

Production Operations Models: Development of a First Experience Graduate Course in Manufacturing Operations

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Abstract

The Master of Science degree in Engineering at Grand Valley State University offers an emphasis in Manufacturing Operations. As part of the Manufacturing Operations emphasis, students are required to take a sequence of courses in areas such as Production Operations Models, Material Handling and Plant Layout, Manufacturing Simulation, and Manufacturing Work Environments. The design of the Production Operations Models course is structured for students who have industrial experience in manufacturing operations but lack previous exposure to the theoretical models involved in analyzing manufacturing operations. The course is designed to provide a structured flow of materials that represents a variety of production analysis techniques and can be delivered as a one-semester experience. The resulting topical coverage in the course includes some standard production operation topics such as inventory models and MRP systems as well as more current topics in lean manufacturing such as construction of value stream maps and design and implementation of kanban systems.

Introduction

The objective of this paper is to describe the design of a production operations course that focuses on the current issues and techniques that impacts the competitive position of manufacturing companies while still providing students with the necessary theoretical background to investigate a variety of production related issues. This paper is divided into two main sections. The first section discusses the background of the Manufacturing Operations emphasis at Grand Valley State University that lead to the development of this course. The next section identifies the sequence of topics covered and provides examples of student projects as well as indicating the future direction of the course.

Program Background

The Master of Science in Engineering degree in Manufacturing Operations at Grand Valley State University is a program which is open not only to students which have an undergraduate degree in engineering but also for students who have an undergraduate technology or related physical science degree. This particular degree option was developed to meet the technical and professional development needs of practicing engineers. The M.S. program in Manufacturing Operations is a 33-semester hour program that includes a professional practice component, a series of courses in manufacturing operations, a capstone Masters Project, and approved graduate elective courses. The minimum academic preparation required for entry into the program includes

acceptable achievement in undergraduate courses in following areas: calculus (2 semesters), general chemistry, physics (2 semesters), computer programming, computer-aided-design, engineering mechanics, electric circuits, engineering design, and materials science. In addition to the academic preparation, current engineering employment in local industry is an additional requirement for entry into this program.

The manufacturing operations sequence includes courses in Production Operations Models, Material Handling and Plant Layout, Manufacturing Simulation, and Manufacturing Work Environments. Students are required to complete a minimum of three out of the four courses. The Manufacturing Operations courses were originally designed for engineers without any background in industrial engineering topics, such as mechanical or chemical engineers whose primary job responsibilities are in the area of production operations.

The professional practice component includes courses in Project Management, Engineering Design, and a course in Law, Ethics and the Environment. The course in project management is designed to provide the students with the necessary skills to manage engineering projects. The student is expected to use these concepts when planning and completing the capstone project. Law, Ethics, and the Environment is a discussion-oriented course that exposes students to the relevant legal principles and ethical problems facing the practicing engineer. A course in engineering design completes the requirements for the professional practice component. The focus of the engineering design course is to introduce students to various methods and approaches to engineering design using modern design techniques and design projects.

The capstone project experience is designed as a two-course sequence for students whose educational background does not include a capstone undergraduate experience. The initial course, a Masters Project Planning course, allows the students to define the nature and scope of the capstone project as the first step in the analysis of the proposed engineered project or system. The second course in the sequence is providing an engineering solution to the project. The student completes the balance of the 33 credit hours with elective courses. The available elective courses that the student can choose from are dependent upon the individual student's academic background.

Development of the Topics for the Production Operations Models Course

The Production Operations Models course, although developed at the graduate level, is developed for the student who has no previous exposure to the theoretical models involved in the analyzing production operations issues but have understanding of the vital issues in their industries. The course is developed to provide the students with the theoretical background to solve practical problems that are faced in their industries and also to provide a solid background in topics to which they might not have been exposed to in their current professional responsibilities.

The objective of the course is to provide an in-depth understanding of the structure and function of modern manufacturing systems with emphasis on the roles that techniques, such as Lean Manufacturing, address in the current manufacturing environment. The mechanics of the course includes homework assignments, exams, case study analysis, and a semester project. A main objective for the course is for the students to identify and analyze a current issue in their industry in the form of a semester project.

The initial topic covered in the class is Value Stream Mapping¹. Students are introduced to basic approaches for value stream mapping and instructed on techniques for mapping the current state of a process or production line within their company. Students are assigned to teams to develop maps of the current states in their organizations. The objective of this exercise is to help identify potential projects for the students to address in their semester project.

The next topic of discussion in the class is the effects of variability in production operations. Students are introduced to the concept of Little's Law and develop a knowledge of the interrelationships of cycle time, throughput, and work-in-process (WIP). The discussion on the effects of variability is based on the work of Hopp and Spearman in *Factory Physics*². Hopp and Spearman developed Best Case, Worst Case, and Practical Worst Case scenarios where the effects of one piece flow, batching, and introducing randomness into the system respectively are explained. Additional topics addressed includes causes of variability in processes, metrics to measure and compare the variation in different processes or production lines, and the effects of setups and failures on variability.

