A Case Study of ERP Implementation for PCB Manufacturer

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Abstract

This study researched an enterprise resources planning (ERP) implementation project at a printed circuit board (PCB) manufacturer. In depth research was achieved by participating and observing in an implementation project at an actual PCB manufacturer. It is hoped that this study will contribute a valuable reference resource for future PCB manufacturers that wish to select or implement ERP systems. The first step in implementing ERP software is to set a clear target. At the same time, the tasks of each department and the system of cooperation between departments must be clearly defined. In this way, the cycle time of each flow and the accuracy of data will both be improved. In order to ensure smooth implementation of an ERP project, the followings are key factors: (1) an ERP system that suits the PCB industry; (2) effective project management; (3) effective project cost/budget control; (4) project problem management system; (5) comprehensive implementation method and information technology (IT), etc. By keeping to these principals, Company A achieved rapid transactions, and lower total cycle times and inventory levels, and other such benefits that had been predicted.

Key Words: Enterprise Resources Planning (ERP), Information Technology (IT), Transaction System

1. Introduction

Transparency and quick apprehension of information have become absolute necessities for any enterprise wishing to compete in today's world economy. Enterprises are all seeking flexible production, quick packaging, rapid transactions and shorter product life cycles. In this intensely competitive business environment, only wise usage of information technology (IT), effective combination of IT and company resources, correct decision- making, and timely satisfaction of customer requirements can enable a firm to regularly take advantage of business chances. The vast majority of Taiwan's manufacturing firms have implemented information systems that employ finance accounting, PMI (Procurement-Marketing-Inventory), warehouse control, production scheduling and material requirements planning (MRP) systems [13]. Recently in Taiwan, we see global operation management becoming commonplace. The Department of Industry of the Economic Bureau aggressively pushing its "Corporation Automation and IT" promotion, and more Taiwanese companies moving to the mainland. This set of circumstances has made integration of upper and lower levels of the supplier chain management system an urgent necessity for manufacturers [14]. Therefore, the process of making firms electronically compatible includes making all internal operations and all communications with upper and lower members of the supply chain electronic. Enterprises have come to accept the validity of the concept and methods of the "from internal to external" approach to compatibility. This approach requires first integrating internal information, then coordinating with suppliers above and beneath. The ERP systems can meet these internal information coordination requirements while simultaneously creating a proper foundation for integration with upper/lower members of the supply chain.

ERP has evolved from MRP I and MRP II. These forms of traditional resources planning placed emphasis on an accounting-oriented, transaction-based information system [1]. Different industries (IC packaging, semiconductor, PCB, IC design, etc.) have different requirements and methods. The electronics industry, long the leading exporter of Taiwan's manufacturing industries, has had the greatest need and support for electronic compatibility [13]. The main reasons for this have been the government's promotion of supply chain planning (plans A, B, C, and D), overseas plants' requirements, the importance of electronic compatibility, and the necessity of information management brought about by the migration of plants overseas. On top of that, Taiwan's electronics industry is principally engaged in performing manufacturing operations for tasks (OEM, ODM) that place emphasis on delivery date, production flexibility, cost, safety and quality. Electronics manufacturers are thus struggling to reduce cost, shorten delivery time and achieve customized production and at the same time not sacrifice profit. Therefore the role of an information system especially suited to the manufacturing industry-ERP-grows greater day by day.

Over the last ten years, in terms of production value, Taiwan's PCB industry has been near the top of the list. The reasons for this success story include the quality of the work force, wise investment, the proliferation of collaborative production with upper level members of the supply chain, the rapid growth of lower level member information industry, and the steady increase of computer sales. All these factors caused Taiwan's PCB industry to grow at a constant pace. Among the many electronics industry suppliers, PCB manufacturers are comparatively upper level. PCBs are widely used in all types of electronics facilities and equipment. Due to the fact that cross-straits trade becomes more commonplace by the day, the need for information systems, in particular manufacturing information systems, has become very strong. How to maintain the cooperative setup employed up to this time with mainland China, ascertain reliable production and manufacturing information, supply parts/materials and production status has already become a major challenge that the PCB industry must face and overcome. Likewise, how to implement a PCB manufacturing ERP system which, while adhering to the principals of integration and self-control, achieves quick response (QR), satisfies delivery deadlines, achieves on-site management, and increases competitiveness with the industry has become the focus of PCB manufacturers.

