

Simulation Modeling with



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Produced by:



Simulation Solutions

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Jo-Dee Burbach Tuling

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Preface

As a simulation user, developer, and advocator, I am pleased to see the development of a book that not only looks at how to use SIMUL8 software but also explores and discusses the uses and application of simulation in general. It has always been the mission of SIMUL8 Corporation to make simulation a general purpose, easy-to-use tool that is available to all types of decision-makers regarding the flow of work or people. As a result, the uses of simulation and SIMUL8 applications are great and varied. This book is a good introduction to a variety of applications of SIMUL8 over the years since its introduction in 1994.

The authors of this book, apart from myself, are all part of a company called Viusal8 Corporation that has, since SIMUL8's inception, been the primary support and solution provider within North America. As a result, this team of authors is well equipped with the necessary experience to tackle the use and application of simulation techniques using SIMUL8. I was excited about learning more on the applications that this advanced team of consultants has undertaken over the years, and welcomed the introduction of SIMUL8 as the basis for a simulation-based textbook for students and new users alike.

The scope of this text is wide and well surpasses any reference material currently available on the use of SIMUL8. Not only does the book cover all aspects of SIMUL8 and forms a practically useful guide to the use of SIMUL8 software, but it also extends further into the use of simulation, industrial applications, and case studies. This created a mammoth task for the team in terms of collecting information on typical case studies and making them of general use to the reader. The group's main goal was to provide a textbook that would inspire readers to tackle new areas of simulation application as well as instruct them into methods to easily apply the technique. Consequently, this book is an excellent collection of case studies, knowledge, and expert reference to simulation and the tool SIMUL8.

As SIMUL8 approaches its twelfth year, its ease of use makes it a great tool for all decision-makers. This book provides a practical guide to the use of the tool within many industries and I am excited to see this area of the text grow over the coming years.

Mark Elder, CEO and Founder of SIMUL8 Corporation

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Simulation Overview

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The first section of this textbook introduces the concept of simulation modeling.

Although it has been used for operational analysis for a number of years, few decision-makers are comfortable with the technique or even have a basic knowledge of the concepts. Therefore, we cover first the basics of simulation, such as what it is used for, how it works, and what new developments are occurring. Then we describe a typical approach to carrying out a simulation study, and deal with some of the issues that are often faced by those building models for clients. Finally, we have included some statistical considerations, so the general reader will understand how model results obtain their validity.

Chapter 1: Introduction to Simulation

What is Simulation?

Simulation is the use of a computer program to model a real world system, in order to validate decisions affecting the system. Simulation provides decision-makers and clients with the equivalent of a 'flight simulator' of their factory or other decision system. It does this by representing (in computer code) every significant resource and event in the factory or decision system and displaying on a computer screen an image that moves with 'simulated time'. This enables the client to try out different ways of operating the system without experimenting with the real system. Consider the following scenario:

A new factory is being designed. How many lift trucks will be needed? There is seasonality in the demand, and shipping times can vary considerably. This does not present a difficult problem, since the design group has been modeling the factory with a visual interactive computer simulation. Spreadsheets alone are not adequate, and a poor guess could lead to an expensive and problem plagued startup. Travel paths and times are added to the model, and the best data on order levels, production lead times and truck traffic, varying randomly within a known pattern, are used. Various fleet sizes are tested, and the model is observed for congestion, idle lift trucks, lineups at the shipping docks, and other signs of imbalance. Only a few simulation runs are required to establish the size of a permanent fleet and rules for deciding when to rent additional trucks. This will ensure that overall transportation costs and service levels are acceptable.

Simulation is used to help with the design or modification of complex systems - factories, businesses, etc. - by experimenting with alternative combinations of resources - people, machines, etc. - and with alternative

● Throughout this book, the term “simulation” refers to visual interactive computer simulation modeling. ●

operating policies. It can be used to test out plans or to gain insights into which alternatives can be worthwhile under a number of different assumptions about the operating environment - for example, customer demand.

'Simulated time' usually moves much faster than 'real' time - so a day in a factory might be simulated in a few seconds in the simulation model.

