Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

ENSURING THE SUCCESSFUL ADOPTION OF DISCRETE EVENT SIMULATION IN A MANUFACTURING ENVIRONMENT

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ABSTRACT

Discrete event simulation has long been recognized as a valuable tool for manufacturers, but converting the recognition of value into an embrace of the technology can be a challenge. Like most technologies, with which an organization has little or no experience, timing and the manner in which simulation is introduced can significantly influence whether its adoption will succeed or fail. Without careful planning and adequate foresight, simulation technology will not prove its benefits in the workplace and will be viewed as an unnecessary expense. In this paper, we examine the characteristics that signal the need for discrete event simulation, and we discuss the strategies and methods we have found to ensure its successful adoption.

1 INTRODUCTION

Discrete event simulation has become an extremely valuable and easy to use tool for analyzing complex systems. Manufacturing companies are among those that can benefit immensely from this technology. However, getting a company to adopt simulation software may not be as easy as it sounds. Most companies are wary of investing in new technology, especially something that isn't deemed absolutely necessary. Although the long-term benefits of simulation are indisputable to anyone with experience in the field, they may just seem like every other promised solution to those making the decisions. Without a detailed strategy for incorporation, it may be difficult to get such an expense approved. We will examine some of the issues that need to be dealt with before bringing simulation into a company as well as how to ensure that its adoption is successful once it's approved.

The examples provided are from a privately owned mid-sized manufacturing company that makes large industrial/construction equipment. Rapid growth in number of employees and expansion of the product lines has spawned a variety of different manufacturing strategies throughout the company.

2 SIGNALS THAT A COMPANY NEEDS DISCRETE EVENT SIMULATION

A company may need simulation software when they are have no formal way of documenting information, complexities within the company are growing and they are in need of a cost effective way of dealing with these issues. Simulation Software can help companies get a handle on complex process and decisions that they might not be able to otherwise. This tool will consolidate and simplify large amounts of information that may cause problems otherwise.

Table 1: Signals That a Company May Benefit From Simulation Modeling

No formal documentation	Information about Company processes is passed by word of mouth
Growing Complexities	A substantial increase in the number of products made Changing production processes
Cost effective analysis	Need to analyze situation with many variables at minimal cost

During the early stages of development, key individuals within a company typically have a good understanding of the processes and equipment. These individuals either

make corporate decisions based on their own judgment, or they are the source of information for those who are making the choice. This may be effective during the early stages of development, but as a company grows, it will take more of those key individuals to keep track of the operations within the company. At that point, bringing together a group of people to aid in a corporate decision becomes much more complex. All too often, two people presented with the same information will differ in their opinions on the correct course of action. In order to avoid getting mixed opinions, the company needs to find a way to rationally analyze their options based on valid data. Discrete event simulation yields information based on facts. By modeling a manufacturing facility using simulation, decision-makers have an unbiased source from which they can pull their information. All options are evaluated under the same conditions, thus eliminating guesswork and individual opinions about which option will perform the best.

When a company begins to confront increasing complexity, whether in products, production processes, or both, they should consider the benefits of discrete event simulation (National Research Council 1995). There are many types of complexities across companies that may indicate the need for simulation. First, the type of machines used in manufacturing processes are typically large, complex, and most importantly, heavy. This makes the need for planning crucial because moving these monsters is costly and time consuming. It is also impractical to change configurations multiple times in order to optimize the layout. Simulation allows for the modeling of any number of layout changes before moving a single piece of equipment. Secondly, each new machine introduces an array of variables that need to be included in the overall performance of the facility. As more and more pieces of equipment are introduced, it becomes increasingly difficult to keep track of all of the variables needed for process analysis. Trying to coordinate all these factors and put together a representative model by hand would be extremely difficult. Third, manufacturing facilities usually have many parts and part numbers flowing through the system. Accounting for quantity and characteristics of these parts becomes increasingly difficult as the company grows. Finally, complexity comes from the variability in process across the company. One plant may have a completely different way of doing things than its sister plant next door. Again, modeling all these factors by hand is much more difficult that it needs to be. When a company has too many details and variables to do an adequate job of tracking and forecasting performance, the use of simulation will benefit the company. As these complexities grow and become more widespread, the need for a computerized solution becomes apparent. Simulation software lets the user capture and manipulate all of the variables mentioned above. A user can quickly and easily evaluate multiple scenarios that would be nearly impossible to calculate by hand.

