IMPLEMENTING JIT/MRP IN A PCB MANUFACTURER

KIT-FAI PUN
KWAI-SANG CHIN, PHD
Department of Manufacturing Engineering, City University of Hong Kong, Tat Chee Avenue, Hong Kong

K. H. WONG
Mica-AVA Industrial Ltd., Tai Po Industrial Estate, New Territories, Hong Kong

Facing the escalating costs of material, land, equipment, and labor, coupled with increasing customer demand for reduced price, more product variety, reduced order quantity, and shorter delivery lead time, manufacturing companies must equip themselves aggressively and seek new ways for continuous improvement, growth and survival. Various modern manufacturing technologies, systems, and accompanied programs have been promoted in industry to enhance operational efficiency and global manufacturing competitiveness. Just-in-Time (JIT) manufacturing and material requirements planning (MRP) are two notable methodologies. Adoption of these methodologies may necessitate changes in the overall production system, in the structure as well as the vision of an organization. Probably, those organizations with the ability to achieve a higher flexibility and adaptability in these changes will have a better chance of success. In light of this, we will describe the implementation of a JIT/MRP system in the production system of a multinational printed circuit board (PCB) manufacturing company.

INTEGRATING JIT AND MRP

The JIT approach levels the production load by eliminating waste in the production processes and by providing the right part at the right place at the right time; whereas MRP stresses the completion of shop-floor orders on schedule and the assurance of proper operation of production lines [6, 10, 11, 14]. There have been numerous reported cases of successful implementations of both approaches [2, 4, 7, 9, 10–14]; however, they still have weaknesses. For instance, JIT may lack the forward visibility of future material requirements and it takes time to achieve results. MRP suffers from a lack of a system vision and is incapable of efficiently solving excessive inventory problems [6, 10, 11, 14]. Therefore, integrating JIT and MRP may be a possible answer.

Nowadays, many manufacturing companies are operating in a hybrid manufacturing setting (i.e., a mix of intermittent and repetitive production) where the use of an MRP or a JIT system solely is not feasible. Since MRP-push and JIT-pull practices are synergistic, elements of both can cooperate with each other in an integrated platform [1, 6, 10]. The authors have advocated an integrated JIT/MRP approach in an attempt to deal with such hybrid environments. The approach primarily focuses on selected improvement areas, striving to preserve the MRP components in the original production system, as long as they do not violate the JIT philosophy. This allows the JIT components to be effectively injected into the master production schedule (MPS) and shop-floor control. The simplicity of the JIT control can reduce the complexity of executing the MRP programs in accordance with the constraints of lead times and reorder levels [6, 8, 10].

COMPANY BACKGROUND

MAVA is a subsidiary of a multinational group of companies. It has a PCB factory in Hong Kong, and operates two joint-venture plants simultaneously in mainland China. These plants manufacture copper-laminated boards and multilayer raw materials (called the prepreg) for use in the PCB industry in Europe, the USA, China and other Asia-Pacific Rim countries. In MAVA, a conventional push-type MRP system has been used for years. Monthly master production schedules would be produced in line with the sales forecasts, orders and inventory records. Raw materials would be pushed into the production line as planned. Production priorities would be determined by means of backward loading using fixed capacity calculations; and orders of the same products would be grouped into a large production batch to minimize setup costs. Such a system relied largely on the availability and accuracy of the shop-floor data, and any data errors and mistakes would deteriorate the operational effi-

ciency and productivity. Moreover, MAVA has been facing difficulties in responding to any dynamic operation situations (e.g., material delays, order changes). Consequently, excessive inventories in raw materials, work-in-process (WIP), and finished goods would always result.

In early 1995, a task force was instituted by the management to tackle these deep-rooted production problems of the company. The possibility of adopting an integrated JIT/MRP production system was studied, and technical aspects of the system were analyzed. The final recommendation was that the new system would use MRP as the framework for capacity planning, with JIT components injected into the master production scheduling and shop-floor control. Moreover, the JIT philosophy of striving for continuous improvement in all areas of production would be employed.

