Integration of Enterprise Resource Planning Systems into a Production and Operations Analysis Course*

WOOSEUNG JANG and HUAY HUAY LIM
Department of Industrial and Manufacturing Systems Engineering, University of Missouri–Columbia, Columbia, MO 65211, USA

The use of a commercial Enterprise Resource Planning (ERP) system is integrated into an Industrial Engineering (IE) curriculum. The ERP system, a business information system that considers all facets of a business, provides an integrated presentation that is needed to emphasize the connections and balances of fragmented topics. It also creates an active-learning environment that uses the appropriate technology. In addition, the integration simulates real employment and addresses many industrial concerns. Teaching the industry's needs to students and introducing them to a state-of-the-art ERP system can pave the way for their future development.

INTRODUCTION

INDUSTRIAL ENGINEERING education today is undergoing great changes. Many of these changes are driven by the ABET 2000 criteria [1] and the concerns expressed by business and industry [2–4]. There appears to be agreement at virtually every level that the content and the delivery method of engineering education need to be changed. As an approach to solving these issues, we integrate the use of a commercial Enterprise Resource Planning (ERP) system into our curriculum. This approach allows us, to a certain degree, to simulate real employment and to address many industrial concerns. It also develops an educational experience that activates the talents and capabilities of all students by immersing them in active-learning environments that use the appropriate technology.

The changes in information technology are affecting the way that business is conducted in any type of enterprise, from basic innovation and product/service development and design to product/service delivery. The ERP system, a business information system that integrates all facets of a business including planning, manufacturing, sales, and marketing, has become very popular, thanks to new technologies. In just a few short years the ERP market accounts for over half of the total dollars spent on software licence and maintenance fees. ERP system sales are expected to grow by over 20% per year in the next five years. ERP is the foundation of a future trend towards the full integration of enterprise-wide applications [5–7]. The literature agrees that it is a prerequisite to the successful deployment of e-commerce and e-business applications [8]. The leading vendors of ERP systems are SAP, Oracle, PeopleSoft, JDEdwards, and Baan.

We use the SAP R/3 ERP system in our curriculum. The SAP R/3 system is considered to be the most popular ERP system. SAP has supplied business application software to over 7,000 companies in 40 countries. The system is supported with extensive training and implementation assistance programs. It uses an integrated relational database and consists of client–server information systems. It has four main modules: Sales and Distribution (SD), Materials Management (MM), Production Planning (PP), and Accounting (AC). These four modules operate in real time to capture the process and transaction data and to instantly reflect them in the general ledger account balances. The processes support customizable forms to record and edit data and reports to summarise information for managers, clients, and suppliers. Thus, the SAP R/3 system effectively integrates both the engineering and business processes. Figure 1 illustrates examples of the business processes with SAP functionality. The application topics and issues of the SAP system can be found in many publications [9, 10].

