manager, quality manager, plant accountant, production and inventory manager, process engineer and plant research co-ordinator.

Analysis

The data set was divided into three groups, representing fast, medium and slow product innovators. Multiple discriminant analysis was used to determine the key factors which differentiated between the three groups, thus demonstrating how plants which differ in product innovation speed also differ in quality management and infrastructure characteristics.

The analysis followed several steps. In the first step, the statistical significance of the discriminant functions was analysed, using Chi-square. This determined whether there was, indeed, a significant difference between the three groups, in terms of infrastructure and quality management characteristics. Discriminant functions which were not statistically significant at the 0.05 level or less were not interpreted further. In the second stage, the validity of the functions was assessed, using the “hit ratio”, which describes the percentage of the plants which were correctly classified as fast, medium or slow innovators, based only on their infrastructure and quality management characteristics. The criterion value was adjusted upwards to compensate for the bias inherent in the use of a non-split sample. Finally, the individual discriminant loadings were examined and interpreted, in order to determine which infrastructure and quality management variables contributed most to the differences between the groups, in terms of product innovation speed.

Results and Discussion

Table I provides descriptive information about the database. For the purposes of this table only, the data were divided into four groups: US-owned fast, medium and slow product innovators and Japanese-owned plants. The Japanese plants were positioned between the fast and medium product innovation speed US-owned groups, in terms of their innovation speed.

Table I reveals a number of interesting findings. Fast product innovators purchased a relatively larger percentage of materials from outside the company and relatively less from outside the US. Slower product innovators tended to have substantially more inventory than the other groups, while the Japanese plants had particularly low levels of inventory. Fast product innovators tended to be primarily small batch operations, while the medium speed innovators

		US plants		
	Fast innovators	Medium innovators	Slow innovators	Japanese plants in US
Percentage of materials coming from outside the company	89.4	79.3	77.3	70.6
Percentage of materials coming from outside the US	17.8	20.0	24.7	58.3
Value of finished goods inventory	5,212	5,546	8,568	2,569
Value of work-in-process inventory	7,679	4,978	14,836	2,813
Value of raw materials inventory	3,492	6,558	11,509	3,786
Total cycle time (RM receipt until customer receipt)	70.6	57.9	53.3	67.9
One of a kind	6.4	9.4	6.9	0.8
Small batch	50.7	34.5	30.0	16.7
Large batch	16.4	28.9	10.6	8.3
Repetitive/semi-continuous	23.9	27.8	36.4	38.8
Continuous	3.5	6.7	16.4	38.6
Engineering change orders	412.2	378.6	778.6	80.5
Turnover – hourly	2.6	13.5	8.25	4.2
Turnover – salaried	2.9	10.6	4.5	5.2
Perception of product introduction speed, relative to industry (1=fast, 5=slow)	1.2	2.5	3.7	2.1

Table I.
Overview of the Data Set

were split between small and large batch and repetitive semi-continuous, and the slow innovators were closer to the continuous end of the scale. However, although the Japanese plants described themselves as predominately repetitive/semi-continuous or continuous, they were able to support their operations with dramatically less inventory and were relatively fast innovators. They achieved this despite having a much greater percentage of materials coming from outside the US than the US-owned plants of the same type.

The slow product innovators had a very large number of engineering change orders per year, relative to the other groups, indicating that, in addition to being slow, their product development process did not result in a manufacturable product. Employee turnover was quite a bit lower among the fast product innovators, indicating a greater level of job satisfaction among their employees.

Quality Management

The first hypothesis addresses the role of quality management in fast product innovation. Tables II, III, IV and V summarize the results. Table II lists the means, by group, of the quality management variables. A lower value indicates better performance. In general, the fast product innovators had better performance on the quality management variables. The differences were tested with an *F* test, with a significance level of 0.10 or less indicating statistical significance. Thus, there were significant differences between the fast, medium and slow product innovators in terms of top management quality leadership, feedback, cleanliness and organization and product design characteristics. The measure of product design characteristics focuses on reliability engineering and design for manufacturability, thus, it is not surprising that it is related to fast product innovation. As there are fewer parts and parts are designed for ease of fabrication and assembly, new products and product enhancements can be introduced quicker and with fewer quality problems. The measure of top management quality leadership deals with the strength of support for the plant's quality efforts which is provided by top management. As top