DEVELOPMENT OF INTEGRATED JIT/MRP SYSTEM

The task force has diligently examined its corporate objectives, organizational resources and constraints (both external and internal), current problems and potential improvement areas. A critical diagnosis of both JIT and MRP elements has also been carried out. It was found that the MRP-push elements (e.g., materials, capacity, and business planning) could bring the sales forecasts into detailed production schedules and material requirements, while JIT-pull elements (e.g., mixed-model scheduling, single sourcing, and kanban system) could be injected to tackle the dynamic inventory problems and improve the efficiency of the system. Figure 1 illustrates an analytical examination of MAVA's production system, problematic situations and potential improvement areas.

The skeleton of a proposed JIT/MRP system was built upon the results of the analytical examination. As shown in Figure 2, the annual business plan would provide information concerning the markets and product mix of the company, and also project annual sales and material forecasts, which would be used for long-term order arrangements with suppliers. Based on the business plan, quarterly aggregate production plans would be determined, and the physical and financial resources would be identified to help formulate the sales and production programs for the company. For instance, the issue of quarterly purchasing orders, the portfolio of product mix, and the allocation of resources would be determined. Incorporating the philosophy of the JIT approach, the

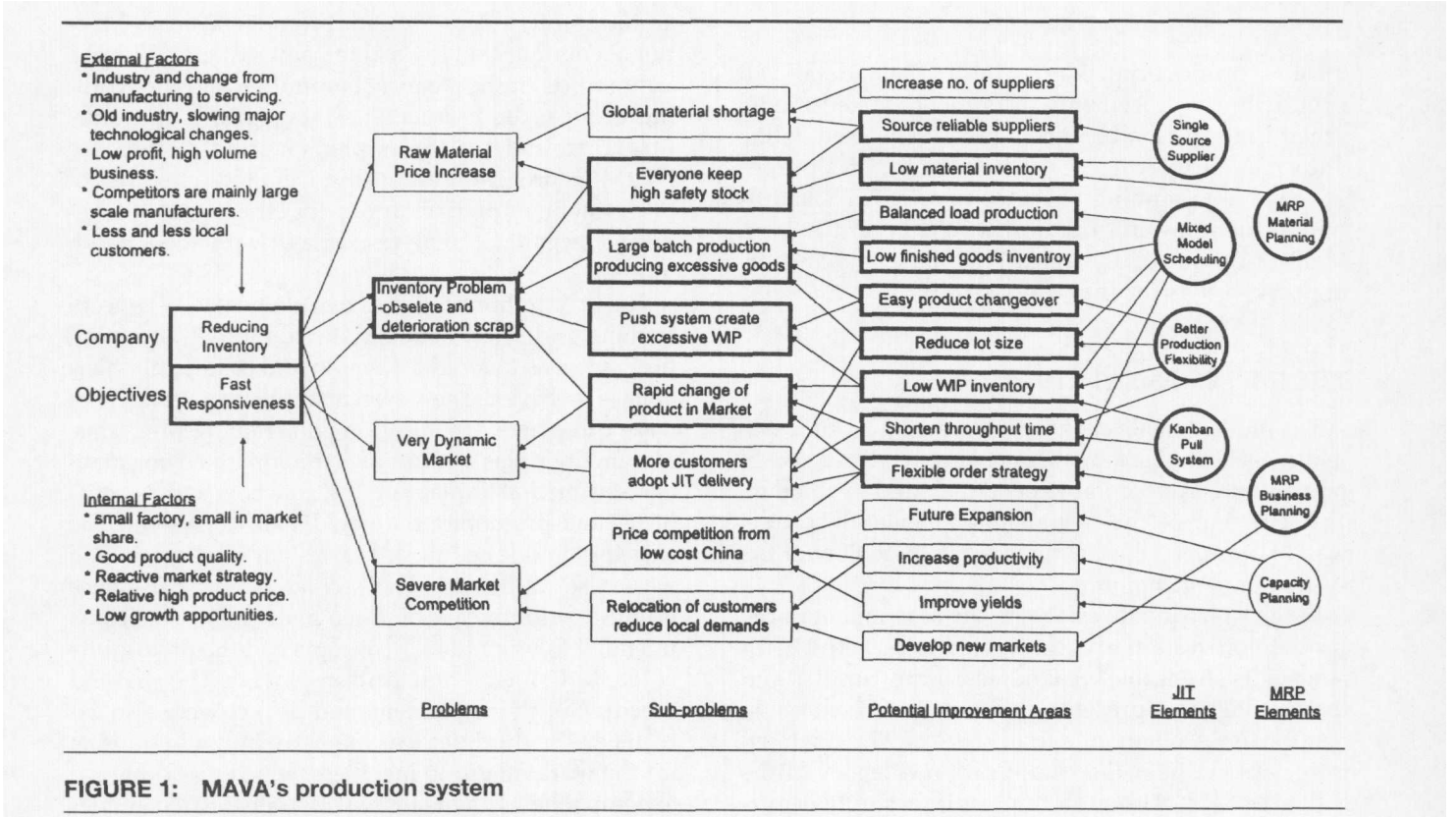

FIGURE 1: MAVA's production system

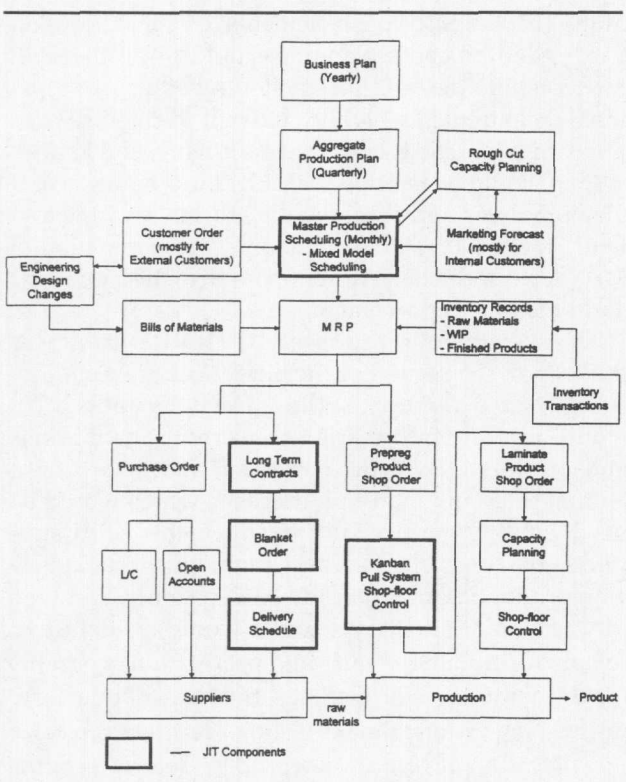

FIGURE 2: Proposed JIT/MRP system

master production plan would then detail all production requirements. Moreover, mixed-model scheduling and load balancing would be used in line with market forecasts, orders on hand, and rough-cut capacity planning of the company. All scheduling and loading information would be put into an MRP program for the release of materials and orders, as well as for shop-floor control.

THE IMPLEMENTATION MODEL