By the time a company is in need of simulation, they are facing decisions that can be costly and time consuming. Some companies may have the resources and can afford a 'try it and see' attitude. Of course, actually trying new things is the best option for examining results because you are actually doing it. Most companies, however, can't afford to make this kind of investment in time and money (Law and Magmas 1999a). Simulation efforts require an initial investment in software (typically much less than the costs involved with making a change) and someone familiar with simulation and modeling techniques. These costs are much more appealing to the growing company and yield results that are second only to actually making the changes and observing the effects.

3 IMPLEMENTATION ISSUES

Saying that you are in need of simulation is one thing; actually getting it implemented in your company is another. There are many barriers and issues that need to be dealt with and planned for before making the argument for simulation to senior managers and executives. They must be convinced that the benefits of simulation software will outweigh the costs associated with it. To do this, you must be aware of the issues involved in implementing this technology and be prepared to deal with them. Table 2 lists some of the basic questions that should be addressed.

Table 2: Issues to Consider ***Before*** Implementation

Software	Which package is right for your company?
Senior Management	How will we get approval for the investments.
Users	How to create models that can be used by anyone
Modelers	Who should be creating your models?

3.1 Software Selection

Choosing the software that most accurately suits your needs is one of the major factors in getting simulation introduced into your company. If you choose a software package that no one likes to use, chances are the project will not go over very well. It is hard to know where to begin looking for simulation packages because of the sheer number of products on the market. The scope of your needs will narrow the list of simulation software packages that will suit your company.

The driving factor in every business choice is the bottom line. Before you begin looking at software, try to determine a range of how much you are willing to spend. Keep in mind that utilizing this technology in just one key project could prevent the company from making a crucial error that could cost the company a large amount of money. It is better to make sure that the package you choose will completely address your needs than to purchase a package based on the best deal available. Prices can range from hundreds to millions, so you should be able to find something that will fit into your budget.

After establishing a price range, the next step is to find the package that is easiest to use. Software that is not understood or is difficult to operate is a wasted expense. The basic structure will vary between systems and the old saying of "You get what you pay for" typically holds true. The more you are willing to spend, the more user friendly the software will be. If you are an experienced modeler and programmer, then graphical interfaces may not be necessary. You may even prefer to write your models in the base code instead of plotting them out in a graphical modeling environment. Keep in mind, though, that the modeler is only half of the equation. If non-programmers are going to be using your models, then a graphical interface may be necessary. A model will do you no good if the only person who can understand it is you. The easiest packages are set up for drag and drop model building. They provide the modeler with a set of pre-made functions in graphical form. Building a model becomes a matter of putting the blocks is the correct order to represent the manufacturing system. The advantage of this type of software is that it gives users with little or no modeling experience the ability to step in and begin using it very quickly.

Maturity of product is another factor to examine in every simulation software product. Developing a simulation engine is relatively straightforward task. Many of these packages started out as graduate student projects that were brought to market. It is important to know the company behind the software and how long it has been in business. Although the cost might be higher, it may be less risky to consider a product that has been on the market for a few years and has an established company behind it. This ensures that most of the major bugs in the software have been eliminated. Not only does new software run the risk of being unreliable, but you also aren't ensured that the company you bought it from will be in business in the next five or ten years. For these reasons, it's may be better to buy one of the more popular software packages.

An established company will also have the level of technical support necessary to satisfy the needs of your company and its modelers. It is essential to have someone to answer any questions you have about the software. Some support lines will answer basic modeling questions and even take a look at your models and help debug them. This can be enormously helpful, especially if you are new to simulation modeling.