The main course into which we have integrated the ERP system is Production and Operations Analysis (P&OA). This is one of the required courses for the industrial and manufacturing systems engineering students at the University of Missouri–Columbia. The course objective is to teach students various production and operation theories used in modern manufacturing and service systems. This course covers topics such as forecasting, aggregate planning, inventory control, material management, scheduling, and integrated
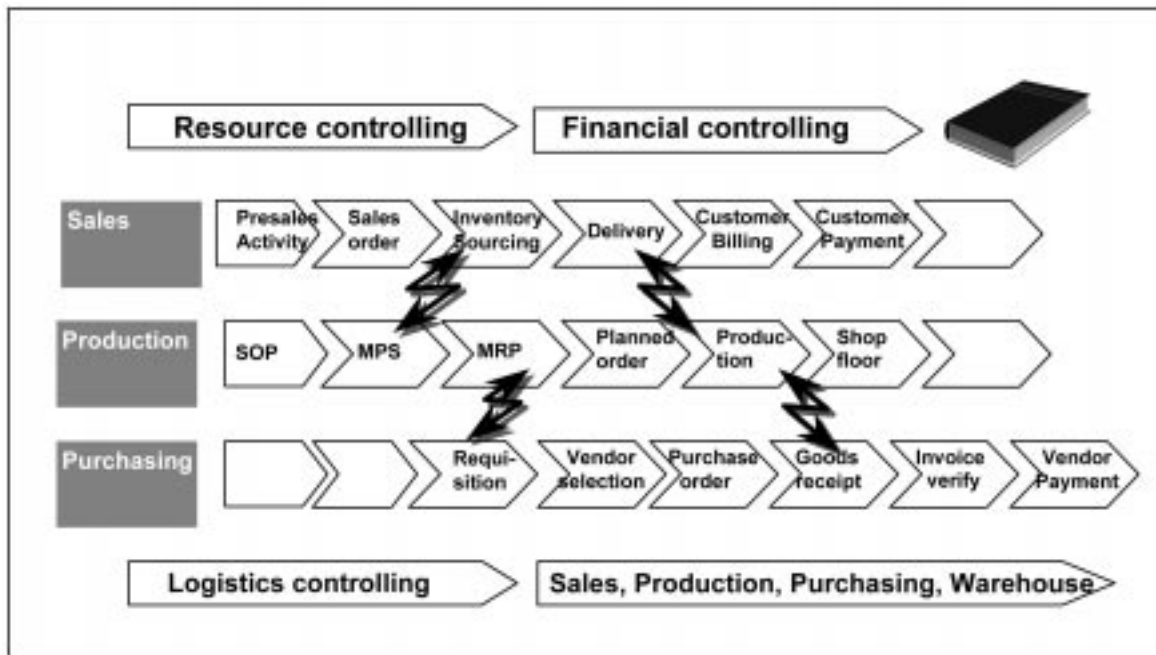
Fig. 1. Business processes with SAP functionality (copyright by SAP AG).

production control. It also discusses the role and structure of information systems used in production and operation management. Throughout the course, students apply the concepts they have learned to the ERP system and use it to solve a wide range of problems.

BENEFITS OF USING AN ERP SYSTEM

Thanks to advances in information technology and software design, interactive tools or software usage has become very common in engineering colleges. Moreover, interactive tutorials are motivated by the need to help engineering students develop a more intuitive understanding of the basic concepts that are important for engineering design and analysis. These concepts are often lost while learning specific computational tasks [11]. Many articles in the technical literature discuss the various software and hardware tools and techniques used in learning environments [12, 13].

The benefits of ERP systems to education can be numerous. However, academic institutions have been lagging behind the corporate world in introducing topics such as ERP into their curriculum, and many industrial engineering courses still do not follow the information technology revolution. Hence, engineering students have few chances to experience commercial business information systems. There are complex reasons for the lag effect, but certainly the cost of systems, untrained faculty members, and the lack of appropriate teaching materials are some of the major reasons.

In our P&OA course, we use the SAP R/3 default program that was installed for training and curriculum purposes. It is used as both a presentation and a problem-solving tool. The program operates like a virtual company and has the ability to provide students with close-to real business transactions utilizing better visualizations. This program encompasses all of the essential engineering and business processes, including financial, sales and distribution, production planning, and material management. The program also allows instructors the option to make integrated presentations when they are needed to emphasize the connections and balances among fragmented topical presentations. This, in turn, provides students with an integrated understanding of the basic concepts in the course and enables them to build a stronger platform so that they will be able to more easily assimilate new technology as it evolves.

Our approach balances the narrow focus of practice problems with the numerical solutions or graphical interfaces. By utilizing this software package, a new concept can be presented at a level of detail that is not possible in textbooks or blackboard presentations, as pointed out by Wood [14]. Furthermore, the ERP system provides better environments for learning through interactive modification, dynamic presentation, the multi-colored observation of results, the conceptual description of examples, and showing several perspectives simultaneously.

Another benefit of using an ERP system is that it provides more examples than would normally be covered in most textbooks. Students are also able to identify the significance level of given problems and to distinguish the main structure of each assigned problem. Its advantages include the capability of performing large and complex calculations in a short period of time and the ability to

Fig. 2a. General customer data (copyright by SAP AG).

generate 'what-if' analysis so that many alternatives can be investigated.

An ideal software package would be one that is easy to use and can be adapted to engineering courses. Although the implementation of an ERP system requires a significant initial investment, it is easy to maintain and adapt. Considering its popularity in the marketplace, it is a great opportunity to introduce an ERP system to students. This experience will better prepare the students for the real-world industries, where they will likely encounter the use of an ERP system.