The implementation of the integrated JIT/MRP system went through four distinct stages: prerequisites, preparation, system implementation, and evaluation. The duration of the overall implementation project was 14 months. Figure 3 depicts the logic flow of the system implementation.

In the prerequisites stage, a self-assessment of the production system was conducted to objectively diagnose its strengths, weaknesses, opportunities and threats. Figure 4 presents a summary of the assessment. MAVA obtained a total score of 23, which fell into class D under the classification category of the Fisher test [3]. Although the result was not encouraging, it helped the company to identify potential improvement areas as well as JIT elements in quality management, production process, master planning, factory flow, purchasing, education and training, and data integrity. Since striving for new JIT/MRP practice required strong management commitment and support, a steering committee was then formed. The committee provided management leadership and took strategic initiatives for the new system implementation. Three collaborative working groups were formed under the guidelines of the steering committee. First was the mixed-model scheduling group which was composed of the production and material control (PMC) manager as leader, and production planners, shop-floor supervisors, and sales coordinators as members. Second was the kanban system group which consisted of the production manager as leader, and production planners and shop-floor supervisors as members. Third was the procurement group which consisted of the purchasing manager as leader, and procurement officers and PMC controllers as members. The most challenging task was to consolidate mutual understanding and set common goals among staff members toward the new system implementation. Therefore, there have been several internal and external speeches and workshops conducted to eliminate the diversity among staff members and promote a cross-functional commitment toward the new system. With the joint efforts of the steering committee and the working groups, the prerequisites stage has built a nurturing ground for the implementation of the core JIT/MRP programs and tasks. Detailed schedules of the system implementation, together with the required organizational resources, were then determined.