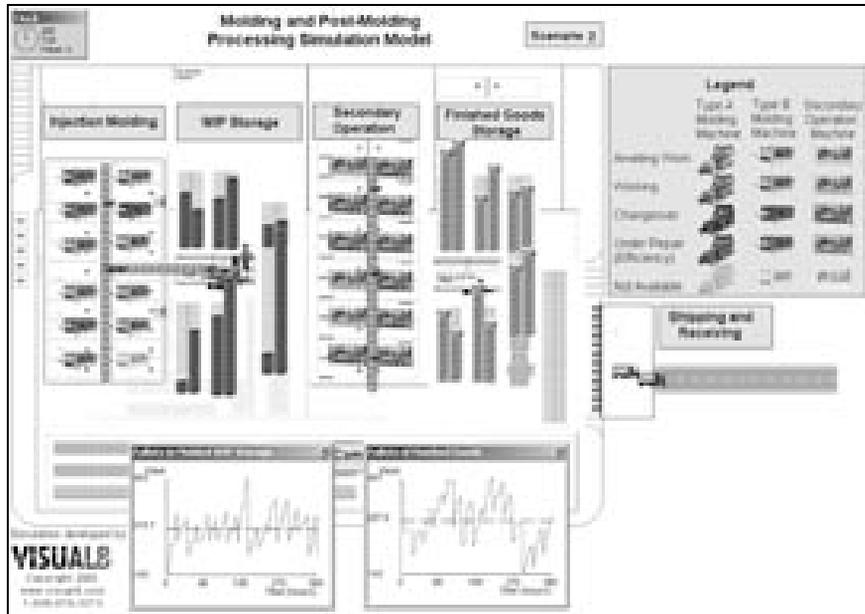


Figure 1-1: Sample Simulation Screen

Modern simulations provide a graphical representation of what is happening in the system as the model is running, and allows the user to make changes to the model through a graphical interface. This is called Visual Interactive Computer Simulation, and is the topic of this book. The picture on the computer screen is often a 'plan view' of a factory, or even a 3D representation, but any useful graphical representation of the process can be used. This allows the users of the model to 'see' what is happening inside the model. The design of the screen image is therefore one of the most important aspects of simulation today.

Today's packages are becoming easier and easier to use, and are well within the grasp of decision-makers at all levels of the corporation. Using, and participating in the building of, models with visual interactive simulation

software is in fact becoming an essential skill of decision-makers. It supplements, and even sometimes supplants, the use of spreadsheets and other management information sources, in decision-making over a wide range of mission-critical activities, including logistics, communication, operations, human resources, and finance.

Why Simulation?

One of the main benefits of simulation is its ability to model the way things occur in the real world. The types of systems typically modeled exhibit dynamic (changes over time) and stochastic (statistical variability) behavior.

Static vs. Dynamic

Dynamic modeling ensures that a time dimension is explicitly included. Static modeling provides a snapshot of the system with no time element. Using simulation means that the dynamics of a system can be played out over time. It is very difficult to accurately model a system that is dynamic using static analysis such as spreadsheet modeling or flowcharts. Rates of change are the most difficult component to understand and handle statically. A steady stream of customers is the desire of every business, but all customers arriving at once overwhelms most systems and must be planned for properly. Modeling a system over time instantly makes this kind of complexity understandable.

Without an understanding of the dynamics of a system, we tend to use the worst case (needlessly expensive) or the average (dangerously under-designed) to describe the system. How many elevators should a building have? The worst case occurs just around 8:00 AM, when 80 employees arrive simultaneously from the subway train. The average, over the course of the day, is only 30 people per hour. Six elevators are needed, if no one is ever to wait for more than three or four minutes. One is enough to handle the average traffic. Neither is the correct answer. A simple (and inexpensive) simulation will establish the best balance between costs and wait times.

Deterministic vs. Stochastic

- A stochastic or probabilistic simulation can act like a deterministic model by using fixed distributions.
-

Simulation provides the capability to model variability in systems. For example, a welder may be supposed to be able to weld one box every 5 minutes but in practice, there will be some variability in this. More variability will be experienced in how often the customers place orders for boxes. Variability can often be described using statistical distributions. The best known is the normal (bell curve) distribution. This would describe the natural variation in the time for welding a box. There are many other distributions, which describe particular situations (e.g. the exponential distribution, which describes the typical interval between order arrivals).