	Speed of new product introduction				Statistical
	Fast	Medium	Slow	*F*	significance level
Top management quality leadership	3.35	3.69	3.76	3.51	0.0452
Rewards for quality	2.68	2.88	3.05	2.10	0.1435
Process control	2.55	3.07	3.00	0.96	0.3948
Feedback	3.09	3.27	3.54	2.93	0.0718
Cleanliness and organization	3.34	3.64	3.94	4.06	0.0298
New product quality	3.20	3.53	3.48	0.75	0.4843
Product design characteristics	2.64	3.30	3.57	7.88	0.0022
Interfunctional design efforts	3.04	3.45	3.58	1.12	0.3416
Supplier relationship	2.99	3.20	3.08	0.47	0.6308
Customer interaction	3.72	3.69	3.86	0.36	0.7015

Table II. Results for Quality Management Variables management makes this support clear, it will be reflected in the design process, as well as other parts of the organization. The measures of feedback and cleanliness and organization are more related to management of the manufacturing process. Receiving immediate and useful feedback from the manufacturing process is instrumental in speeding new products to the market, as well as in testing prototypes prior to full scale production. Cleanliness and organization facilitate quick changes between products, making it simpler to phase-in new products without disrupting shopfloor operations.

Table III demonstrates that the first discriminant function was statistically significant, indicating that there are significant differences between one group and the two remaining groups, combined, in terms of some of the quality management characteristics. The second discriminant function, which is orthogonal to the first and explains the residual variance, after the variance described by the first function has been removed, was not statistically significant. Analysis of the group centroids and Table IV indicates that the fast product innovators are significantly different (better) than the medium and slow innovators in terms of product design characteristics (design for manufacturability), and had stronger top management leadership than the medium and slow innovators. Feedback and cleanliness and organization, which were more related to the control of shopfloor operations, accounted for

Function	Eigenvalue	Canonical correlation	Wilks' lambda	Chi-square	Significance level
1	0.9906	0.7054	0.4766	17.42	0.0261
2	0.0540	0.2264	0.9487	1.24	0.7443

Table III.

	Function I	Function II
Product design characteristics	0.7447	0.3174
Top management quality leadership	0.6324	–0.0058
Feedback	0.0289	0.8009
Cleanliness and organization	0.2092	0.7065

Table IV.

	Predicted group membership Fast %	Medium %	Slow %
Actual group membership			
Fast	80	10	10
Medium	20	60	20
Slow	0	37.5	62.5
Hit ratio=67.5%			

Table V.

the primary difference between the slow innovators and the combination of the fast and medium innovators, which was not statistically significant. The validity of this analysis is demonstrated by Table V, which shows that these discriminant functions correctly classified 67.5 per cent of the plants as fast, medium or slow product innovators, based solely on their quality management characteristics (the criterion value was 44.8 per cent).

Infrastructure Components

The second hypothesis deals with the impact of infrastructure components on fast product innovation. The analysis was divided into three parts, corresponding to organization characteristics, human resource management and JIT.

Organization characteristics. Tables VI, VII, VIII and IX indicate the organization characteristics variables which contributed to differences in product innovation speed between plants. There were significant differences between the groups in terms of co-ordination of decision making and decentralization, and communication of strategy approached statistical significance. Fast product innovators have a more decentralized organization structure and better co-ordinated decision making. This is important in the product development process and facilitates the effectiveness of interfunctional

Table VI. Results for Organization Characteristics Variables

	Speed of new product introduction Fast	Medium	Slow	*F*	Statistical significance level
Communication of strategy	3.16	3.42	3.60	2.51	0.1017
Co-ordination of decision making	3.12	3.30	3.33	3.67	0.0399
Decentralization of authority	3.17	3.08	3.53	5.52	0.0449

Table VII.

Function	Eigenvalue	Canonical correlation	Wilks' lambda	Chi-square	Significance level
I	0.3174	0.4908	0.5888	12.708	0.0479
II	0.2896	0.4735	0.7758	6.093	0.0475

Table VIII.

	Function I	Function II
Co-ordination of decision making	0.9663	0.1927
Communication of strategy	0.7329	0.3772
Decentralization of authority	0.2707	0.9447

design teams. Fast product innovators also communicate their overall strategy more effectively than slower product innovators.

Table VII indicates that both discriminant functions were statistically significant. The first discriminant function (explaining the largest difference) describes the difference between the fast product innovators and the medium and slow innovators, combined. Table VIII shows that the faster product innovators exhibited better co-ordination of decision making and better communication of strategy than the medium and slow product innovators. The second discriminant function describes the difference between the slowest product innovators and the combination of the fast and medium speed product innovators. The slowest product innovators used a more centralized decision-making structure. These two discriminant functions were able to correctly classify 60.71 per cent of the plants as fast, medium or slow product innovators, based solely on communication of strategy, co-ordination of decision making and decentralization of authority (Table IX).

