RESEARCH TO APPLICATION SUCCESS STORIES: MANUFACTURING

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ABSTRACT

Successful uses of simulation proliferate throughout manufacturing and the papers presented here illustrate the range of uses suitable for simulation models. The forum format allows participants to exchange success stories of using simulation in a variety of applications.

1 INTRODUCTION

The forum for the *1997 Winter Simulation Conference* highlights examples of successful simulations in a range of manufacturing applications. This variety demonstrates the similarity in areas and phases of development cycles and illustrates the applicability of simulation to all types of manufacturing. The purpose of this session is for participants to share success stories of using simulation models to support manufacturing applications in both traditional and supporting roles.

2 THE PANEL

The panelists all relate stories of successful simulation in a range of applications. Their experiences illustrate the wide applicability of simulation as a vital tool in all phases and types of manufacturing. The panelists themselves range in experience from software developers and consultants to new simulation users. Their individual success stories compose the remainder of this paper.

3 SANJAY S. UPENDRAM & ONUR M. ÜLGEN: SIMULATION OF AN AUTOMOTIVE BODY SHOP

This section discusses the role of process simulation in the automotive industry with a real-world application to the body shop area. Uses of simulation during the different phases of an engineering project are identified as the conceptual design, detailed design, launching and fully-operational phases.

3.1 Simulation in the Automotive Industry

Automotive assembly plants typically have three major sections with respect to the stages of the assembly process: Body Shop, Paint Shop, Trim and Final Assembly. Each of these areas has different types of processes with unique features. There are many issues throughout the plant that are effectively addressed through simulation models. The following is a discussion of the typical issues.

The applications of simulation in the design and operation of vehicle manufacturing systems can be categorized in two different ways (Ülgen et al. 1994). The first classification is based on the stage of the development of the design of the system. Four categories are observed in this classification, namely; conceptual design phase, detailed design phase, launching phase, and fully operational phase.

3.1.1   Classification One: Stage of Development

The conceptual phase refers to the initial stage where new methods of manufacturing and material handling concepts are tested by the engineers. Discrete-event simulation packages with 3D animation capabilities are the popular simulation tools at this phase e.g., Auto-Mod, Quest. The detailed design phase refers to the stage where detailed layout designs and equipment operations are verified for the system. The principle factors considered here include equipment justifications (e.g., the number of hold tables, power and free carriers, the size of buffers), cycle time verifications (e.g., conveyor speeds, line throughput), line operational and scheduling issues (e.g., strip logic for ovens and paint booths, repairs, and product mix decisions). Discrete-event simulation packages with 3D animation capabilities are commonly used at this phase. Among the discrete-event simulation packages, the ones with the built-in detailed equipment features and 3D animation features appear to be the most popular ones used at this stage. The launching phase refers to the stage where the plant operates below the designed operational conditions. In some cases, it may take up to six months for the plant to operate under maximum capacity conditions. Simulation studies done at this stage are generally used to test operational policies (e.g., operate one of the two paint booths at a time, run each shop for half of the total available time, use different product mixes). Discrete-event simulation packages used at this stage do not typically require the detailed equipment features or the 3D animation features. The simulators with user-friendly features are the most popular packages used at this phase as models tend to be at a macro level than a micro level. Fully operational phase refers to the stage where the plant is operating under full capacity conditions.

The simulation studies done at this phase consider factors such as product mix decisions, new product introductions, new operational policies, and line modifications. Simulation packages used at this phase generally require the same capabilities of the packages used at the launching phase.