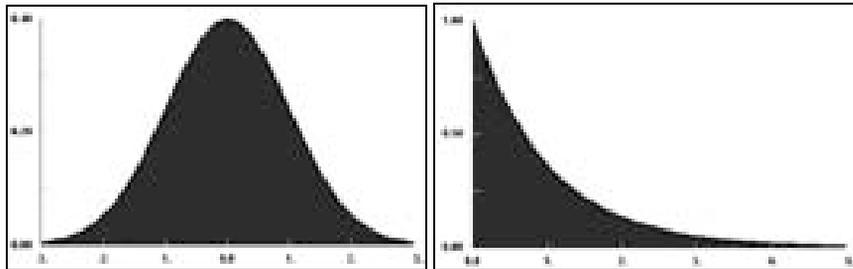


Figure 1-2: Normal and Exponential Distributions

Simulation creates this type of variability, or randomness, by using a stream of 'random numbers' to generate random events that fit the appropriate statistical pattern. Random events imply that one event has no effect on what the next one will be.

Sometimes simulation models do not contain any built-in random elements, since variation is not of interest to the purpose of the simulation. This is frequently the case for simulation-based planning and scheduling applications.

Benefits of using simulation

The advantages of a simulation-based approach to a project have been discussed at length by many authors, and go much further than just the ability to simulate forward in time. The following provides a summary of some of these advantages, as described by other authors, such as Banks, Carson, Nelson, and Nicol (2000); Law and Kelton (2000); and Schriber (1991):

- Determining the 'best' choice – By simulating a proposed change, it is possible to select the best choice for change before implementing it. This is extremely important, since designs that have been implemented are difficult and expensive to alter. By testing all assumptions prior to installation, expensive mistakes can be avoided.
- Manipulating time periods – Simulation provides the ability to speed up or slow down time for evaluation purposes. Many simulation packages provide the ability to simulate a whole year's production within a couple of minutes, giving the user access to a large simulation period quickly. Similarly, for in-depth analysis of a specific period, the simulation model can be slowed down or stepped through for investigative purposes.
- Understanding systems – Simulation is especially useful when systems cannot be viewed or observed in their entirety. Managers can use simulation to reconstruct the system and view the operation in its entirety to gain insight and understanding of the interconnectivities and interdependencies of the system.
- Exploration – When undertaking new initiatives, such as those which come from a Six Sigma project, the simulation model of the system can be used to evaluate and explore the recommendations made without disrupting the current system.
- Problem identification – Most modern systems are complex in nature. Simulation provides a place to explore these systems for the identification of problems. Only by understanding all of the interdependent variables is it possible to identify the true source of the problem. This results in less time spent trying to remedy the symptoms of a problem instead of solving the problem itself.
- Bottleneck Analysis – Through identification of the bottleneck by means of simulation it is possible to quickly evaluate methods for addressing that issue.
- Visualizing the plan – When designing a completely new system, many potential design flaws cannot be anticipated through evaluation of a static system. By monitoring the design in an animated model, it is possible to find inherent design flaws and eliminate them.

- Gaining approval – Simulation provides an excellent platform for demonstrating new ideas and concepts for system improvement. When managers can see the immediate benefits of a change, it is much easier to get acceptance or budget approval.
- Preparation through ‘what-if’ analysis – By running many simulations of potential problems, which can occur over time in the system, it is possible to be prepared for most eventualities, and develop plans to address them.
- Analyze capital improvements – A typical simulation study costs approximately 1% of the cost of capital improvements. By using simulation to ensure that the correct capital improvement is made, large savings can usually be realized.
- Training other employees – Simulators have been used for years for training. In the same manner, a discrete-event simulation can be used to demonstrate a new policy for employees. Visualization provides an accelerated learning platform.

Challenges in using simulation

Many of the difficulties in using simulation are being addressed with advances in computer technology and simulation capabilities, but some are as follows:

- Special knowledge is required – In the past, only simulation experts could create simulation models. This was generally expensive. Simulation packages, especially those based on Windows™ technology, are becoming much easier to use, and require little to no code.
- Hard to interpret – As many of the outputs are the results of random number generation, it can be difficult to determine the accuracy of the results. Most simulation packages will provide summary and detailed reports for improved analysis, as well as export features to programs like Minitab™, and Stat::Fit™ for analysis of statistical significance.
- Time-consuming – Detailed simulation models sometimes take a long time to develop, tying up valuable resources. Through the use of dialog driven, drag and drop build objects, simulation models can be built quickly and easily for analysis.