What separates the good simulation packages from the average ones is the functionality that is bundled with the core engine. An output analysis function is essential if you plan on doing any significant modeling. In order to get statistically valid data; you will need to run your model a number of times. An embedded output analyzer will take the data produced by the model and put them in a meaningful context. Without such an option you will be stuck with a large amount of numbers from the models and no real way to compare and understand them.

Finally, you should look at the level of animation capability that is incorporated into the software. In some situations, the animation in a model may be the element that determines the success of your project (Sadowski and Grabau 1999). Animation is the bridge between modelers and those who have no experience or desire to get into the field. Trying to explain a complicated model, without any animation, to a manager who has no experience in simulation is no easy task. Adding animation helps people visualize the model. They can actually see what is going on instead of trying to imagine how it works. Senior managers and executives are much more likely to trust your numbers if they know where they came from and understand how you got to them. Otherwise your recommendations are nothing more than your own opinion and will not be given full consideration. Make sure that the animation portion of the software has the capabilities that you need because that is what people will see when you present your model.

3.2 Convincing Senior Managers/Executives to Invest in the Technology

Successful incorporation of simulation requires that senior management/executives agree to purchase the software and provide training and support for designated modelers. Getting them to agree to this may be a difficult proposition depending on how open the company is to new technology. Unless your particular industry is already a strong supporter of simulation modeling, it may be difficult to prove the benefits of simulation until executives can actually see what the technology can do. Without the software to do this, you are left with your own powers of persuasion.

The first step is to designate a champion for the cause. This will be the person who will take the proposal to the executives and argue the benefits of simulation. To ensure that the argument is effective, this champion must have some modeling experience so that he or she can relate specific examples of how simulation can be beneficial. Without experience, the champion will not have any credibility

and will merely be relying on what he or she has heard and read about simulation.

Next, the champion must formulate an argument for simulation that includes examples of what the technology can do for the company. Using success stories from other companies that have adopted simulation may be a good way to establish what is possible with this technology. Once the champion has pointed out the benefits of simulation and what it has done for others, he or she needs to relate them back to specific areas within their company that could profit from such a tool. It is essential that specific projects be identified within the company before taking the proposal to upper management. Without a clear plan, executives may have a hard time understanding how it could be applied to their organization's benefit. These endeavors must have clear and defined objectives that will benefit the company in some specific way. Part of this is establishing how the results from the model or models will be used. If the output from a model is not going to be put to use in some specific way then there really is no point in developing it. Make sure that the proposal brought to senior management is well thought out. Be prepared to justify the proposal with examples and to take personal responsibility for seeing that the project gets implemented and completed as planned.

Management will make a decision about the purchase of software based on the strength of the champion's proposal. The decision may depend on how large the company is, how expensive the software is and the size and scope of the project. Investing in new technology always involves a certain amount of risk. In order for executives to agree to take this risk, the potential benefits must outweigh the possibility that the project won't get off the ground and the software will never yield beneficial information for the company. If the proposal is thorough and the benefits of simulation are translated into direct improvement for the company then the chance of approval is fairly good.

3.3 User Issues

Targeting your projects and the people involved in them will be an important part of how successful the project is. You must account for the users of your models and the issues that will arise because of them. There is a difference between a modeler and a user. The modeler builds the model and knows every detail about how and why it was created. The user, on the other hand, inherits the model from its creator and uses it to answer certain questions. Users may or may not have simulation experience so it is important that they are given enough information to run the model properly. If not given enough, the users will question the model's validity. If you give the users too much information, then they will get bogged down in the details and may not be able to decipher the main objective of the model.

When building a model, always anticipate a diverse group of users. Keeping detailed documentation will ensure that anyone who uses a model you created will be able to understand it and adapt it to their needs. The logic behind simulation models can become very complex, so documenting its development will save you the headache of trying to figure it out later. After a few months you won't be able to remember the details and you'll need to reverse engineer your own model to answer any specific questions that a user may have. Documenting your model will add a little more time to your project, but in the long run it will save you much more.