This study researches the implementation of an ERP system to a PCB manufacturing firm, Company A. By actually participating in an ERP implementation project and performing in depth investigation and analysis, we hope to provide future PCB manufacturers with a valuable reference that can be used when selecting or implementing ERP systems. Company A was established in 1971; annual profits approximate 2 billion NT, workforce approximates 1000. The major products are the PCB used in production data transfer and storage. Currently this firm is in the process of making all its production facilities electronically compatible. The firm plans to have the entire ERP system on-line by the middle of 2003. In the latter half of 2003, the firm plans to expand electronic capability to upper and lower supply chain members and other companies with which it has dealings. In this way, it hopes to strengthen supplier chain response speed. Company A currently relies on a close finance and PMI system. There is a system, Legacy System, to deal with work-in-process (WIP), machine control, etc. and to maintain company sales related tasks. The information system is structured as illustrated below.

Finance, human resources (HR) and PMI are performed with a closed platform. Because the system has been used for twenty years and is a closed system, it does not have the information processing ability to deal with the future strengthening of the supply chain. Shop flow WIP and work order processing is performed with the shop floor control software supplied by the local software company. Ultimately, this system lacks the ability to integrate front-end sales, purchasing, and inventory with back-end finance operations. Moreover, the existing system is already showing signs of being unable to keep up with the demands of the latest technology (e.g. HDI), short-term delivery deadlines, and flexible production. Therefore, the plan to be implemented will be chiefly a replacement of the existing closed transaction and WIP system. Company A currently accepts orders via the Internet and performs simple electronic tasks such as issuing purchase orders, transferring manufacturing information, etc. Therefore, as shown in the Figure 2 ERP/E-Business Matrix [6], after Company A implements ERP system, electronic compatibility will shift from position A to position B. The integrated ERP solution scheme provides for integration of customer with supplier operations and front-end with back-end tasks, thereby strengthening the connection between upper and lower level suppliers.

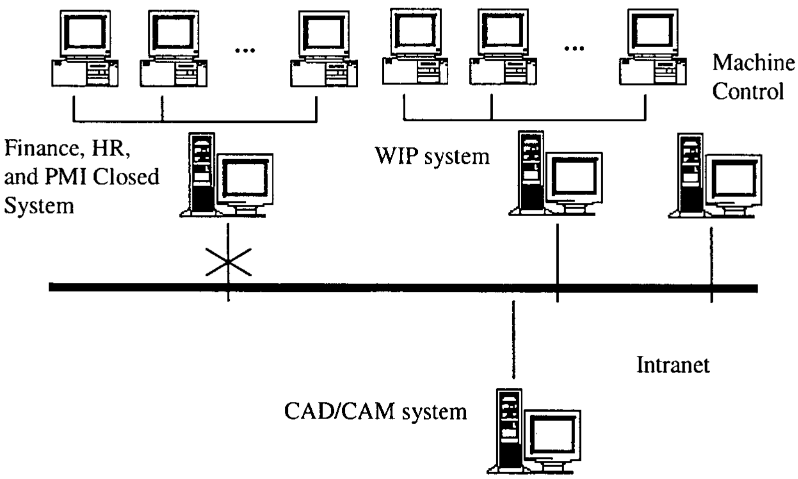

Figure 1. Company A's IT Structure

2. ERP Solution Selection

Currently, the ERP software functions in virtually the same manner whether dealing with finance or with distribution/marketing.