The disadvantages that we have found include the considerable amount of time commitment from faculty members and the limitations of the installed ERP system. Because the system is in a training and education mode, it does not include a complete database for students to explore all of the available functionalities.

COURSE STRUCTURE AND EXAMPLES

The focus in engineering education is moving from an emphasis on theory to a balance between concrete experiences and analysis [15]. We reformulate the content and delivery to better provide diverse learning in our P&OA course. We also use hands-on activities, interactive multimedia content, and improved team dynamics for enhancing an IE curriculum.

The P&OA course uses two main delivery methods: class lectures and laboratory sessions. During class hours students first learn theoretical aspects of each topic, including concepts and methodologies, and solve exercise problems. In addition, students are required to attend laboratory sessions, where they apply what they have learned by creating the same situations and by finding and implementing solutions in the ERP

Fig. 2b. Material master data (copyright by SAP AG).

system. Handouts present the step-by-step procedures for students to navigate through engineering and business processes within the system. Thus, students can fully understand and try different transactions in the system. Exercises are assigned to ensure that students understand the system and its processes as they navigate through it.

At the end of the semester, students are required to develop and solve case studies by applying various production planning and control techniques learned in their class. A case study is a business problem similar to those faced by individuals in real-life organizations. It is a descriptive situation, actual or simulated, in which decisions must be made or actions taken to solve a problem. Cases usually provide a richer student experience than that found merely by doing exercises. A good case study contains key elements such as relevance, motivation, active involvement, and consolidation/ integration.

Case studies used in this class combine multiple engineering and business problems to mimic the real working environment, unlike typical cases, which focus on only one issue. Students facing case studies as team projects are expected to use the ERP system as one of the key tools needed to provide problem identification, analysis and action.

The several examples we used in the lab sessions are outlined below to better illustrate the course work covered using the ERP system.

Company and material information

In order to execute transactions in the ERP system, it is necessary to create the appropriate company and material data. Figure 2a demonstrates general customer data, such as the customer number, name and address. Figure 2b displays the basic view of the material master data. General product information such as the material group and the product dimensions is currently shown. Other information, such as production type and
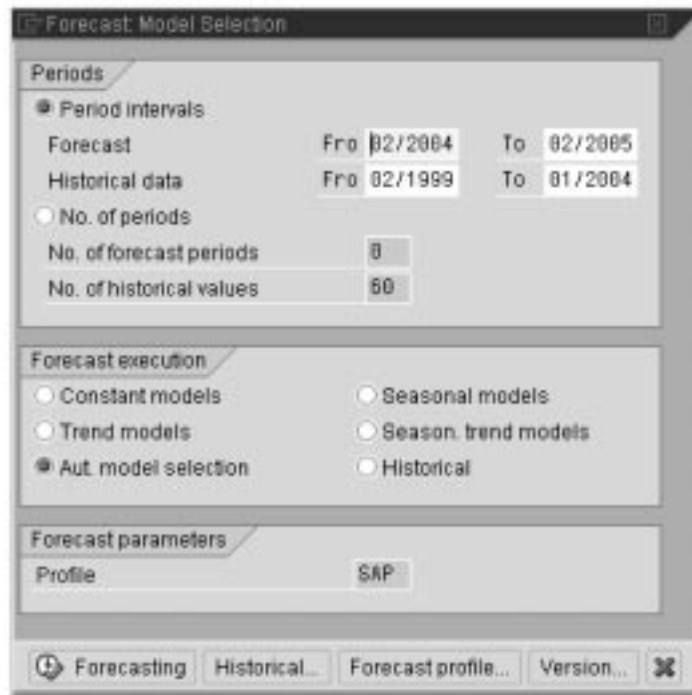
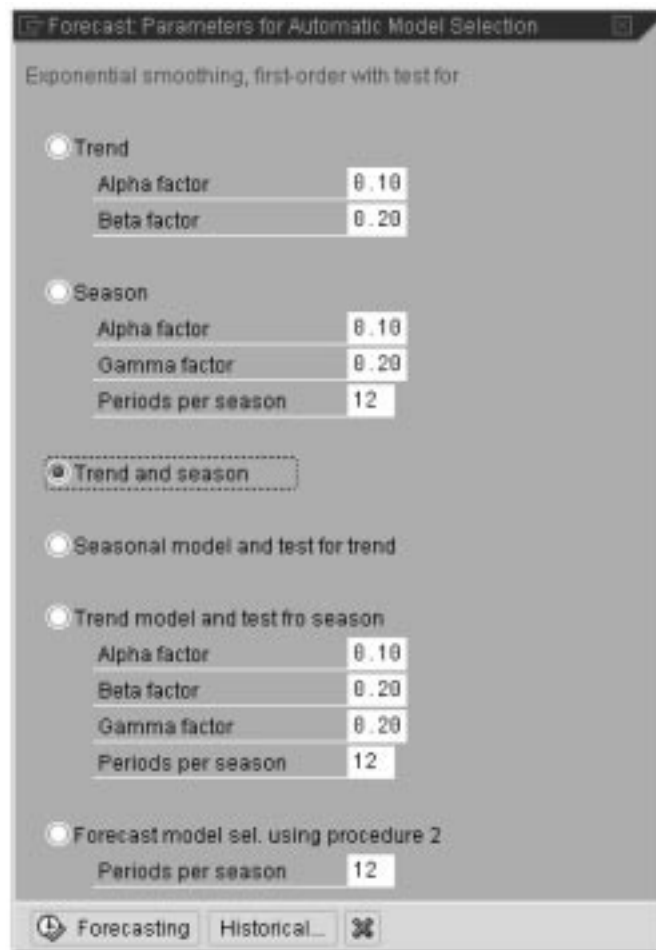Fig. 3a. Forecast model (copyright by SAP AG).