The Position of Simulation in the Organization

Approaches to Simulation

Simulation holds a unique position within an organization. It is not a traditional function such as marketing, finance, IT, HR, or operations, but instead can be applied across any or all of these departments. Depending on the simulation software package used, the type of application, and the size of the company, organizations dedicate varying amounts of effort and resources to simulation.

The following table shows of how different kinds of companies will typically approach the use of simulation.

Approach	Typical User	Considerations
No staff assigned to develop or use simulation.	Small companies without engineering staffs Occasional simulation users	Rapid model development, through use of consultants Reliance on consultants to interpret results of modeling projects Cost effective for well-defined projects
A few staff to <u>use</u> simulation part time	Midsize companies with industrial engineering departments Users who want to play a part in the development of recommendations	Rapid development of models, through use of consultants, with user training provided Ability to explore a wider range of options Cost effective for ongoing projects, with fairly simple structures
A few staff to <u>develop</u> simulations part time	Medium to large companies, with a variety of engineering disciplines	Slower development of models, with some reliance on consultants, to ensure models and results are valid

Approach	Typical User	Considerations
	Users with occasional expansion or reengineering projects	Cost effective for ongoing projects, with structures and testing of medium complexity, and the need to modify models constantly
Dedicated internal simulation consulting group	Large companies with a variety of specialist engineering departments and other analysts on staff serving several locations Users constantly expanding or going through improvement initiatives (e.g. Six Sigma, Lean)	Internal group acts as consultants to managers and project leaders, who have an understanding of the uses of simulation Cost effective where there are many, or large, projects requiring constant assistance from simulation specialists

Figure 1-3: Position of Simulation in the Organization

Who should be doing Simulation?

It is fast becoming accepted that any decision-maker who is capable of using a spreadsheet should additionally be using simulation, or should have access to simulation to make informed decisions. Simulation is becoming much easier to use and as a result is becoming more accessible to the general decision-maker, including some of the following:

- Project Engineers,
- Six Sigma Black Belts,
- Plant Managers,
- Process Improvement Planners,
- Plant Design Engineers,
- Manufacturing Engineers,
- Business Consultants,
- System Analysts
- Production Planners

Choosing Simulation Software

The following discussion will deal only with modern visual interactive simulation packages and, in particular, those designed to be used in interaction with clients.

Like most software today, simulation software packages are adding features and capabilities very quickly due to competition and customer expectations. Although there are many users of simulation around the world, the market for simulation software is still quite small. Consequently, there are many small companies producing specialist simulation software. No two packages are alike (in contrast to word processing software packages, for example, which have similar features and operate nearly identically, and are marketed by a few large developers).

Implementation on high-power hardware has always been preferable for effective simulation, since large simulation models would otherwise be slow to run. If the user has a large number of runs to undertake, a fast computer is essential. Conversely, user-friendliness is also very important, so mainframe computers are inappropriate. Personal computers with high power processors have been popular with simulation vendors. With one notable exception, very few simulation packages are available for the Apple Macintosh operating system.

● Use the Simulation Software Survey from OR/MS Today as a starting point when evaluating simulation packages ●

<p>Software selection checklist:</p> <ul style="list-style-type: none"><input type="checkbox"/> Captures the essence of the system in the screen image<input type="checkbox"/> Uses industry standard interface<input type="checkbox"/> Uses customizable templates<input type="checkbox"/> Allows for different levels of detail<input type="checkbox"/> Automatically collects statistics<input type="checkbox"/> Allows freedom to build custom screen displays<input type="checkbox"/> Allows the builder to implement custom control logic in code

Figure 1-4: Software selection checklist

Currently, any simulation software that is selected should provide the user with the following facilities:

- Capture most of the logic of the model as the picture of the factory (or other system) is drawn on the screen. In the past, it was necessary to write a program or fill in forms describing the system, and either attach the display afterward or program the model to drive the display. The display is a vital element, as indicated above, so this is where the model should be built.
- Use an "industry standard" operating system (e.g. MS Windows™).
- Provide standard high-level elements that can be customized. For example, if the user simulates an automated warehouse as part of a system, the simulation package should provide a standard "automated warehouse" template that can be customized.
- Allow different degrees of detail in the model. For example, when modeling a car factory, the developer may need to model each car individually, whereas in modeling a canning line, the developer may treat each can as part of a continuous flow of 'product.'
- Automatically collect statistics on the performance of the simulated system and make these available so they can easily be placed in reports. Packages are becoming available now that take care of a good deal of the statistical calculations (including helping to decide on warm-up time, etc).
- Enable the developer to design and build screen displays that are tailored to the requirements of the client. They must be recognizable to the client, and also designed to help the developer and the client see the key variables in the problem
- Allow the developer to customize the logic in the model to match the situation modeled. It is possible to create simulation packages that are very easy to use, but they do not have sufficient flexibility to enable the developer to describe the exact situation being modeled. Therefore, having captured most of the description of the model as it was drawn on the screen, the package should provide a means to modify and add detail to this logic. The extent to which this can be done can be an important element in the process of deciding what simulation package is suitable.

How does Simulation work?

A simulation model is a computer program. As with other user-friendly programs, the inner workings are usually hidden from the user. This allows the model builder to concentrate on getting results, rather than having to learn to construct code.

While the user does not need to know how a simulation model works in order to run and use a model, knowing a little about it usually helps facilitate the development and analysis process.

All Simulation models contain three important, though frequently hidden, items:

1. A **time clock** that represents 'simulated time'. In computer terms, this is simply a variable in the computer's memory. This changes on the screen as events take place in the model. The time might be measured in seconds (quite common in a factory simulation where the length of jobs might be measured in minutes and parts of minutes), but could be weeks (if the simulation dealt with the exploration of the North Sea for oil fields) or micro-seconds (if the simulation focused on the performance of some electronics for a new type of telephone exchange).
 2. A **list of future events**. An 'event' in a simulation model changes the state of some part of the model into a new state at a particular time (for example machine 21 in the factory will finish welding the side on a box 5 minutes after it starts). The list of future events contains those events that have already been calculated to occur at specific pre-determined times. At any given time the simulation model will only have determined a small number of the events that will actually occur - for example, it will not be able to determine when the machine will finish welding the box until it has *started* to weld the box, since the finish time is the product of the start time plus a process time determined from sampling a statistical distribution of possible times.
 3. A **record of the current states** of all the things in the system that can change state. For example, machine 21 is currently welding the side on a box and this is the seventh box it has welded this morning. This information will be used for additional calculations, such as determining when to halt the welding process for machine cleaning (which happens after welding 10 boxes).
- Recommended units of time:
 - Seconds for less than 1 day
 - Minutes for less than 6 months
 - Hours for less than 2 years
 - Days for more than 2 years ●

The clock is set to zero at the start of each run of the simulation. At this point, the computer looks at the list of future events and decides which comes first, by reading their corresponding time label. The computer then changes the clock to read that time and deals with the corresponding event. This is simply a matter of adjusting the states (point number 3 above) in whatever way is appropriate for the type of event - for example, the machine is now idle having finished welding the box. The computer then adds to the list of future events any new events that are now capable of being determined, and perhaps changes states. For example, as there is another box waiting to be welded, the machine is set into a busy state again and another 'finish weld' event is added to the list of future events. During all this activity, the time clock has been reading the same time. Now the computer starts over again and looks at the list of future events to see what time to set the clock to next.

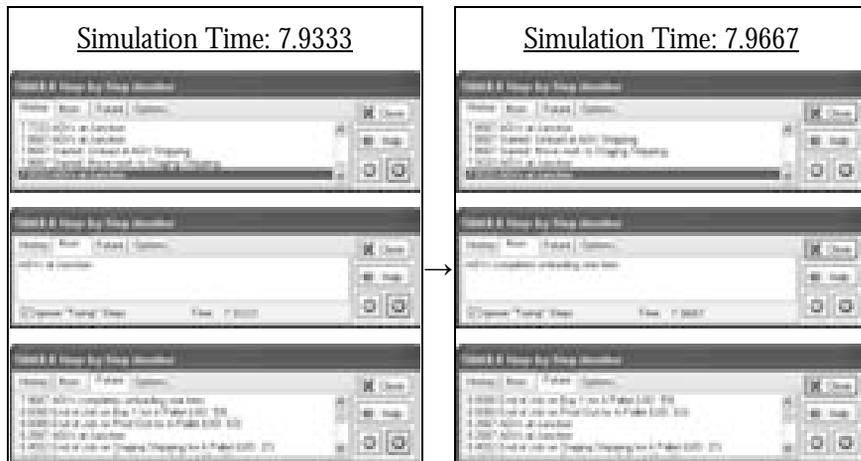


Figure 1-5: Simulation History, Now, and Future Events

Although the above comes in many guises, all simulation systems (at their heart) work in this way.