Therefore, Company A selecting ERP software must consider not only cost, but also manufacturing module functions. Whether or not the software framework is flexible and has the ability to go electronic in the future are matters of the great importance. Especially vital is the ability of modules' functions to accommodate characteristics specific to the PCB manufacturing industry. The Taiwanese PCB manufacturing industry production style possesses the following characteristics:

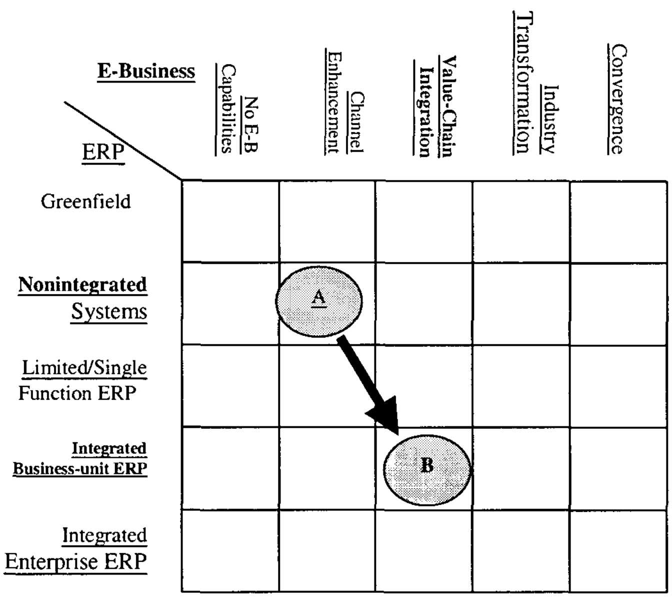

Figure 2. ERP/E-Business Matrix

1. Production is "build-to-order" and the focus is on export, therefore enterprises must amass experience in opening markets and must apply for tax-free benefits in order to lower cost, save on taxes, and increase profit.
2. The PCB industry places an especially high value on quality, price, safety, and delivery deadline. The manufacturing process involves more than ten stations and can significantly influence product quality. Moreover, WIP statuses must be constantly maintained and production rate must be constantly estimated.
3. PCB production process changes are plentiful. The equipment used for each production process is highly expensive. Production capacity discrepancies are great. Often the production conditions demand substitutions in the schedule or generally place on burden on production control.
4. Products are composed of a wide variety of raw materials. Control of material quality, inventory quantities, and entry into the manufacturing process is extremely complex. Proper usage of units of measurement (UOM) is imperative, e.g. when coordinating tasks, arranging shipping, etc.

From the Figure 3, we see that communication between the order-received system and the production system is highly important. The ERP system must enable the front-end sales system to transfer order requirements (e.g. specifications, delivery date, etc.) to the back-end system, where this information will be used as a basis for production classification, production entry, and task assignments. At the same time, the ERP system must enable flexible routing division, routing combination, and replacement of materials. Each station's production status must be fed back to the front-end system, thus providing a reference that can be used to respond to customers. In addition to the above, transfer and feedback of shop floor information must be immediately reflected in the financial system.

Therefore, an excellent PCB ERP system must take into account the following information:

1. Before receiving orders, delivery date must be set and quotations given based on correct assessment of the following requirements:
  (1) Materials: PCB board, copper foil, film brand and specifications.
  (2) Construction: Quantity and part number of inner and outer panels to be conjoined.
  (3) Process Specifications: Material and model size (including panels and PSC).
  (4) Manufacturing Process: The settings concerning standard materials used during inner and outer panel processing and standard operations.
  (5) Predicted Material Usage and Manufacturing Quality: Each inner and outer panel processing operation, including settings concerning wear and damage of standard materials.
2. When receiving orders, one must take into account manufacturing specifications, capacity, cost and other limitations as well as the supply of original materials, tax exemption, finance matters, and other required tasks.
3. During shipping, provisions must be made for shipping grade, distribution, and applicable documentation.
4. Because PCB industry manufacturing processes are complex, division of tasks is detailed. Therefore production processes and inspection tasks must take into account pilot run, mass production, batch sizing, and even mixed production and quality problem countermeasures. Provision must also be made for SPC (statistical process control) and WIP.
5. New manufacturing technology must consider developments of the recent years; for example, HDI, BGA, etc. In order to accommodate new technology, the information system design must have flexible manufacturing setup capacity.
6. The actual production capacity of a PCB manufacturer is limited, and often the actual