It is impossible to anticipate every person that will be using your model so it's best to be thorough. If someone with modeling experience picks up your model, they will want a detailed account of the logic behind it. Someone without experience will only need a general overview of how it works and what inputs they need to enter. Keeping two different sets of documentation would be a good way to satisfy everyone's needs; one for the modelers and one for the users.

If the model you are going to build will be used one time to answer a specific question, your chances of having a large number of users is greatly reduced. In that situation your model may not need to be quite as polished and documented. You will need to be able to explain it to the people making the decision, but once they have your information, the model will most likely be filed away and not used again. If your model is going to be used as a tool such as a forecasting or scheduling device then a little more polishing is in order. You need to assume that anyone can pick up the model and try to use it for their needs. The documentation needs to be complete and clear and the animation should be easy enough for anyone to understand.

If multiple users are anticipated then you must determine what exactly they will be using the model for. This will help you decide what kind of front end, if any, you should put on the model as well as how much access should be given to the user. Allowing users full access to the model opens up the possibility that someone might corrupt it. By putting a front end on your model, you allow the user to get at the information they are looking for without touching the code behind the model. Typically the less access you can give the user while still allowing them to get the needed information, the better.

3.4 Modeler Issues

The strength of your project will depend on the individuals who create your models. Poor models will effect the final result of the project and can be the downfall of simulation

within your company. For this reason it is in your best interest to pay attention to who will be doing the modeling within your company.

The people building the models within the company will obviously have the most control over how they turn out. These people must be trusted to have enough experience with simulation to know how to put the software to good use. They must also have a good enough understanding of the company's processes to know how to model them. The project at hand will determine how you should approach hiring modelers. If the company hasn't used simulation in the past then you can assume that they don't have any dedicated modelers on staff. There may be a few employees who have experience from past jobs or from school but don't have modeling in their current job description. It is important to find people who have adequate simulation skills and are familiar with your company and its processes. At least one person should have extensive modeling experience to drive the initial project. That person can act as a tutor for those who are new to simulation. Having a resource to answer the questions of novice and intermediate modelers will help everyone involved get up to speed.

Working on a major simulation project is the best training for those new to simulation. No amount of training can beat hands on experience. Helping create the model will force them to learn simulation and modeling techniques as well as how to examine and break down the process being modeled. By the time they finish their first project, newcomers should have a basic understanding of how to structure and create their own models. Experience and time will sharpen their skills.

Understanding the process being modeled seems a simple task. When it comes time to break it down, however, people will usually find that they don't have all the answers. In order to get an accurate representation of the system, modelers need to examine it at its most basic level. At the beginning of your project, you will most likely be unable to anticipate the questions that will need to be answered. Not until you actually build the model will you understand it at its most basic level. Over the course of the project, you will need to continually revisit the process to fill in the gaps in your knowledge of the system.

As a model is being created, the builder should continually ask how much detail is necessary. If the model isn't detailed enough, it won't be able to produce the information needed and will be an inaccurate representation of the system. Too much detail will make for longer development and run times as well as increase the chance of bugs in the model. The goal should be to include just enough detail to answer the specific questions the model is intended to answer. Do not try to broaden the scope of the model just because it is possible. Keep the objective in mind at all times and stay focused (Law and McComas 1999b).

4 USES FOR SIMULATION WITHIN A COMPANY

Simulation can be put to use in a variety of ways within a company. It is important to target a specific application for the technology before trying to adopt it. As you write up your proposal for the company, here are a few ways to sell the advantages of simulation.

4.1 Provide Information to Support Decision Making

The first use for simulation software is to provide information to the people who are making decisions for a company. These are the senior managers and executives that will have the final say when it comes to large projects such as building a new facility. Before coming to any conclusions on a project, they will want to examine all of the data available on how such an investment will affect the company. Simulation can provide information that will help decision-makers evaluate a project (Pang and Hodson 1999).

The primary factor executives will examine when evaluating a project is the financial benefit to the company. Some sort of cost-benefit or ROI analysis needs to be done to provide this information. Without monetary figures, there is no chance executives will risk any financial resources to get a project off the ground. Simulation can provide much of the needed information as to the costs associated with undertaking a project. Not only can simulation provide cost information, but a model can also break down exactly where the expenses occur. A detailed model will show costs and projected profits of the project under different parameters. Breaking down the information in this way will give executives a better understanding of the project.