3.1.2   Classification Two: Nature of the Problem

The second classification of the use of the simulation in body and paint shops is based on the nature of the problem to be investigated. Four major categories can also be identified in this classification, namely; equipment and layout design issues, issues related to variation management, product-mix sequencing issues, and other operational issues. The equipment and layout design issues include typical problems such as location of departments and equipment, cycle time verification, identification of surge bank locations, buffer size (strip conveyors and sequencing banks) analysis, and conveyor length and speed determination. It should be noted that, in addition to simulation the use of layout analysis tools such as LayOPT (Grajo 1996) and FactoryFLOW (Sly 1996) have proven to be very effective in solving the facility layout design problems. The typical problems in the variation management area are repair and scrap policy analysis, order size variation, and paint gun spray surge scheduling. The product-mix sequencing issues typically include trim line and body shop sequencing, shift scheduling, and trim and final assembly line balancing. In the other operational issues area, typical applications involve priority assignment at traffic intersections, assembly line sequencing, and shift and break scheduling. Table 1 summarizes different uses of simulation in vehicle assembly plants in a matrix

Table 1: Application of Simulation in the Four Phases of an Automotive Project

APPLICATION CATEGORY	EXAMPLE APPLICATION	PHASE			
		Conceptual Design	Detailed Design	Launch	Full Operation
EQUIPMENT AND LAYOUT	Buffer size analysis	x	x	x	
	Surge bank locations	x	x	x	
	Cycle time verification	x	x	x	x
	Conveyor length and speed	x	x	x	
VARIATION MANAGEMENT	Test-repair loop analysis		x	x	x
	Scrap analysis		x	x	x
	Paint gun spray purge scheduling		x	x	x
PRODUCT MIX SEQUENCING	Trim line sequencing		x	x	x
	Body shop sequencing	x	x	x	x
	Shift overlap scheduling	x	x	x	x
DETAILED OPERATIONAL ISSUES	Traffic priority management		x	x	x
	Assembly sequencing		x	x	x
	Shift and break scheduling		x	x	x

format where the crosses indicate the typical phases(s) that the use of simulation can play an essential role for the particular application area.

The crosses in the table indicate only where certain types of problems are more likely to be attacked by the designers or managers. For example, cycle time verification problems are more likely to happen at earlier stages of the design and operation cycle.

However, shift scheduling problems are likely to be solved once all equipment and layout design issues are finalized. It should be noted, however, that the table constitutes only a broad framework since, in reality, each type of problem area can be attacked in any phase of the design cycle.

3.2 Case Study of Application of Simulation to an Automotive Body Shop

This simulation study involved modeling and analysis of skid movement on roller flight, production, power and free, and cross transfer conveyors in a new body shop. The model was used to verify if the body shop would meet the required production rate. Additional studies determined the shift timing necessary to coordinate production with the paint shop, and determined the minimum stock required in individual surge areas to maintain continuous production.

3.2.1 System Description

The simulated facility consisted of 2 power and free conveyors, 14 roller flight conveyors, 5 production conveyors, 20 cross transfer conveyors, and 50 power roll conveyors.

3.2.2 Problem

The automotive plant is expanding to increase capacity of light trucks. A new light truck body shop will be built. Will the proposed design meet the capacity requirements? Additionally, the existing medium/heavy paint shop will also paint the light trucks in the first and second shifts until a new light truck plant shop is built. Can the light truck body shop build up a large enough reserve of trucks in one shift to allow the paint shop uninterrupted production in both shifts?

3.2.3 Objective

The objective of this study was to determine if the new body shop could meet the required production rate in phase 1, when the existing paint shop would paint the trucks, and in phase 2, when a new light truck paint shop would paint the trucks and a higher production

rate would be necessary.

3.2.4 Solution

The study determined that the proposed design did meet the required production rate in both phases of production. In phase 1, coordination of the shift schedule between the body shop and the paint shop was necessary for the body shop to build up a large enough reserve of trucks for the paint shop to paint in the second shift.

3.2.5 Savings

The proposed design can be built with much greater assurance that it will work correctly. Correct coordination of shifts between the body shop and the paint shop will be achieved immediately.

3.3 Conclusion

Simulation has become an indispensable tool in designing and operating automotive plants as their cost and competition for productivity increases in such systems. The problems that can be attacked by using simulation arise in all phases of the design and operation cycle of a vehicle development program. Although these problems depict a great variety in nature, they also show similarities with respect to application areas and the phase of the development cycle. A classification scheme based on those features was developed and presented in the paper. It is expected that such a classification will lay the groundwork for the characterization of simulation models and tools that can be used in addressing those problems.