Fig. 3b. Parameter selection (copyright by SAP AG).

Fig. 4. Production plan (copyright by SAP AG).

time, lot size, inventory, lead time, and work scheduling information, can also be displayed.

Demand forecasting

In this example, we illustrate the procedure used to forecast customer demand based upon historical data. In today's market-driven production systems, forecasts are more important than ever. It is essential for students to learn a wide range of forecasting techniques, their underlying principles, and their usage. It is also important to monitor the forecasts and to adjust them if necessary. The ERP system enables us to perform these activities fairly easily by using several time series forecast methods such as constant, trend, and seasonal models. After learning theoretical concepts in classes, students can apply these various models with different parameters for given data sets to determine the best forecasts. Figs. 3a and 3b show forecasting model and parameter selection screens. The results of demand forecasting are used for production planning in the next example.

Production planning

Based on estimates for end product demand (sales level) obtained from any of the forecasting approaches and planning measures such as target stock level and target day's supply, we can create periodic production plans. Figure 4 shows one of such examples. It displays the sales level estimation, target stock level, and monthly production plan. This production plan is later used in the Material Requirements Planning module to determine the detailed production and inventory planning.

Bill of material (BOM)

BOM, which is also called the product structure, shows the sequence in which raw materials, purchased parts, and subassemblies are manufactured and assembled to produce an end product. BOM provides one of the key pieces of information

needed in order to make detailed planning decisions such as purchase orders and work orders. The ERP system has a function that displays BOM in tableau and graphical formats. Figures 5a and 5b show BOM for an item created by students during lab exercises. With these screens, we can view the properties and identify the relationships among the various components required to assemble the end product. The ERP system creates BOM very easily and provides excellent visual tools for the users.

Material requirements planning (MRP)

Given a production plan, we need to calculate the required quantity of each component that makes up the end product. MRP determines the material requirements and timings for each production phase. This process is performed automatically in the ERP system once a production plan and the BOM information are entered. The MRP output of a component, which is a part of the dependent requirements for an end product, is illustrated in Fig. 6. It shows multiple purchase orders, order quantities based on the given batch size, and order dates based on the given delivery time.

CONCLUDING REMARKS

The new ERP-integrated P&OA course has been taught for three years so far, and it has met several objectives, such as providing students with a more coherent view of the subject area, providing students with real-world experience through exposure to real problems and their solutions, providing students with experience in business practices, using projects that emphasize communication and teamwork, using projects and assignments that require the use and knowledge of computer and data analysis, and using case studies that evolve over time and require the usage of many different tools and techniques.

Explode BOM: Level by Level

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Material    A-51              1000       Alt.    Usage 1
            Part 51                              Valid 02/20/2004
Reqd qty              1.000 LB    Base quant     1.000 LB

Lv Item Component no.                      Quant Un Ict Asm
        Description                                    Ex.