System oriented issues in manufacturing is the next area of analysis. As a precursor for the introduction to aggregate planning, the topic and applications of linear programming are covered. Initially aggregate planning is explained and analyzed using spreadsheet solutions. The students then begin to develop linear programs to solve to aggregate planning models³.

After discussing aggregate planning, a series of independent demand inventory models are introduced and analyzed. One of the main objectives is for the student to understand tradeoff between 1) setup or ordering costs and the costs of holding inventory; and, 2) customer service and the costs of holding inventory. The analysis begins with the discussion of the economic order quantity (EOQ) model and the economic production quantity models (EPQ). Analysis of the assumptions used to develop these models is discussed and critiqued. Stochastic models are introduced to reinforce the concept and effect of variability on lead-time and customer demand. Continuous review systems are analyzed to differentiate between customer service systems that specify fill rate from inventory as opposed to probabilities of inventory shortages. Analysis of calculations of shortage and implied shortage costs are also covered.

The topic of dependent demand inventory systems is the next area of discussion. This topic is covered to ensure that have a thorough understanding of benefits and drawbacks of Material Requirements Planning (MRP) systems. The production planning process is further extended from aggregate planning to include Master Production Scheduling (MPS) and Capacity Planning. MPS is discussed in relationship to the type of product market, such as make-to-stock, make-to-order, or assemble-to-order, in which the industry is operating. The mechanics and inputs to the MRP process are identified and examined. Specific attention is given to the integration of lean manufacturing techniques with MRP systems. During the discussion on MRP systems, the basic philosophy and mechanisms of push and pull systems is compared and contrasted.

After completing the topics on systems issues, the course returns to production floor issues. The basics of manual assembly lines are covered. The analysis ranges from metrics required to analyze assembly lines, such as staffing issues, parallel workstations, and efficiencies, to various line

balancing algorithms, such as the largest candidate rule and the Kilbridge and Wester methodology⁴. Mixed model analysis for manual assembly lines includes discussion on fixed and variable rate launching methods used to determine launch sequences.

The next topic that the course addressed is manufacturing cell analysis and design. Methods for grouping parts into families such as similarity based clustering and part machine grouping algorithms are presented. Two part machine groupings algorithms, the Bond Energy Algorithm (BEA) and the Rank Order Clustering⁵ algorithm (ROC), are used to develop part families. The analysis of the part machine matrix includes discussing methods to handle exceptions and voids in the matrix. Determining maximum output of the cell using process capacities, calculating TAKT times, developing standard operation combination charts to verify operator work cycles, and identifying methods for assigning operator tasks within the cells are also discussed⁶.

After completing the discussion on manufacturing cells, the topic of pull systems is re-introduced and covered in more depth. Reinforcement of topics covered earlier in the course, such as the effects of variability and the use of inventory in production systems, is reviewed. The mechanics of pure pull or supermarket pull systems, single and dual card Kanban systems, as well as the introduction to Constant WIP (CONWIP)² systems are analyzed using physical product line simulations. An important concept that is introduced is the different states of manufacturing flow and what is required to transition a company from a traditional batch environment to the lean state. Discussions on designing pull systems using mathematical analysis includes issues such as; use of cards or other visual signals, methods of withdrawal, and the use of signal kanbans⁷. CONWIP analysis includes basic and multi-loop CONWIP systems as well as the issue of shared resources in CONWIP assembly lines and calculation of critical WIP in different feeder lines to ensure smooth flow.

Examples of Student Term Projects

A desired outcome from the course is for the students to analyze and address a current issue that is specific to a local industry. Examples of two student term projects developed under this philosophy includes a project that addressed excessive WIP in a production line and a project that formulated a plan to improve the current production process. In both of the projects, mapping the current state of the value stream was the initial step of the project. The first project analyzed a production line that consisted of four main processes. The current state map indicated that an excessive amount of WIP was contained between two of the processes in the system. After analyzing the inventory production and usage data, a proposal that changed production quantities and visual signal methods for replenishment was presented. A map of the future state was created that incorporated the planned improvements. The second student project analyzed a current production process with the intent of identifying areas for process improvements. The value stream analysis indicated a specific process that was a bottleneck and an economic analysis confirmed the significant contribution of this process to the overall product cost. The identification of an alternative process resulted in a significant reduction in product cost and floor space requirements. At the end of the term students are required to submit a written analysis of the project as well as an oral defense of the approach and results of the project analysis.

Future Direction for the Course

At the end of the course, the student feedback indicated that the design of the course, as well as the assignments, aided in their learning of the material presented. Since the course covers a wide variety of topics, which are not typically covered in a single textbook, the students depended on lecture notes as well as references to the literature cited in the bibliography. Developing a more comprehensive textbook that sufficiently covers all the topics is required. Additionally, the rearrangement of some of the topics was suggested through some student feedback. The primary rationale for rearranging these topics was to cover materials earlier in the semester that were required for use in the term projects.

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