Arguably the most significant advantage of simulation is its ability to assimilate a large amount of information in to an easy to understand format. Simulation takes an enormous amount of inputs and variables and does all of the computation for you. In most cases, there is no way a manual analysis could track all of the information needed to get an accurate picture of the process. Being able to give evidence of the performance of a system under different situations is immensely valuable (Mielke 1999). Simulation takes the guesswork out of project planning. Without this tool, decision-makers are left with the best guesses of those involved in the project.

Much of the information about company processes is kept informally as tribal knowledge. More often that not, however, this information is not captured and documented as it should be. The only way to access this information is to find the persons holding the relevant knowledge and question them. Gaining access to these key individuals may be a problem and you may also find that the information

may be a little bit different every time. Simulation captures tribal knowledge and documents the details of a process which yields much more accurate and reliable data when it comes time to run an analysis.

Many times during a project, those involved will spend time evaluating an option that should be discarded very early in the process. It may be difficult to identify the poor choices without the use of simulation. Once a simulation model is created for a process, it becomes a simple matter of making slight alterations for every alternative. The model will then produce the data needed to identify and discard possible scenarios that will not work. This prevents the company from wasting time and resources on options that are not feasible.

The first simulation project we undertook was the analysis of one of our vertically integrated manufacturing plants. The goal of the model was to demonstrate the ability to make product without keeping any inventory. Under the ideals of Lean Manufacturing, inventory is considered waste, so parts should be produced only when they are ordered. The project has forced us to capture and document the processes employed in the plant. As we began analyzing their production system, we realized that there was no central source of information that we could access. All of the information and operations of the plant had been based on tribal knowledge. We had to conduct multiple interviews and spend time observing the plant to get a detailed understanding of the processes involved. Once we were able to get an accurate snapshot of the facility, we created a model that could deliver statistically valid information. We continually revisited the processes in the plant to ensure that the model was an accurate representation of the real thing. Our results showed that under certain conditions, producing without inventory was possible. The information from the model provided the plant with the data they needed to make beneficial changes to their facility. Incorporating these changes meant fewer inventories, which equaled less money wasted. The project demonstrated the benefits of simulation by capturing tribal knowledge, providing valid information in an easy to understand format, and translating that information into direct savings for the company.

4.2 Training and Education

Simulation can be used as an effective teaching tool (Williams 1997). A simulation model is simply an electronic abstraction of a real world process, so the models you build don't have to be exact replicas of the processes used within your company. A model can be used to show how a process should be structured under different principles. This gives people a visual example to look at while they are trying to understand these processes. Using simulation models to teach certain methods or concepts can be very effective and will increase the learning curve for the students.

The first training models we developed were to demonstrate the advantages of inline manufacturing vs. shared resources. This is a relatively simple application for simulation technology. The inline model (Figure 1) is simply a string of sub-processes put together to represent a manufacturing line. Each line in the model operates as its own process and doesn't share resources with any others. The shared resource model (Figure 2) has multiple lines that share a single resource for one particular sub-process step. By running the two side by side, it is easy to see the differences between them and how they affect overall output.