4 JASON DUFF: SIMULATION—A FACTORY RENOVATION TEAM MEMBER

Simulation has many uses. Traditional applications include determining production capacity, identifying number of equipment or personnel required, even validating new design prior to construction. Normal simulation applications are projects in and of themselves. Simulation, however, also plays an excellent support role to other types of projects as well. A recent project at Motorola's Radio Network Solutions Group in Schaumburg, IL provides us a good example. The project was an architecturally driven factory renovation.

Factory renovations are a popular choice over new construction for obvious reasons. Costs of construction are minimized, land acquisition/development is not an issue, facility infrastructure is already in place, etc. However, a factory renovation also produces its own

financial and engineering challenges. In the case of the Radio Network Solutions Group (RNSG), the engineering team had two concerns regarding the architectural renovation of their facility, ensuring the functionality of any new designs and backing up the costs of the changes. Management desired to improve the appearance of the production facility. Concurrently, management insisted that the RNSG team provide a level of confidence that the renovation plan would also improve the production environment and generate sufficient savings to justify the project. Thus the need for simulation, specifically, an analysis of the factory layout using FactoryPLAN and FactoryFLOW.

Before the addition of simulation as part of the design team, RNSG personnel and the architectural design team had developed a "first-cut" improved factory layout. This new design, a block diagram (each block representing a specific workcenter) provided for an excellent jumping off point for our simulation analysis – the workcenter relationship analysis. The purpose of a workcenter relationship analysis is simply to determine how effective a particular layout is in terms of the importance of one workcenter's location in relation to another, i.e., making sure the blocks are in the right place. This led to our first data collection requirement:

- Development of a workcenter relationship chart (Muther's algorithm)

The workcenter relationship chart summarizes the relationships among workcenters and their relative importance to one another. First, both the as-is condition and the first-cut improved design (the to-be scenario) were modeled with FactoryPLAN. Such an analysis provided high-level insight into the functionality of the two layouts. Based on the intuitive results of FactoryPLAN, additional functional improvements were recommended and incorporated into the factory layout. Utilizing the scores generated through the application of FactoryPLAN, it was demonstrated that a 31.6 percent improvement in functionality could be realized through the renovation project.

What is improvement in functionality? In this case, it is an improvement in the ability of a factory layout to accommodate those relationships among workcenters deemed most important by RNSG personnel. In other words, a qualitative 31.6 percent improvement in that warm, fuzzy feeling that the design team was headed in the right direction with the new design of the factory. Next, a more analytical, quantitative analysis was conducted to develop a more accurate depiction of functionality and to fulfill the requirement for supporting project costs.

The two layouts, the as-is scenario and the new to-be scenario (that developed by RSNG personnel and the architectural design team, but improved through the

FactoryPLAN exercise) were now subjected to the more detailed FactoryFLOW analysis. FactoryFLOW provides excellent insight into the cost of material handling associated with a particular factory layout. This is accomplished by rolling up the cost of labor and material handling devices with the time required supporting the movement of material. This includes an analysis of product subassemblies and raw material, batch movement sizes and distances between operations. Improve the layout or how material is managed – reduce the cost of material handling. This exercise led to our next data collection requirement:

- Definition of product volumes of flow patterns
- Collection of material handling costs associated with the factory
- Definition of operation and assembly locations throughout the factory

The analysis indicated that our new to-be scenario provided a 30.9 percent reduction in material handling costs. This amount alone, in terms of annual dollar savings, provided sufficient return-on-investment to pursue the project. However, more opportunities for improvement still remained. The improvement realized thus far was strictly a result of minimizing the distances traveled (i.e., improved layout). Opportunity still remained through reducing the number of moves required (i.e., improved methods) to support production. This was a residual benefit of conducting the simulation exercise.