The preparation stage has two elements: JIT concept training and system stability building. A JIT training program was tailored for employees of different hierarchies to drive the new system implementation. There were three tiers of education and training programs. The first tier was a series of seminars for senior managers, aimed at explaining the concepts and benefits of JIT and promoting the new JIT/MRP system. The structure and schedule of the system implementation were also addressed. The second tier was in-house training (with the aid of video materials), which was intended to bring the JIT concepts and the philosophy of JIT/MRP integration to all employees. The goal and schedule of the implementation project were also explained. The third tier was intensive in-house training for the working group members, which was designed to equip them with the JIT/MRP strategies, techniques

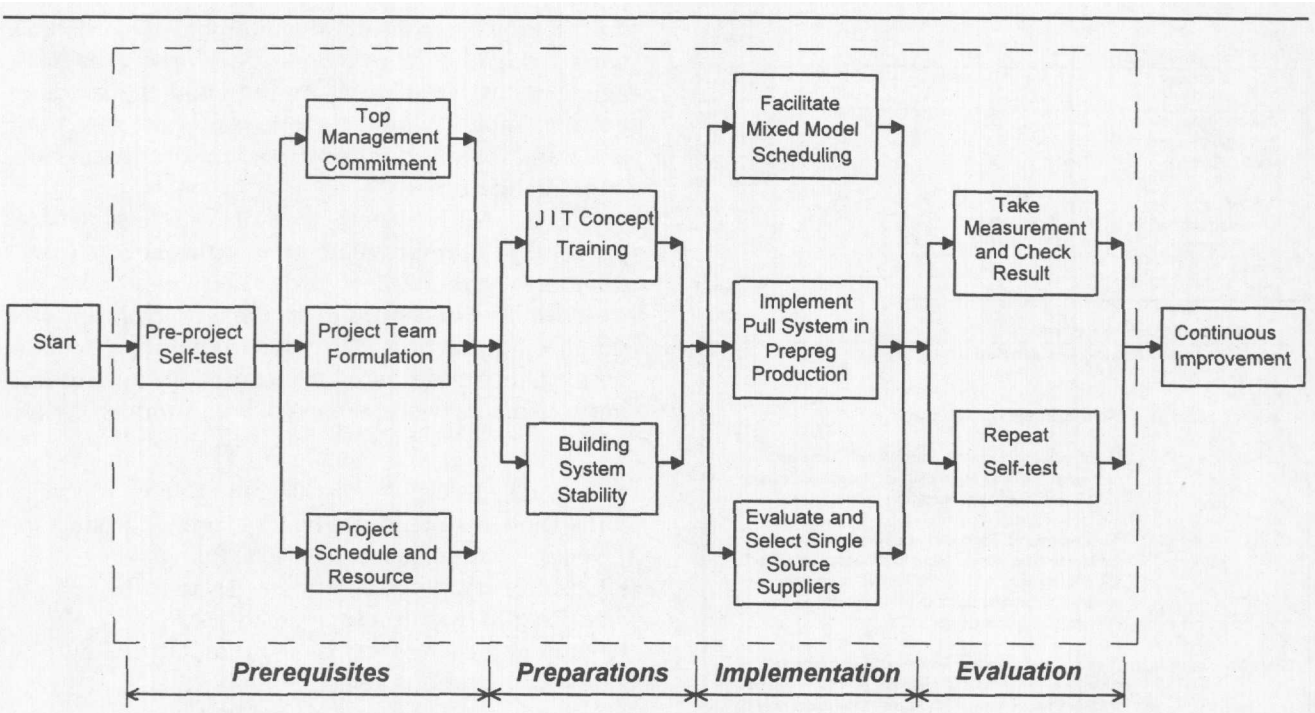

FIGURE 3: JIT/MRP system implementation

and skills to implement the new system across the company. These training programs have facilitated proactive changes among employees and also stabilized the implementation of the new system in the company. There have been several improvement programs (such as preventive maintenance, JIT quality management, and changeover time reductions) proactively initiated in the company during the preparation stage.