order of production/marketing operations is adjusted to accommodate other demands or equipment repairs. To ascertain whether or not those who control production and materials will be able to meet the new order's deadline, a production capacity simulation must be executed, and perhaps even a material requirements plan simulation. These simulations will reveal whether production capacity and material quantity are over or under what is necessary. Once this is known, execute capacity review and material requirement adjustment (CRP/MRP).

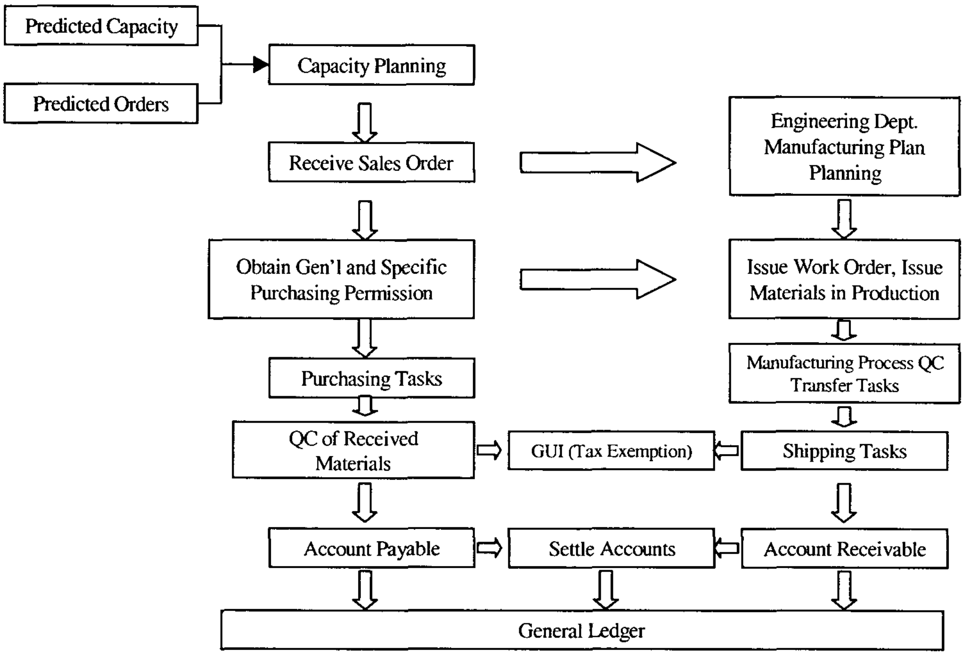

Figure 3. PCB Manufacturer Operation Flow Model

In addition to the standard production scenarios, the PCB industry often adopts three outsourcing scenarios: (1) outsourcing of all production processes; (2) outsourcing of a single process; and (3) outsourcing of pre-processing operations. These scenarios, which are explained below, are often necessary because PCB production requires significant equipment investment. Outsourcing may also be selected to deal with differences in pre-processing and specialized production sub-processes levels of technology and wide discrepancies in production cost and degree of difficult in obtaining materials used.

1. All Production Processes Outsourced: When receiving orders, manufacturers must take into account what will be performed in-house and what will be outsourced. Reasons for

outsourcing include technical level considerations, production cost, the presence of three party transactions, or the fact that part of production is performed on the mainland. Because it is difficult to predict material value, inspection task load and material preparation time, the outsourcer often must prepare materials for production on its own-it does not have the luxury of simply processing the materials with which it is supplied.