Both FactoryPLAN and FactoryFLOW require "interactive" data collection. This means the involvement of RNSG personnel during the data collection effort was critical to a successful factory layout analysis. Such a data collection process has residual benefits. The forced consideration of equipment, processes, data systems, methods and capabilities as well as being forced to think about the relationships among workcenters, the methods of material transport between those workcenters and where relevant data resides naturally brings out additional synergistic ideas. With RNSG, simple ideas such as combining similar functions into a single workcenter, separating operations that seemed similar but served unique product lines or re-implementing previously discarded methods of material handling were brought about as part of the "interactive" data collection process.

As a result of this synergistic creativity on the part of the design team as well as the intuitive results of FactoryFLOW (including the detailed reports and the graphic representation of product flow patterns) additional improvement opportunities were identified and modeled. These included architectural changes, changes in material handling methods and material handling devices. Through these additional improvements, it was demon-

strated that an additional 13.9 percent savings in material handling costs could be realized. This, added to the earlier improvements, accounted for a 44.8 percent reduction in material handling costs.

Through the incorporation of simulation into the activities of the design team, RNSG overcame to significant project challenges. First, though the project was driven primarily by an architectural design component, the functionality of the factory was demonstrated to be improved significantly. Second, through the synergistic input of the design team and the results of the FactoryFLOW model, significant return-on-investment was also demonstrated.

The RNSG factory renovation project was a good example of the support role that simulation can play in larger, design-oriented projects. Simulation allowed for a natural comparison of factory layout alternatives, provided insight into the functionality of those alternatives and a return-on-investment analysis with the residual benefits of identifying additional improvement opportunities.

5 JIM DOOLEY: MACHINING OPERATIONS CAPACITY MODEL

This portion of the paper outlines a simulation modeling project that was done to estimate equipment requirements for machining operations for projected production levels. The model was developed early in the product cycle, after the manufacturing processes were defined but in the steep part of the learning curve and with introductory production rates. After a representative model of the process was prepared, a number of iterations were run to predict the best balance of required machine tools and support equipment based on the most likely assumptions of production requirements and process improvements.

5.1 Background

This project came about due to a combination of circumstances. The WSC96 conference was near my home. I attended because I had some years ago done simulations with older software, and wanted to see the newer tools. At the conference I acquired a student version of Extend For Manufacturing from Imagine That, Inc. This software package was powerful enough for me to experiment with modeling and learn how it worked. At the same time my company was in the final development stages of a new golf club to be introduced. This club required some close tolerance machining, and in the volumes anticipated would require a substantial investment in machine tools. Simulation looked like a good approach to determine the balance of equipment

needed to support production forecasts. We decided to purchase the Extend software for this purpose.

5.2 Process Description

The new golf club features a large titanium face with a tungsten insert that puts most of the weight at the ideal location. The insert is epoxied and attached with screws, and requires a very good fit. The simulation model only deals with the steps involved in preparing the head for the insert.

A full set of golf club irons includes clubs 1 through 9, plus four wedges. Each iron has a different shape, and requires different machining for the insert. In order to reduce part handling, the machining was planned to process 25 heads in a batch, located on a pallet. Four different pallets were designed that together would hold all of the different heads. In order to obtain exact machining, the position of each head is located on the pallet using a coordinate measuring machine (CMM) prior to milling. An abbreviated description of the process is: 1. load 25 heads onto a pallet at a loading station; 2. move the pallet using a cart to a CMM; 3. exactly locate the parts on the pallet; 4. move the pallet to a milling machine; 5. machine the parts; 6. move the parts to the loading station; 7. unload the parts, return the pallet to the rack.