The mixed-model scheduling approach, the kanban control system and JIT purchasing practices have been the three building blocks of the implementation stage. Mixed-model scheduling was introduced to formulate monthly master production plans. According to the sales forecast and process characteristics, the company's product mix was segregated into four main categories. Scheduling rules were set to reduce the maximum daily products for each particular product type or model. The daily unitary production schedule was then determined for the mixture of the product models. In other words, more product varieties could be handled in daily production (the average number of models produced per day increased from 4.3 to 6.5). With the reduction of changeover time in the production process and an increase in the flexibility of the sales delivery schedule, mixed-model scheduling improved the quick response to customers, especially for urgent orders. In conjunction with mixed-model scheduling, the kanban system was employed to improve the efficiency of shop-floor control by eliminating unnecessary WIP and shortening throughput time in prepreg production. Moreover, JIT purchasing practices were adopted to consolidate the raw materials and parts into groups, as well as the supplier base. With careful selection of single-source suppliers, a JIT supplier partnership plan was initiated.

In the final evaluation stage, the performance of the new JIT/MRP system was assessed and compared against the predetermined standards and performance indexes of the company. The measured results would then be elaborated to verify the viability of the system.

EVALUATION OF IMPLEMENTATION RESULTS

The new JIT/MRP system was implemented according to its development plan in 1995/96. This was an ongoing implementation and involved all main functional areas in MAVA. Its progress was monitored monthly in the early phases and bimonthly afterwards. The overall performance would be measured and the system audited every

JIT Self Tests Results for Mica-Ava

Item	No. of Question	No. of Yes	
Quality Management	9	7	
Production Process	11	3	
Master Planning	6	4	
Factory Flow	9	1	
Purchasing	7	0	
Education and people	9	4	
Data Integrity	7	4	
Results	10	0	
Total	68	23	→ Class D

Individual Rating Scheme - Repetitive

Use this rating scheme if only one individual is being tested.

Score		
Class A	57 to 68	Well implemented! Don't quit now!
Class B	45 to 56	Some missing elements! Check which items are answered "no" and begin analysis. Prioritize items by cost-benefit then by shortest time to implement.
Class C	32 to 44	Half way there! There are a number of major procedural problems to be solved. More training may be needed. Do not let perceived benefits from JIT slow your attention to process flows and WIP reductions. Investigate support groups.
Class D	**20 to 31**	**You are making some headway! Considerable change to the flows and planning processes will be difficult to overcome. Management support may be lacking or misunderstood. Training in both applications and concepts are an absolute necessity. Support groups will be having real trouble adjusting.**
	Below 19	This could be any company. Many of the basic activities for JIT are also necessary for any well-operating firm. The JIT philosophy will require a refocusing of old planning habits, quality control disciplines, demand management data accuracy, and manufacturing process changes.

FIGURE 4: Self-assessment

six months. A considerable number of problems were tackled by the collaborative efforts of the management, the steering committee and the working groups. Table 1 shows the major problems encountered and the solutions proposed for the new system implementation.

The JIT/MRP system was proved feasible and practical. The improvements in efficiency and productivity have been recorded as a result of the mixed-model scheduling, kanban control, and JIT purchasing practices. When compared with the past performance indexes of the company, measurable improvements were achieved and summarized as follows:

- Inventory levels were reduced by 20% in WIP with the kanban system, and by 25% in final product inventory with mixed-model scheduling.
- Obsolete scrap per month was reduced by 38%, as realized in the latest scrap analysis.
- Setup and changeover times were reduced by 33% to 75% on various items.
- Throughput time was reduced by 43%.
- Supplier lead time was reduced by 30% as more local sources were appointed.

