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Simulation of Manufacturing and Material Handling Systems

Manufacturing and material handling systems provide one of the most important applications of simulation. Simulation has been used successfully as an aid in the design of new production facilities, warehouses, and distribution centers. It has also been used to evaluate suggested improvements to existing systems. Engineers and analysts using simulation have found it valuable for evaluating the impact of capital investments in equipment and physical facility, and of proposed changes to material handling and layout. They have also found it useful to evaluate staffing and operating rules, and proposed rules and algorithms to be incorporated into warehouse management control software and production control systems. Managers have found simulation useful in providing a "test drive" before making capital investments, without disrupting the existing system with untried changes.

Section 13.1 provides an introduction and discusses some of the features of simulation models of manufacturing and material handling systems. Section 13.2 discusses the goals of manufacturing simulation and the most common measures of system performance. Section 13.3 discusses a number of the issues common to many manufacturing and material handling simulations, including the treatment of downtimes and failure, and trace-driven simulations using actual historical data or historical order files. Section 13.4 provides a number of short case studies, with references for additional reading. For an overview of simulation software for manufacturing and material handling applications, see Section 4.7.

13.1 Manufacturing and Material Handling Simulations

As do all modeling projects, manufacturing and material handling simulation projects need to address the issues of scope and level of detail. Consider scope as analogous to breadth and level of detail as analogous to depth. Scope determines the boundaries of the project, what's in the model and what's not. For a subsystem, process, machine, or other component, the project scope determines whether the object is in the model or not. Given that a component or subsystem is part of a model, it often can be simulated at many different levels of detail.

The proper scope and level of detail should be determined by the objectives of the study and the questions being asked. On the other hand, level of detail may be constrained by the availability of input data and the knowledge of how system components work. For new nonexistent systems, data availability may be limited and system knowledge may be based on assumptions.

While some guidelines can be provided, the judgment of experienced simulation analysts, working with the customer to determine early in the project the questions the model is being designed to address, provide the basis for selecting a proper scope and level of detail.

Should the model simulate each conveyor section or vehicle movement, or can some be replaced by a simple time delay? Should the model simulate auxiliary parts, or the handling of purchased parts, or can the model assume that such parts are always available at the right location when needed for assembly?

At what level of detail does the control system need to be simulated? Many modern manufacturing facilities, distribution centers, baggage handling systems, and other material handling systems are computer controlled by a management control software system. The algorithms built into such control software play a key role in system performance. Simulation is often used to evaluate and compare the effectiveness of competing control schemes and to evaluate suggested improvements. It can be used to debug and fine-tune the logic of a control system before it is installed.

These questions are representative of the issues that need to be addressed when deciding the correct level of model detail and scope of a project. In turn, the scope and level of model detail determine the type of questions that can be addressed by the model. In addition, models can be developed in an iterative fashion, adding detail for peripheral operations at later stages if such operations are later judged to significantly impact the main operation. It is good advice to start as simple as possible, adding detail only as needed.

13.1.1 Models of Manufacturing Systems

Models of manufacturing systems may have to take into account a number of characteristics of such systems, some of which are:

- Physical layout
- Labor
    - Shift schedules
    - Job duties and certification

- Equipment
  - Rates and capacities
  - Breakdowns
    - Time to failure
    - Time to repair
    - Resources needed for repair
- Maintenance
  - PM schedule
  - Time and resources required
  - Tooling and fixtures
- Workcenters
  - Processing
  - Assembly
  - Disassembly
- Product
  - Product flow, routing, and resources needed
  - Bill of materials
- Production schedules
  - Made-to-stock
  - Made-to-order
    - Customer orders
    - Line items and quantities
- Production control
  - Assignment of jobs to work areas
  - Task selection at workcenters
  - Routing decisions
- Supplies
  - Ordering
  - Receipt and storage
  - Delivery to workcenters
- Storage
  - Supplies
  - Spare parts
  - Work-in-process (WIP)
  - Finished goods
- Packing and shipping
  - Order consolidation
  - Paperwork
  - Loading trailers

13.1.2 Models of Material Handling

In manufacturing systems, it is not unusual for 80% to 85% of an item's total time in system to be expended in material handling or waiting for material handling to occur. This work-in-process (WIP) represents a vast investment, and reductions in WIP and associated delays can result in large cost savings. Therefore, for some studies, detailed material handling simulations are cost effective.

In some production lines, the material handling system is an essential component. For example, automotive paint shops typically consist of a power-and-free conveyor system that transports automobile bodies or body parts through the paint booths.

In warehouses, distribution centers, flow-through and cross-docking operations, material handling is clearly a key component of any material-flow model. Manual warehouses typically use manual fork trucks to move pallets from receiving dock to storage and storage to shipping dock. More automated distribution centers may use extensive conveyor systems to support putaway, order picking, order sortation, and consolidation.

Models of material handling systems may have to contain some of the following types of subsystems:

- Conveyors
  - Accumulating
  - Nonaccumulating
  - Indexing and other special purpose
  - Fixed window or random spacing
  - Power and free
- Transporters
  - Unconstrained vehicles (e.g., manually guided fork trucks)
  - Guided vehicles (automated or operator controlled, wire-guided, chemical paths, rail-guided)
  - Bridge cranes and other overhead lifts
- Storage systems
  - Pallet storage
  - Case storage
  - Small part storage (totes)
  - Oversize items
  - Rack storage or block stacked
  - Automated storage and retrieval systems (AS/RS) with storage-retrieval machines (SRM)