5.3 Model Description

A useful model of the process needed to include the following features: 1. allow for different mixes of head types, which would impact the number and mix of pallet types; 2. randomly generate variable process times that could be easily changed to reflect either current processes or those expected assuming future improvements; 3. process pallets of parts through each station, tracking production output and machine utilization. The completed model included the following features: 1. sufficient pallet loads of parts were generated initially in the model to be sure that one full shift of work would be available for processing; 2. random attributes assigning head type and process times were added to each pallet; 3. parts were matched to the appropriate pallet as the pallet became available, then moved to a loading station when it came open; 4. after part loading, the pallet was moved to the first available CMM (a gate limiting the number of carts that could be captured was incorporated to avoid tieing up all the carts); 5. after CMM processing, an open cart was used to move the pallet to the next available mill (another cart capture limiting gate was built in); 6. after milling, a cart was captured to return the completed pallet to the load/unload station.

5.4 Model Design

The finished model included the following features: 1. a simulation run was set to include five independent shifts of work; the run result was the average of the five iterations; 2. the model was pre-loaded for each iteration by allowing 100 minutes of production, then keeping the work in process but resetting the statistics and the clock to zero; 3. retained information for each run included the average production output per shift with the standard deviation, and the average utilization of machines, carts, and the part change station along with standard deviation of each; 4. variables were cloned to a notebook page for easy adjustment, and outputs were also moved to the notebook page for examination and retention.

5.5 Model Operation

Since the most expensive component of the work cell is the mills, the goal was to achieve the required production by maximizing the mill utilization, and providing enough of the other cell components that they would not become a constraint. The iterative process then worked as follows: 1. set a production rate per shift, then set process times and cart move rates; 2. change the number of mills, CMM's , carts and pallets to optimize mill utilization while consistently achieving the required production and minimizing the number of carts and pallets; 3. repeat the above process with projected improvements in production rates and increases in production requirements.

5.6 Simulation Results

About 60 documented simulation runs were produced. At least that many trial runs were made without documenting as a part of model development. As it turned out about 75% of the documented results became obsolete as refinements were made to the model. So the last 15 runs represented true what-if type runs that led to the accepted results.

The critical unknowns were the product demand, which would dictate the required production, and the production rates that would be achieved as production ramped up. Since the model was set up so that parts were always available for production, the output constraints were available equipment and process times. The method chosen to increase the simulated production was to add a mill, then experiment with different combinations of support equipment to achieve a good balance. Mills were added incrementally until a production output level was achieved that exceeded the optimistic forecasts. To make output adjustment easy,

some of the mills were given on/off switches, so the total number in production could be easily changed, and individual mills could be turned off during a run to see how output was affected. The resultant correlations between equipment and capacity were sufficient to make a reasoned judgement regarding sizing of the work cell. Capital equipment was ordered based on the cell configuration that gave the desired output.

5.7 Conclusion

Simulation was a good method to reach a reasonable solution for a planned work cell where the requirements and best equipment balance could not be directly calculated. Although some process changes have since occurred that were not anticipated, the work cell equipment balance has met production requirements. If necessary, the model can be easily updated to the current work cell configuration.

The Extend simulation software seemed to be a good fit for the task. It has features that addressed the complexities I encountered without having to do any programming. The results were easily collected and applicable. Although I had an understanding of what can be done with simulation, I had no experience with this software. I was able to learn the system, apply it and finish the model within about two months of first exposure, and six weeks after receiving the modeling software.

6 SUMMARY

The panel's three examples of successful simulations demonstrate the broad applicability for modeling in all aspects of manufacturing. The premise of this forum is that despite different products and different stages in the manufacturing process problems can be addressed by using simulation. Forum participants are encouraged to share their success stories and we look forward to learning from each other.

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JASON DUFF has performed two projects for the Radio Network Solutions Group (RNSG) of Motorola in Schaumburg, Illinois as an independent consultant working as part of an overall design team involving Motorola personnel as well as other outside engineers and architects.

JIM DOOLEY is a Manufacturing Engineer at Callaway Golf where he works on material testing and product development. He has performed several simulation projects in previous positions and will perform more as the occasion arises. He is a senior member of Industrial Engineering Society and is a member of ASM International and the Society of Manufacturing Engineers. He has a B.A. in Industrial Engineering from Georgia Tech.