Most simulation packages will actually contain rather more information than these three elements. An obvious category is statistical information collected as the model is running.

Another important category of information contained in a simulation model is structural information. This encompasses all the information about where and how to display the states of everything in the simulation. For example, where to display the machine mentioned above (physically with respect to other machines, etc.), what it should look like, and how its

appearance should change when it is in different states (working, idle, broken down, being cleaned, etc).

Other Types of Simulation

Having defined simulation for the purposes of this book, alternative types of simulation should be discussed.

Continuous Simulation

A category of simulation that remains important is *continuous* simulation. These models simulate systems that cannot be broken down into discrete events because of the mathematically continuous relationship between the variables. An example might be that the rate at which a chemical reaction takes place is dependent on the temperature of the chemical and that is dependent on the rate at which the reaction is occurring. These situations have to be modeled using differential equations. Where differential equations are a central part of the problem system, it is worth using a specialist continuous simulation system to model them. Most modern simulation software packages handle continuous simulation when necessary, by breaking a continuous process into a large number of discrete events.

Historical development of Simulation

Simulation, as a process, has evolved considerably over the years since its inception in the 1960's. Early simulations were developed entirely in computer code, and provided no visual display of the simulated system. As computing capabilities evolved, so did simulation, with the introduction of graphical displays, although these systems were still heavily dependent upon a skilled computer programmer. The latest generation of simulation software utilizes standardized objects and drag-and-drop functionality that make it easy to create simulation models without the need for a computer-programming expert. As a result, simulation is fast becoming a decision support tool for many managers in the same way that spreadsheets have become widely used. There are two main restrictions to this evolution: ease of software use, and the possession of simulation skills to develop usable simulation models.

- See the Institute for Operations Research and Management Science website (www.informs.org) for more information on OR ●

How simulation users approach Operational Research (OR), in general, has a large impact on their use of simulation. OR techniques, in recent years, have started to become standard tools used in organizational decision-making. OR is slowly becoming so engrained in the decision-making process that predominantly OR departments no longer exist as totally separate entities within companies. Real world applications of OR are generally so complex that generating a mathematical model encompassing the entire solution space is simply too large and complex to be useful. OR practitioners have been turning to simulation techniques to model dynamic and mathematically complex situations. In this way, simulation is rapidly becoming a widely trusted and utilized decision support tool. This is the origin of the claim, stated above, that models need to be built and used by the decision makers themselves as often as possible. Decision makers should at the least be heavily involved in the model development process and its direction.

The Future of Simulation

Advanced Planning and Scheduling

Advanced Planning and Scheduling (APS) through simulation has recently become of increasing interest to both academic researchers and business professionals. Several papers on Planning and Scheduling have been published. Advanced simulation packages are now providing the capability to integrate APS into simulation modeling.

Many organizations have implemented ERP systems to satisfy the need for financial and production information for top executives. However, ERP systems are limited in meeting the day-to-day needs of the shop floor. ERP systems cannot help when it is necessary to react quickly with alternative planning and scheduling decisions in reaction to sudden changes in requirements and equipment breakdown.

Simulation, by its nature, provides a detailed capture of all the inner workings and detailed rules and routings of work within a plant. This is a level of detail that large ERP systems cannot possibly approach. By backward planning in the same manner as these ERP systems and then executing the plan through a detailed simulation model, an efficient schedule is generated which actually works on the shop floor.

Simulations are also responsive to the constantly varying needs of an organization. Packages are becoming more and more robust and flexible, and organizations are implementing simulation with ERP to make decisions as quickly as circumstances change, such as machine breakdowns, resource unavailability, and the arrival of rush work orders. The ability to re-plan on a minute-by-minute basis avoids the need for inefficient manual change to a production plan.

AutoSched and SIMUL8-Planner are two products that use simulation as a platform for Advanced Planning and Scheduling.