Human resource management. Table X shows that there were significant differences between the groups in terms of selection for teamwork potential,

Table IX.

	Predicted group membership		
	Fast %	Medium %	Slow %
Actual group membership			
Fast	60	20	20
Medium	20	70	10
Slow	12.5	37.5	50
Hit ratio=60.71%			

Table X.
Results for Human Resource Management Variables

	Speed of new product introduction				Statistical
	Fast	Medium	Slow	*F*	significance level
Selection for teamwork potential	3.00	3.73	4.13	6.03	0.0073
Teamwork	3.29	3.35	3.71	3.29	0.0537
Breadth of experience	3.46	3.47	3.49	0.05	0.9473
Supervisory interaction facilitation	3.59	3.73	4.12	3.81	0.0360
Management breadth	2.41	2.53	2.48	0.27	0.7678
Managerial rewards	2.87	3.08	3.18	1.36	0.2746
Pride in work	4.36	4.30	4.43	0.68	0.5101
Loyalty to the organization	3.56	3.87	3.88	2.98	0.0690
Plant-wide philosophy	3.04	3.35	3.41	3.78	0.0367

teamwork, supervisory interaction facilitation, loyalty to the organization and plant-wide philosophy. In general, these characteristics describe an organization which is able to communicate well between areas, works well together, shares a common vision and has loyal, committed employees. The concurrent engineering approaches used in fast product innovation stress interfunctional teamwork, thus, it is not surprising that teamwork and selection for teamwork potential would contribute to differences between the groups.

Table XI shows that there was a single discriminant function which was statistically significant. It measured the difference between the fast innovators and the combination of the medium and slow product innovators. Table XII shows that this difference was primarily in terms of selection for teamwork potential, plant-wide philosophy and loyalty to the organization. Table XIII shows that the discriminant functions were able to correctly classify 60.71 per cent of the plants as fast, medium or slow product innovators, based solely on their human resource management characteristics. Thus, 60 per cent of the fast innovators could be correctly classified as fast innovators, based only on knowledge of their selection for teamwork potential, plant-wide philosophy and loyalty to the organization scores.

Function	Eigenvalue	Canonical correlation	Wilks' lambda	Chi-square	Significance level
I	0.66	0.63	0.4468	18.53	0.0467
II	0.35	0.50	0.7434	6.82	0.1459

Table XI.

	Function I	Function II
Selection for teamwork potential	0.6994	0.5958
Plant-wide philosophy	0.6286	0.2486
Loyalty to the organization	0.5863	0.1309
Teamwork	0.1977	0.7497
Supervisory interaction facilitation	0.3067	0.7350

Table XII.

	Predicted group membership		
	Fast %	Medium %	Slow %
Actual group membership			
Fast	60	30	10
Medium	20	50	30
Slow	12.5	17.5	75
Hit ratio= 60.71%			

Table XIII.

Just-in-time. Table XIV indicates that there were differences between the three groups in terms of setup time reduction, JIT supplier relationship, material handling simplicity, lot size reduction and schedule flexibility. Although none of these would be expected to have a direct impact on fast product innovation, they are all indicators of a plant which has the shopfloor under control and which is capable of supporting its operations with minimal inventory levels. When the shopfloor is under control, it is more capable of easily adjusting to new products and product enhancements. For example, small lot sizes, which are facilitated by setup time reduction, permit new products to be readily inserted into the schedule and more quickly produced. A better relationship with suppliers permits rapid receipt of materials needed for producing new products, as well as facilitating interaction between suppliers, designers, manufacturers, etc. during the design process. Tables XV and XVI indicate that the single statistically significant discriminant function described the difference between the slowest innovators and the fast and medium innovators, combined. The slowest innovators were less successful or made less effort in lot size reduction and had poorer relationships with suppliers, particularly in terms of delivery time. Table XVII indicates that these discriminant functions are valid, correctly classifying 64.29 per cent of the plants as fast, medium or slow product innovators, based solely on their JIT characteristics.