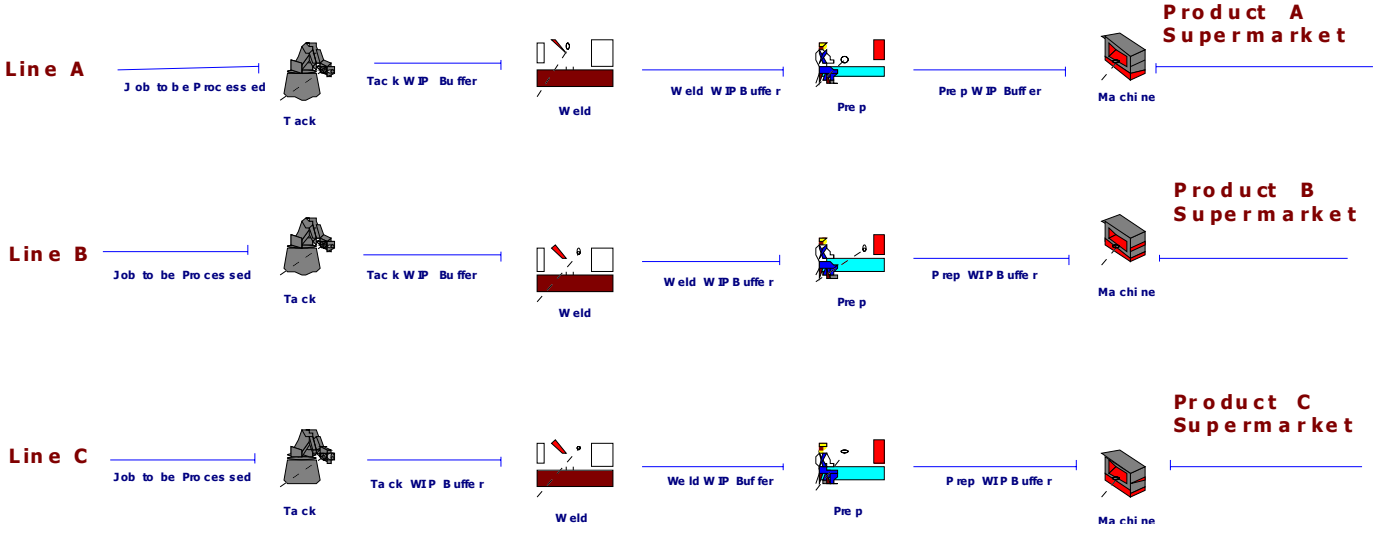

Figure 1: A Simple Model Demonstrating the Concept of Individual Production Lines per Product

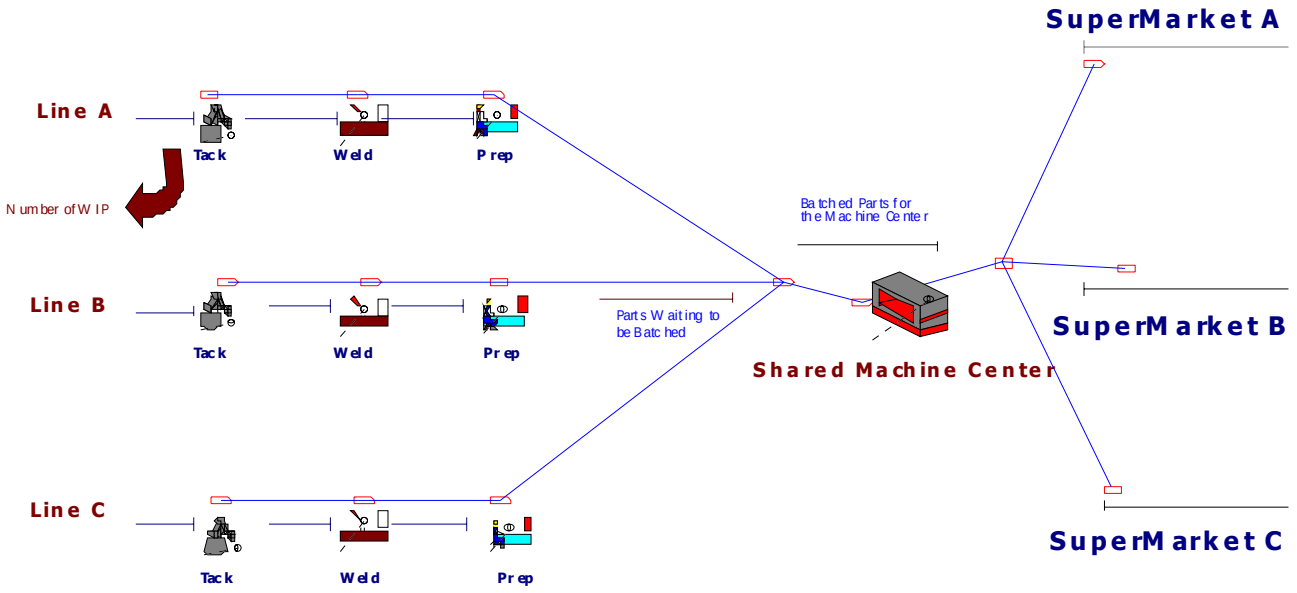

Figure 2: A Contrasting Model for Examining the Problems Caused by Shared Resources

