A Generic Approach to Material Flow Simulation using AutoMod

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Material flow in a typical manufacturing facility is a critical activity in accomplishing timely product deliveries. There are many dynamic factors that impact the movement of material within a facility. Among those factors, delivery schedules, availability of material handling equipment, routes of movement, aisle widths are the important ones. Simulation is the most suitable tool to capture such dynamic nature of operations. Material flow systems show many common characteristics for particularly systems that are characterized by discrete moves of a given quantity of material with a transport unit. A transport unit may be in a variety of forms from a human operator to an automated vehicle but the nature of the operation remains the same. In this paper, we present a generic modeling framework in Automod for modeling such systems. The model described in the paper can be used for analyzing similar systems by tailoring to a particular layout. The paper also includes some of the benefits of using simulation for analyzing material flow in a manufacturing plant.

1. Introduction

Designing an efficient facility is a key activity in planing a manufacturing system. Without an efficient design specifically meant for a manufacturing vision, a facility is more likely to fail in supporting a corporation's vision in building better products. The philosophies of Just-in-Time or Lean Manufacturing can be achieved only if the facilities are built to support them. Some of the immediate benefits from an efficient facility are: reduced costs, less damage to product, better utilization of space and equipment, and safer work environments. Once those benefits are realized, increased throughput and better productivity follow naturally.

Central to the design of a good facility plan (or any facility plan) is the design of a material handling system concurrently with the design of a layout. Facility design is typically an iterative procedure where multiple layouts are generated before a complete design is obtained. Furthermore, a major factor in designing a layout and a material handling system is the material flow requirements. Consequently, adequate analyses of the material flow are required in subsequent iterations of the facilities design cycle.

To understand the relationships between a layout and the material flow in a facility, the movements of material from receiving docks to intermediate storage and to consumption points should be analyzed by considering the distances and the volumes. Then, by analyzing the frequency of movements between various points of a plant layout, a quantitative assessment of its efficiency can be made in relation to the flow of materials. An analysis of those frequencies and ratings of aisle congestion yields to an understanding of where the improvements can be made. Software such as FactoryFlow provide utilities for such analyses. An important point to remember is that relying completely on static analyses can be misleading in establishing a good layout. Production schedules, variation in product mixes, availability of material handling equipment, and random breakdowns create varying loads on the system. Consequently, a final analysis of the material flow should be made by using simulation to take into account such variability. A simulation model can be built to study the effectiveness of different forms of material handling equipment by considering their detailed parameters such as speed, acceleration, movement paths, and traffic and control logic. In addition, simulation can also help to make dynamic analyses of aisle congestion, buffer space utilization, and traffic congestion at critical intersections. Clearly, static and dynamic analyses should both be utilized in evaluating the efficiency of a layout in terms of flow of materials for complete, accurate, and timely analyses.

Simulations built for these purposes will show many common characteristics as target systems share many common operating procedures. This is particularly true for the systems of similar kind. For example, engine plants would show similar characteristics even for different car companies. With a very brief view, a typical manufacturing plant would have receiving docks, storage areas, process and assembly lines, and shipping docks. Material would be moved between various points by a transport unit in containers of different sizes. A transport unit may be in a variety of forms from a human operator to an automated vehicle but the nature of the operation remains the same. Some parts of the facility (machining an subassembly) would be making the parts that would go into an assembly or a subassembly. Final products would be consisting of parts and subassemblies made in the plant or purchased from outside. In a plant that manufactures multiple products, it is typical that each manufacturing area will be running with a different schedule. Those common features also require similar types of analyses be made. The aisle and intersection congestion statistics, machining and assembly line stoppages due to material handling inefficiencies, and the space needed for in-process storage are the typical performance measures needed for analysis. As a result, the requirements from simulation model will be very similar an many cases.

Modeling Challenges

The objectives of the simulation study were twofold: (i) design a macro modeling approach that could be extended to other plants when necesssary, (ii) to create a flexible model to analyze several issues including: aisle and intersection congestion, material handling equipment utilization, loss of production due to material handling inefficiencies and scheduling conflicts, and space requirements at storage locations. These objectives required that (i) it would run by using a data set common to all plants, (ii) customization efforts should be minimum for creating models for different plants, and (iii) statistics should be obtained and presented in the most meaningful way for novice users.

Model Description

The first phase to developing a generic simulation model was to determine the common operational characteristics of the manufacturing systems. Receiving and shipping docks, staging and storage areas, process and assembly lines were considered as the standard departments of the generic simulation model. In addition, each department had a pick up point and a drop off point. The most important observation is that the aisle network could be represented as a network of nodes, each node representing an intersection. By a further abstraction each node could be represented as a decision points where a transport unit needs to be routed to one of the three directions depending on its final destination. The model uses six different input files. It consists of the following data sheets.

- From-to Chart
- Product Tree
- Schedule Calculations
- Line Schedule Chart
- Paths
- Delivery Schedule and Shipment Schedule

In the model, it is assumed that each department has input part(s), input buffer, output part(s), output buffer, dedicated materials handling equipment for part delivery, and dedicated containers for input and output parts. The simulation model first reads the “Line Schedule Chart” data sheet to determine which kind of products will be produced in which department and it provides the start time and the duration information of the production. After resolving the output part of the department, the model reads the “Product Tree” data sheet to determine required input parts and their specifications to produce the particular output part. The materials handling equipment is triggered based on the work-in-process level of the input and output buffers. If input buffer is starving or output buffer is full, the model finds the available material handling equipment for that department and using the “From-to Chart” it determines the path number for this delivery. The intersection names are read from a data file to define paths for each route using “Paths” data sheet. input parts in containers are carried to the department by materials handling equipment , and placed in the dedicated input buffer. Then, the input parts are processed in that particular department based on required part volume and hourly process rate of the machine. After processing the input parts, based on number of input parts required to make a unit of output part information, the output parts are generated and placed in the output buffer of the departments and using the same logic, the materials handling equipment are called to take the output parts to next department or storage area. The another part included in the model was the shipping and receiving schedule. The related data tables, “Delivery Schedule and Shipment Schedule” data sheet, are used to extract the delivery and shipment information such as time, material handling equipment specification.

The routing logic was the one of the challenging part of the generic model. The work-in-process level of the input and the output buffers for departments and storage areas are control by simulation model. If the materials handling equipment is required for delivery purpose, the code determines the beginning and the destination points of the path. Considering this, the routing information such as path numbers and the list of intersections that the material handling equipment is supposed to follow are extracted from corresponding data files. The model converts the format of the extracted routing data to simulation program format during the simulation run. This allows the user to control the movements of the material handling equipment without hard-coding the routing logic during the development or experimentation stage.

The generic simulation model provides the following outputs automatically; (i) throughput of the assembly plant, (ii) traffic congestion based on trips per hour on aisles based on a fixed production schedule, and (iii) material handling equipment requirements, utilization, and capacity.

In conclusion, since the generic simulation model can be used as template for future material flow studies, the user saves time from modeling. The model can be used for most of the manufacturing facilities. Scheduling, routing and production information can easily be entered to simulation model using data tables instead of hard-coding these information. In addition, experiments can easily be performed and consistent analysis of different systems can be made.