2. Prep Processing Orders Outsourced: Because prep processing requires great human resources, manufacturers must judge whether or not there is a need to have a layout (inner/outer board) drawn up and/or put on film by an outside firm. The former requires that personnel with a high degree of engineering knowledge create a layout design, the latter requires considering whether or not the completed negative will be able to withstand the potential damage inflicted during exposure/development.
3. Outsource a Single Process: Normally a single process is outsourced because of product cost or production load considerations. The supplier selected must be carefully monitored for quality and delivery deadlines.

Based on the above special demands of the PCB industry, currently there are, broadly speaking, two types of information systems being used by PCB manufacturers: ERP system and MES (manufacturing execution system). These two systems are supplied by different software companies, thus in a competitive atmosphere where manufacturers are striving for quick response and global competitiveness, the interface between these two must be strengthened-the more thorough the measures taken, the better the benefits gained. In selecting a software supplier, Company A's main priority was suitability (i.e., has a good reputation; is suitable for the PCB industry and for Company A's operations, scope and cost restrictions). After calculating its own financial ability, resources, and the factors that caused competitors to fail to implement successfully, Company A decided to seek an ERP software with an flexible structure and comprehensive functioning. Furthermore, they sought an ERP software that had been used in the PCB industry and in setting up a plant-wide information system. After selecting ERP software structure, Company A contributed domain knowledge and began developing production modules. In the end, Company A selected I-ERP, a PSITech Information ERP System that used Delphi as its development tool. Company A utilized this software to establish an ERP designed for PCB manufacturing ERP systems.

3. ERP Implementation Project

3.1 Implementation Plan

There are three basic ERP implementation strategies available [8]: (1) The Step-by-step Strategy, in which one module at a time is implemented; (2) The Big Bang Strategy, in which function modules are implemented all at once; and (3) The Roll-out Strategy, in which construction is first carried out, then activities are gradually implemented. This project selected the Big Bang Strategy for standard modules and the Roll-out for those modules which were specific to the PCB manufacturing industry. Table 1 below describes the Roll-out stages of implementation.

Table 1. Stages of Implementation

Stage	Functionality
I	GL, AP, AR, VAT, INV, PO, OM, GIB, HR
II	WIP, ENG/BOM, COST, OSP, QC
III	HR Customization

3.2 Implementation Process

The implementation steps and method of ERP project are shown in Table 2. The starting time is from May 2002. The firm plans to have the entire ERP system on-line by the middle of 2003.

4. Analysis of Implementation Problems and Benefits

Many scholars have researched the crucial factors that lead to the success or failure of ERP implementation [2, 3, 7, 8, 10, 11, 15, 16, 17]. In this study, we identify four such factors: system, project management, employees and enterprise culture.

1. System: Factors that have to do with ERP systems include those described below.

(1) ERP Software Function Degree of Comprehensiveness (Transnational Demand). During implementation, on the one hand it is hoped that ERP software will be suitable to the industry demands, on the other it is hoped that the ERP system tools will provide a certain level of effectiveness and thus help the firm execute re-creation of flow. Employees at different levels of the organization will have different expectations of the ERP software implementation and business process reengineering (BPR). When high executives have decided to implement ERP software, it means they have no doubts about the importance of ERP (or else they would not make such an investment). From this we can tell, to make an

ERP project succeed, a certain degree of alteration of the enterprise flow and information system in unavoidable [4]. Two crucial challenges that must be overcome are (1) making the employees who are in charge of operation processes willing to accept changes, i.e. convincing them that ERP flows/methods are superior to current ones and (2) how to express the project progress status in a manner than high executives can understand.

(2) ERP software cost.

(3) ERP software future expansion ability. Must be able to expand to conform to future functions or business models.