1 0010 B-51                                2.000 LB  L   ☑
       Part 51
1 0020 C-51                                1.000 LB  L   ☐
       Part C 51

1 0000 B-51            Part 51
2 0010 D-51                                8.000 LB  L   ☐
       Part D 51
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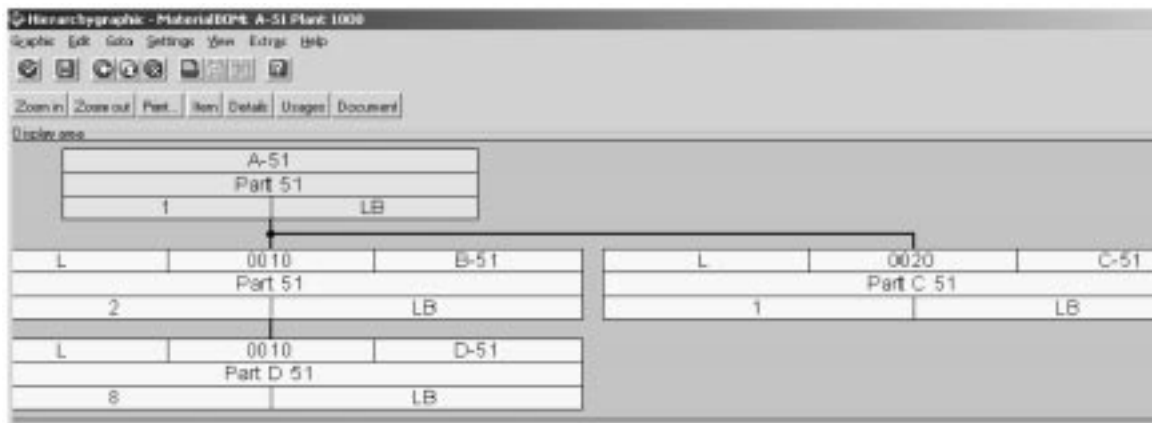Fig. 5a. Multi-level BOM in a tableau format (copyright by SAP AG).

Fig. 5b. Multi-level BOM in a graphical format (copyright by SAP AG).

Student feedback indicates that this course is a great success. The course and the effectiveness of the teaching strategy have been carefully assessed through homework, exams, class projects, students' evaluation, and entry and exit interviews. This assessment identifies strengths and weaknesses, hence determining what needs to be done. Student evaluations indicate that the usage of ERP is extremely useful, and the most common complaint is that there are not enough topics. They indicate that the ERP-integration provides an alternative perspective on the course materials, which broadens understanding. This improves retention for average students, and makes students more responsible for directing their own learning. Student evaluations also demonstrate an improvement in the perception of quality of instruction and an indirect indication of improved student learning.

The ERP system definitely makes the entire teaching experience more interesting and valuable to students. The excitement of using new technology improves student performance, even though more materials are taught. The students have the opportunity to become familiar with the popular ERP system, and this is a definite bonus for their careers. However, we do not expect students to be expert with the system after taking this one course. Rather, they will have enough basic skills and understanding to expedite their learning of any management information systems in the real world of employment.