Furthermore, promising feedback was reported from product design and development in eliminating design waste; from manufacturing accounting in simplifying cost tracking; and from marketing in better technical support and servicing. Another Fisher JIT test was conducted, and its results are given in Table 2. This score was 48 which fell into Class B, compared to the score of 23 in Class D at the prerequisites stage of the system implementation, showing a significant improvement after JIT/MRP implementation.

TABLE 1: Summary of Encountered Problems

Step	*Encountered Problem*	*Solution*
Pre-project Self Test:	No major problem.	—
Project Prerequisites:		
(a) Top Management Commitment	No major problem.	—
(b) Project Team Formulation	Some invited members were reluctant to participate.	Replaced the member with his senior subordinate.
(c) Project Scheduling and Resources	No major problem.	—
Project Preparation:		
(a) JIT Concept Education	High absenteeism of some members during training.	Spent much time to explain, discuss and convince these members on the project, some even have to use directives from their superiors.
(b) Building System Stability	Assigned project jobs always finished late in the early stage of the product implementation.	More expediting was required and the situation become better in the later stage.

TABLE 1: *(Continued)*

Model Implementation:		
(a) Mixed-Model Scheduling in Master Production Planning	(1) Productivity decreased and scrap increased due to too much product changeover.	(1) Engineers modified and improved the machines and processes such that it returned to normal.
	(2) Increased usage of indirect materials in the beginning.	(2) In long term, the usage was lowered as the total finished good inventory was decreased.
	(3) For overseas large orders, the benefits of mixed-model scheduling were not significant.	(3) After analysis, the team was convinced that inventory is always a waste and the mixed-model scheduling was still helpful in this case.
	(4) Some methods to reduce changeover time were too costly.	(4) Pressure exerted on the manufacturing engineers to improve. Eventually feasible methods with normal cost are developed.
	(5) Serious interruption of production in the early stage of running the new scheduling method.	(5) Solicit strong management support and seek cooperation from the supporting departments.
	(6) Large amount of JIT (urgent by small) orders come at the end of this stage.	(6) After implementing the mixed-model scheduling, the factory was well prepared for such orders and not many problems found.
	(7) Misunderstanding on project goal by marketing staffs. They just concentrated on the benefits of reduced lead time and make every orders as JIT orders.	(7) Explain to them the production constraints and JIT orders are luxurious and costly. Also discussed raising the product price of the JIT orders.
(b) Kanban System in Shop Floor Control	(1) One process needed a sudden increase in WIP in every month to sustain continuous production in subsequent processes.	(1) Special kanban cards added to account for the sudden increase. Removal of these cards by the MRP control afterwards.
	(2) Usual transfer size between the processes was large and required a lot of kanban cards if each card maintained the basic unit of one.	(2) Kanban cards with multiples of the basic unit are used. Several cards are combined to represent the actual quantity.
(c) JIT Purchasing —single source reliable suppliers	(1) Some materials are not possible to have only a single source.	(1) Dual sources or multiple sources are allowed as long as these are a minority of the total material purchased.
	(2) Some purchasing officers still wanted to maintain multiple source and develop partnership with all. Those suppliers sometimes did not honor their own commitments as there is always backup from other suppliers.	(2) They found that it is difficult and time-consuming to develop partnerships with so many suppliers. Eventually they are convinced that single source is the solution.
	(3) Many distant suppliers were invited to develop as partnership suppliers in the beginning but their response time did not meet our requirement.	(3) More and more distant suppliers are replaced by local and vicinal suppliers for delivery lead-time reduction.

CONCLUSION

MRP deals with establishing an ideal system for inventory control and production capacity arrangement, whereas JIT emphasises the philosophy of waste elimination and continuous improvement. It is advantageous to integrate the dynamic features of JIT into the discipline of MRP to close the loop between the shop floor and the medium- and long-term planning processes. The integration could also drive continuous improvements in production planning and control systems. The case study presented in this article is a demonstration of a successful experience in adopting the

TABLE 2: Fisher Test Results

Item	No. of Questions	No. of Yes
Quality Management	9	8
Product Process	11	8
Master Planning	6	6
Factory Flow	9	6
Purchasing	7	2
Education and People	9	8
Data Integrity	7	5
Result	10	5
Total	68	48

integrated JIT/MRP concepts in a multinational manufacturing company.