2. Project Management Concerns: Normally emphasizing current project control technology, project control tools and effective communications, etc. Besides these, change management, e.g. dealing with project scope change, rotation of consultants, key-users, etc., is a crucial factor in regaining a grip on a project [5].
3. Employees: Includes implementation consultants, implementation project members, key-users, and end-users. Consultants must possess implementation expertise, communication skills, industry knowledge, etc. Implementation project members must be carefully selected from company employees. Project enthusiasm must be intensified. Employees must also be provided with a suitable degree of career guidance and education/training.
4. Enterprise Culture: At the onset on the project, clear project objectives must be established (for example, this study used total cycle time as one project objective). After becoming thoroughly acquainted with company culture, a variety of strategies are employed to achieve project objectives.

The rest of this paper utilizes the principals and factors just described to analyze the problems and benefits uncovered during implementation of ERP system.

4.1 Investigating Implementation Problems

Problem 1: Controlling New Requirements and Specifications

Before the PSITech information system was implemented, each of Company A's information systems (payroll, shop floor control, accounting, production management, etc.) was purchased at a different time and supplied by different software companies. The software of each department was designed for that department's specific needs. Therefore each department operated under self-serving principals in carrying out tasks: the idea that tasks should serve other departments and the company as a whole was lacking.

During ERP implementation, a variety of obstacles crop up: those that demand expert judgment, those that concern flow, education, company culture, etc. To deal with these obstacles, experts from a variety of fields (in-house or external consultants) who can carry out their duties with high-level reasoning and communication skills are necessary. However, each expert will add a bit of his/her own particle "style" (or prejudice) to the system. Even though automated systems impress people, if there is too much automation or flashiness for the functionality provided, weaknesses will be created at the management/control level. Often the newly implemented system is judged using the perspective engrained by the old system, and this often gives rise to "new requirements," especially during Stage II and III of project implementation. Dealing with this phenomenon requires (after getting confirmation from key-users) using the documents that were to be created at each implementation step (as shown in Table 2), to ensure that the problems of each step can be thoroughly checked and tracked and a rash of new problems/demands does not emerge during Stage II or III of project implementation. Therefore, a Company A's internal "customer problems and project problems control" system should be implemented to create project manager and project member guidelines, to control the project operation platform, and thus to ensure that implementation process problems are subject to real time control.

Problem 2: Shop Floor Employee Education and Training

The development of the manufacturing module and its coordination with other modules are vital to project success. Therefore, the cooperation of shop floor employees must be obtained: assuring their obedience and general work quality is vital. A major challenge is to get workers familiar with using computers before going on-line; they must have a sufficient degree of familiarly with the new system and interface tools. When implementing the manufacturing module, key-users must first be trained. These key-users should be used to execute the pilot run, during which actual data should be used to perform actual tasks (like allocating materials, performing materials account transfer, dealing with WIP, batch sizing and inventorying, etc.). After such tasks can be performed smoothly, then key-users should proceed to train end-users, thereby reducing the risk involved in officially going on-line.

Problem 3: Enterprise Culture

Because Company A has a history of thirty years, it possesses a certain degree of the culture typical in such well-established enterprises. Monitoring and controlling the project amidst this entrenched culture required great effort; moreover, the number of implementation modules being controlled was sixteen. Thus to ensure that the project got on-line successfully, careful control