We believe that this course improves the way in which industrial engineering courses are taught to students. Teaching students the industry's requirements, introducing them to a state-of-the-art ERP system, and providing them with methods of modeling and analyzing such systems can pave
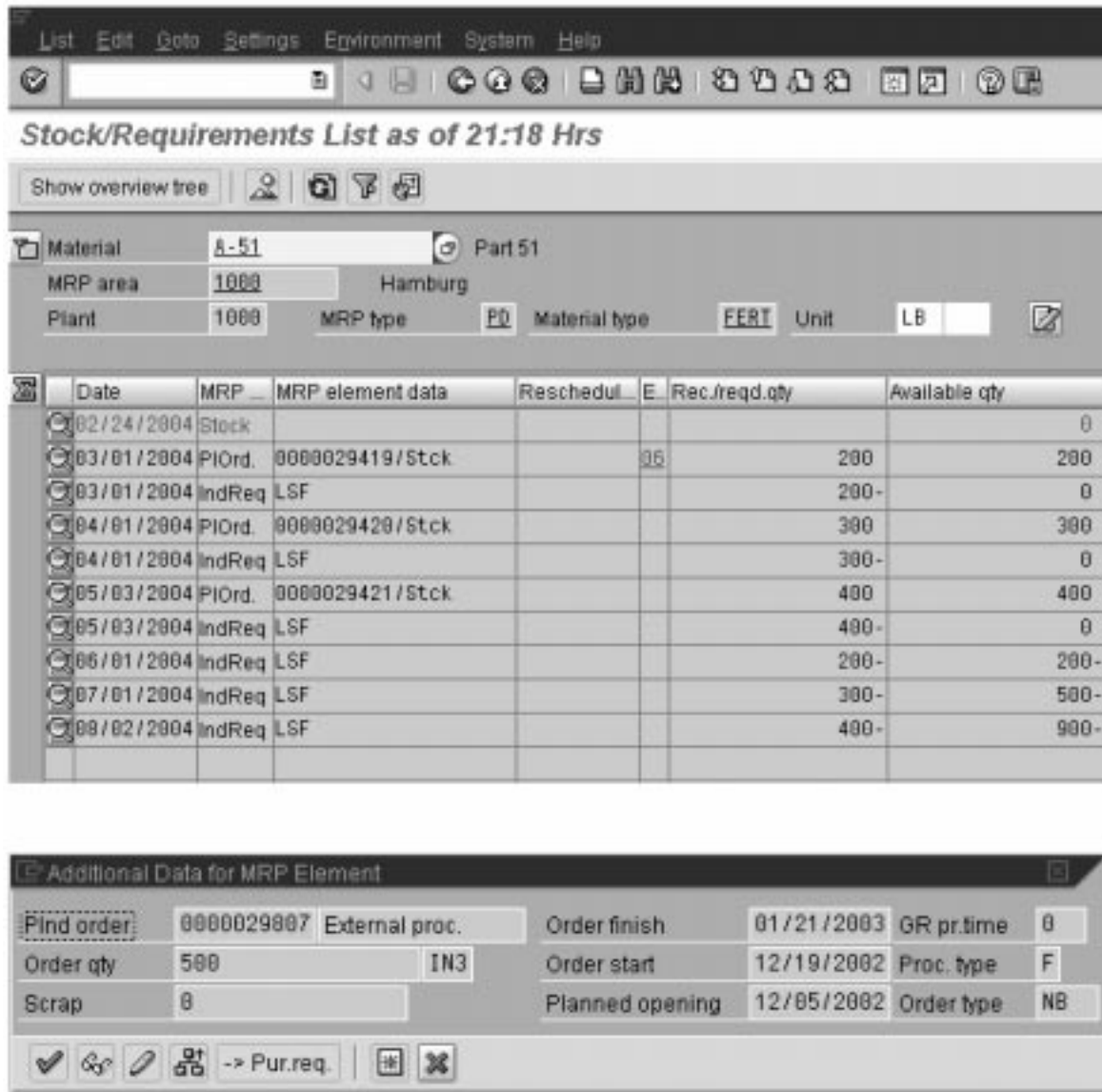
Fig. 6. Material requirements planning (copyright by SAP AG).

the way for their future development. Our approach provides all students, including previously under-represented minority groups, with real-world experience and better prepares them to enter the workforce and meet the needs of industry.

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Wooseung Jang is an Associate Professor of Industrial and Manufacturing Systems Engineering at the University of Missouri–Columbia. He received his Ph.D. in Industrial Engineering and Operations Research from the University of California at Berkeley in 1997. He previously worked at KLA Instruments Corporation, San Jose, CA, as a Yield Management Research Scientist. His research interests include stochastic modeling and optimization, supply chain management, scheduling, production, and quality control, and ERP systems. His publications have appeared in *Naval Research Logistics*, *Operations Research Letters*, *European Journal of Operational Research*, and *International Journal of Production Research*.

Huay Huay Lim is currently a Ph.D. candidate in the Department of Industrial and Manufacturing Systems Engineering at the University of Missouri–Columbia. She also received B.Sc. and M.Sc. degrees in Industrial Engineering from UMC in 1999 and 2001, respectively. She previously worked at the Missouri Lottery as a Management Analyst, which involved operation optimization and business process reengineering.