REFERENCES

1. Bockerstette, J. A., and R. L. Shell. *Time Based Manufacturing*. New York: McGraw-Hill, 1993.
2. Bowson, D. J. "A Decade of Just-in-Time Experience." *Proceedings of the 33rd APICS International Conference*, New Orleans, LA (October 8–12, 1990): 332–333.
3. Fisher D. "The Just-in-Time Self-Test." *Proceedings of the 33rd APICS International Conference*, New Orleans, LA (October 8–12, 1990): 272–275.
4. Griffith, W. E., and S. F. Tuscher. "Time-Phased JIT: The MRP Path to JIT." *Proceedings of the 32nd APICS International Conference*, Orlando, FL (1989): 601–603.
5. Hobbs O. K. "Application of JIT Techniques in A Discrete Batch Job Shop." *Production and Inventory Management Journal* 35, no. 1 (1994): 43–47.
6. Mejabi O., and G. S. Wasserman. "Basic Concepts of JIT Modelling." *International Journal of Production Research* 30, no. 1 (1992): 141–149.
7. Miller J. G. "Supporting JIT Manufacturing with a JIT Organization." *Manufacturing Systems* (September 1990): 24–30.
8. Oden, H. W., G. A. Langenwalter, and R. A. Lucier. *Handbook of Material and Capacity Requirements Planning*. New York: McGraw-Hill, 1993: 270–282.
9. O'Grady, P. J. *Putting the Just-in-Time Philosophy into Practice: A Strategy for Production Managers*. London: Kogan Page, 1988: 32–51, 80–101.
10. Przybyla, K. "JIT Scheduling with the MRP II Production Environment." *Proceedings of the 33rd APICS International Conference*, New Orleans, LA (October 8–12, 1990): 322–327.
11. Schniederjans, M. J. *Topics in Just-in-Time Management*. Boston, MA: Allyn & Bacon, 1993: 24–154.
12. Sohal A. S., and D. Naylor. "Implementation of JIT in A Small Manufacturing Firm." *Production and Inventory Management Journal* 33, no. 1 (1992): 20–25.
13. Vora J. A., J. V. Saraph, and D. L. Petersen. "JIT Implementation Practices." *Production and Inventory Management Journal* 31, no. 3 (1990): 57–59.
14. Wasco, W. C., R. E. Stonehocker, and L. H. Feldman. "Success with JIT and MRP II in a Service Organization." *Production and Inventory Management Journal* 32, no. 4 (1991): 15–21.

About the Authors—

KIT-FAI PUN is a lecturer in the Department of Manufacturing Engineering and Engineering Management at the City University of Hong Kong. Before joining the teaching profession he worked in industry as an operations executive, researcher and engineer. He has also provided consultancy and in-house training services to companies in Hong Kong and Mainland China. Mr. Pun is a member of the Society of Manufacturing Engineers, ASQ, and IIE (USA), and the Hong Kong Society for Quality and Hong Kong Computer Society.

KWAI SANG CHIN, PhD, is an assistant professor in the Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong. Before joining the university, Dr. Chin had more than ten years of experience in the manufacturing industry. He is a Charter Engineer in the UK and a Registered Professional Engineer in Hong Kong. Dr. Chin is a senior member of IIE and the Society of Manufacturing Engineers (USA). He is currently the Hon. Secretary of the Hong Kong Society for Quality. His current research interests are future product development strategies, quality management strategies beyond ISO 9000 for Hong Kong and China, and the use of expert systems technology in product design.

K. H. WONG is the Director of Engineering of the Meadville Group and the Operations Manager of Mica-AVA (F.E.) Industrial Limited. He has worked in the assembly, PCB and laminate businesses for more than 17 years, in the areas of production, PMC, quality control, purchasing, maintenance and engineering.