Combined, these findings support the second hypothesis, which states that there are differences in infrastructure which correspond to differences in product innovation speed. Differences in infrastructure were demonstrated in

Table XIV. Results for JIT Variables

	Speed of new product introduction Fast	Medium	Slow	*F*	Statistical significance level
Maintenance	2.89	2.90	2.93	0.01	0.9993
Setup time reduction	2.70	3.06	3.26	3.79	0.0366
JIT supplier relationship	2.78	2.85	3.39	2.87	0.0755
Material handling simplicity	3.20	3.43	3.87	2.71	0.0862
Repetitive master schedule	2.62	2.60	2.38	0.46	0.6401
Lot size reduction	3.45	3.27	4.03	5.33	0.0118
Kanban	2.41	2.47	2.72	1.35	0.2769
Schedule flexibility	2.97	3.11	3.16	2.84	0.0776
Pull system support	3.19	3.43	3.63	1.45	0.2606

Table XV.

Function	Eigenvalue	Canonical correlation	Wilks' lambda	Chi-square	Significance level
I	0.74	0.65	0.4132	20.33	0.0263
II	0.39	0.53	0.7178	7.63	0.1063

all three dimensions of infrastructure: human resource management, Just-in-time and strategic management/organizational characteristics.

Table XVIII, XIX and XX provide an analysis of the combination of the infrastructure and quality management variables. Table XIX shows that the fast product innovators, compared with the combination of medium and slow innovators, had better product design characteristics (reliability engineering and design for manufacturability), incorporated the potential for teamwork more into their selection process, had a more pervasive plant-wide philosophy, had better co-ordination of decision making, had stronger top management quality leadership, did more setup time reduction activities and had cleaner and better organized work places. Based on these characteristics, 82.14 per cent of the plants were correctly classified as fast, medium or slow innovators.

Conclusions

This study provides strong preliminary support for the notion of a quality foundation and an organizational infrastructure which support fast product innovation. In order to be effective, this infrastructure should include elements

	Function I	Function II
Lot size reduction	0.7787	0.2393
JIT supplier relationship	0.5178	0.4231
Setup time reduction	0.3349	0.8033
Schedule flexibility	0.2367	0.7203
Material handling simplicity	0.4277	0.5484

Table XVI.

	Predicted group membership Fast %	Medium %	Slow %
Actual group membership			
Fast	50	20	30
Medium	20	80	0
Slow	25	12.5	62.5
Hit ratio=64.29%			

Table XVII.

Function	Eigenvalue	Canonical correlation	Wilks' lambda	Chi-square	Significance level
I	1.69	0.7923	0.1815	34.98	0.0202
II	1.05	0.7158	0.4877	14.72	0.0989

Table XVIII. Results for All Variables, Combined

	Function I	Function II
Product design characteristics	0.5839	0.2120
Selection for teamwork potential	0.4986	0.2293
Plant-wide philosophy	0.4176	0.0791
Co-ordination of decision making	0.4125	0.0704
Top management quality leadership	0.4012	0.0846
Setup time reduction	0.3920	0.1921
Cleanliness and organization	0.3761	0.2734
Lot size reduction	0.1111	0.6172
Decentralization of authority	0.1120	0.4938
Supervisory interaction facilitation	0.2876	0.3866

Table XIX.

	Predicted group membership		
	Fast %	Medium %	Slow %
Actual group membership			
Fast	70	10	20
Medium	0	90	10
Slow	0	12.5	87.5
Hit ratio=82.14%			

Table XX.

of human resource management, Just-in-time, and organizational characteristics. The characteristics of this infrastructure are similar to the characteristics which support other aspects of world class performance. Thus, fast product innovation can be considered to be an element of world class manufacturing. The idea of an infrastructure for fast product innovation has been suggested in the literature, but it has not been documented in a comprehensive fashion, nor has it been empirically tested. Thus, this study forms a foundation for future study in this interesting area.

Future work should focus on articulating the relationship between the elements of infrastructure and determining how they are related to fast product innovation. For example, although customer interaction was not directly related to fast product innovation, it may be indirectly related as a predecessor to product design characteristics; design for manufacturability will be enhanced if it is done with accurate knowledge of customer needs and desires. This can be accomplished by the construction and testing of a path model. It is also important to consider the relationship of fast product innovation to the other sources of competitive advantage (delivery performance, low cost, etc.). Do they tend to reinforce each other or occur simultaneously? This type of analysis will be best done in the context of competitive advantage. For example, is fast product innovation most effective when implemented by itself or in tandem with other sources of competitive advantage? Is there any sequential relationship (e.g. does quality performance need to be established before fast product innovation can be pursued?).

Finally, it is important to continue to investigate the role of infrastructure in fast product innovation and quality. Although this analysis provided evidence that organizational characteristics, human resource management and JIT are important components of the infrastructure for fast product innovation, future research should strive to articulate other key dimensions of this infrastructure and their relationship to the components of fast product innovation and quality.

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