Table 2. Steps of Implementation and Documentation Utilized

Steps of Implementation	Task	Consultant Company	Company A	Documentation
(1) Operation Current Status Analysis	Training	Provide Training	Participate in Training Classes	Observations/Thoughts, Actual Operation
	Task Analysis Preparatory Task Explanation	Provide System Task Flow	Collect Current Task Flow and Requirements	ERP System Flow, Current Flow
	Task Analysis Meeting	Discuss Data	Detailed Description of Current Task Flow and Requirements for Future Computerization	Meeting Record
	Confirm Task Analysis Report	Provide Task Analysis Report	Confirmation Report	Post-confirmation Task Analysis Report
(2) Solution Alternatives Design	Enterprise Demand Meeting	Function vs. Task Explanation	Submit Opinion	Function and Task Explanation
	Enterprise Demand Confirmation	Function vs. Task Explanation Document	Confirmation Report	Post-Confirmation Requirement Report
	Discrepancy Analysis Explanation Meeting	Function and Task Explanation Document (with specs)	Participate in Discussion	
	Discrepancy Analysis Confirmation Report	Discrepancy Analysis Confirmation Report	Confirmation Report	Post-Confirmation Discrepancy Report
	System Environment Settings	Settings for System Parameters	Provide Test Data	System Parameter Settings
(3) Solution Alternatives Construction	Establish Standard Task Flow (SOP)	Hold Standard Task Flow Confirmation Meeting	Establish Standard Task Flow	SOP (Standard Operation Process)
	Project Trial	Simulation Data Checklists	Provide Flow Trial Project for Each Module	Trial Report
(4) On-Line Plan and Preparations	Create Documents and Transfer Data	Provide Support	Create User Documents; Training; On-line Environment Settings; Data Transfer Plan; Data Transfer Program; Data Transfer	

and scheduling were absolute necessities. Some of the tools used towards these ends were the daily log reflections, the work breakdown structure/schedule (WBS), Microsoft Project, etc.

4.2 Benefits after Implementation

Lowering total cycle time was one of the goals established at the beginning of the ERP project. Total cycle time is defined as "the time elapsed from the moment the customer expresses demand (by placing an order, inquiring about price) until the moment of order fulfillment. [12]" Total cycle time encompasses all the cycle times of all tasks and subtasks necessary to fulfill the customer order. As domestically implemented ERP systems are still in the development/maturing stage, their potential is not fully known [9]. Moreover, this project is still in the process of being implemented (scheduled completion date: July 2003). Thus this study's benefit portion was based on reasonable assumptions. Detailed evaluation of benefits will have to wait until after the system is up and running. We anticipate that the implementation of the ERP system will bring the following three benefits to Company A:

1. Real Time System: Because the front-end PMI(Procurement-Marketing-Inventory) system will be integrated with the finance and manufacturing systems, quick response (QR) to customer demands will be realized.
2. Total Cycle Time Reduction: Customer order placement, creation of work orders, purchasing materials, outsourcing, production of finished products, and stocking will all be performed on the same platform, thus total cycle time will be reduced greatly. At present, the most obvious benefit is that the monthly process of settling accounts has been shrunk to about ten days.
3. Inventory Level Reduction: This is the most common positive effect [9]. After total cycle time has been shortened, average inventory level will naturally drop [12].

5. Conclusions

In this study, we investigated and analyzed the ERP implementation process by actually participating in an implementation project at "Company A". Our observations revealed that ERP implementation projects must adhere to the functions, task flows and modules provided by the software. The company's existing flow must be re-thought and modified. According to our findings in the section of this paper devoted to ERP project key factors (part four), it is evident that in implementing ERP software, a firm must first establish objectives and at the same time clarify the objectives of each section and the manner of cooperation between sections. This will ensure the improvement of data accuracy and the cycle time of each flow. To smoothly implement an ERP project, sufficient software development capability, completely suitable software functions, effective project management, successful cost control, a comprehensive implementation method and a system for presenting and dealing with problems are all necessary. In addition to providing for these positive elements, the below listed PCB plant and ERP project negative phenomena must be avoided. If this can be done, PCB manufacturers will find that selecting ERP systems and implementing ERP projects will be smoother and far more efficient.

1. The flexible demands of the production process tasks are higher than the ERP functionality can provide (e.g. merge/split batch sizing tasks).
2. Because ERP flow design requires cost management, comparison of the old and new production control is rendered impossible.
3. Basic production data must be frequently drawn up. The construction method that offered by ERP (using assembly design models) system is often unacceptable to PCB manufacturers.
4. The demands regarding shop floor control were high. There was no way of using the WIP in the ERP system to satisfy the demands.
5. System coordination (between ERP and the shop floor control system) cost benefit analysis is difficult. This raises the risk level of tasks related to system implementation and subsequent continued usage.

Acknowledgments

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