Both of these models are heavily dependent on their animation to demonstrate the processes. We found that people had a hard time grasping some of these concepts without a visual representation to aid in the teaching. Since they are geared for people who have little to no simulation experience, they needed to resemble something they could see on the shop floor. This helped give them a frame of reference and kept the methodologies in context. As word of these models spread around the company, more and more people began approaching us about using simulation in their area.

These models are not specific to any one plant, so they can be used throughout the company for training at all levels. We found that this was an excellent way to increase awareness of simulation within the company while using it to teach other topics. Increasing awareness about the benefits of simulation helped bring about new projects in other parts of the company. Once people caught on to what simulation is capable of, it became broadly adopted and can now have a lasting impact on a company.

Simulation models are an excellent way to train people on any number of different methodologies. Some of the concepts we have worked with include one-piece flow vs. batching, and resource utilization. These are simple theories, but they become much easier to explain when you can show the student exactly how it works in a model.

4.3 Forecasting and Design

Senior managers and executives will want to see simulation put to use on projects where they feel there is a lack of information and direction. Typically a good project to demonstrate the capabilities of simulation is one where the company is either opening up a new facility or expanding on an existing one. It is difficult for a company to anticipate how a manufacturing line or facility will perform before actually putting it in place and letting it run. Once that line is in place, it may be difficult to forecast how it will perform under future conditions. Executives want some sort of information to base their decisions on other than people's gut feelings or best guesses. By creating a simulation model that closely reflects the new endeavor, you can produce data that will better resemble how the real thing will perform.

Before moving large pieces of equipment into a building it is best to design the optimal layout for the company's planned processes. This is a long process in which the project team will need to go through many iterations before settling on the best option. Simulation allows for the variation in distances and travel times between machines as well as specific resource characteristics that need to be taken into consideration when deciding on an optimal layout. Creating a model of a facility before it is in place provides information that will help decision-makers evaluate the project when little or no other information is available.

Production planning and forecasting capacities with simulation is an ongoing project that will continually provide useful information. Once the facility has been laid out, executives are likely to want to know what the capacities of the new facility are going to be. The same goes for facilities that undergo process changes, or changes in the product. As long as you include a detailed and accurate representation of resources, the output from the model will closely represent how the system will perform. Each time the plant undergoes a change, the model can be used to provide information about how the change will effect its performance. This information fills in the knowledge gaps and

allows decision-makers to make much more accurate predictions about the company as a whole.

4.4 Shipping/Scheduling

Shipping/Scheduling is also a major area for simulation use. Simple operations with only a few products and deliveries can be modeled by hand, but as a company grows so does the complexity of scheduling. Coordination of all the variables in the system becomes increasingly difficult. The advantage of simulation modeling is that the modeler and user are not exposed to the complexity that is actually embedded in the processes. Once the user enters all the distances and travel times, the software can track and calculate all of the variables in a schedule for you. Running a simulation model for a scheduling operation will essentially give the user a look into to the future (barring any major unforeseen problems or changes). The user will be able to anticipate the snags and problems that are going to occur during the time represented in the simulation run. With this information, he or she can make the necessary changes to avoid any problems.

5 CONCLUSION

Simulation is one of the fastest growing tools in the manufacturing industry. Adopting this technology can have a profound effect on a company's efficiency and performance, but you must first convince the company that it can indeed benefit from the substantial investment in people, software and effort. By thoroughly considering the issues that may impede the adoption of simulation in a manufacturing organization, you will be better prepared to plan and direct its successful incorporation as a valuable management and engineering decision-support tool.

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