Real-Time Decision Support

The use of simulation for real-time decision support is becoming increasingly important. Plants and systems are dynamic in nature. Their needs are constantly changing, as machines go down, new orders arrive, or resource availabilities change. Many simulation tools, including planning and scheduling applications, need to be capable of reacting to these changing circumstances quickly and efficiently. Usually, engineers or model users manually intervene in reaction to changes. However, to ensure data integrity, another method of updating the scheduling system must be used.

The simulation must be tied to the MES (Manufacturing Execution Systems) and ERP systems to obtain data on the current state of the plant. PLCs (Program Logic Controllers) are constantly collecting and feeding detailed operational information to the MES for monitoring purposes. ERP systems contain up-to-date order databases and other operating parameters, which can be used by the simulation model. By downloading this information to a simulation model, it will be working with the current state of work-in-progress, availability or states of machines, and accurate task times at the stations, ensuring up-to-the-minute accuracy of model outputs. In this way, real-time decisions can be made using simulation.

The diagram below shows a typical architecture for real-time decision support using historical and current data from MES and ERP systems to drive simulation and advanced planning and scheduling.

An example of this is adaptive APS using simulation. The simulation-based scheduling tool downloads live updates on the current operating status, process times, reliability, and order status from the MES, and obtains detailed inventory data and order requirements downloaded from MRP systems or other databases. Following the procedure discussed in the

- SIMUL8-Planner is a software package that combines simulation with planning and scheduling tools. ●

previous section, the most efficient schedules are then automatically generated.

Real-time and historical data can also be used to drive a number of other different simulation applications including constraint analysis, line-balancing, capacity planning and workflow analysis tools. For example, a constraint analysis tool can take historical information on equipment cycle time and reliability and dynamically identify bottlenecks in the system.

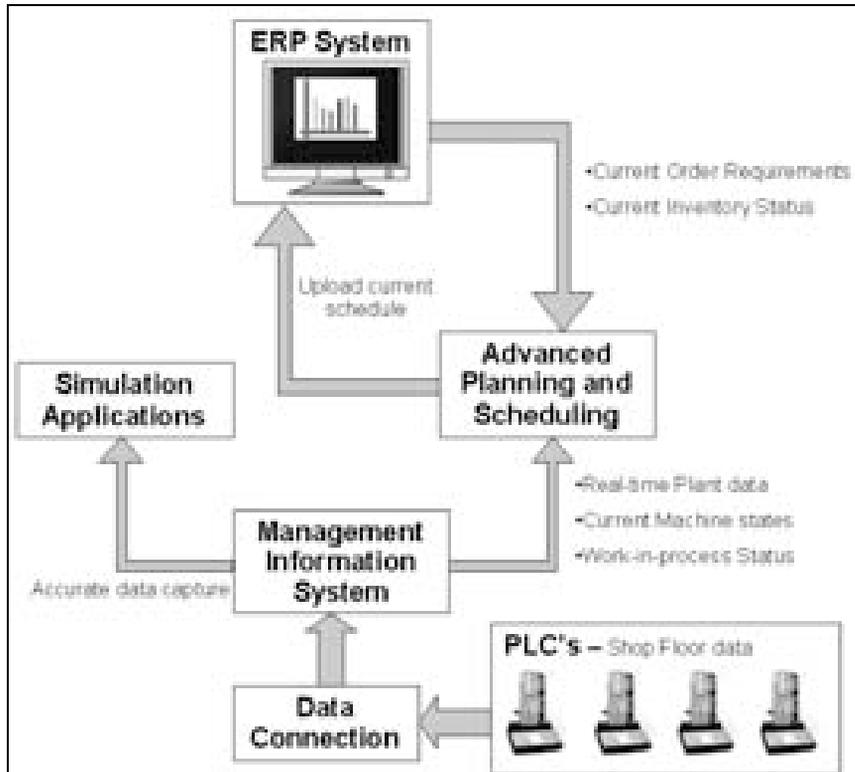


Figure 1-6: Real Time Decision Support Architecture

Chapter 1 Review and Questions

Chapter Summary

We saw that simulation is the use of a computer program to model a real world system. The chief benefits of using simulation to solve problems and help in making decisions, rest on including the time element, and random variation in system characteristics, in order to describe the real world more accurately than static methods of analysis can. Visual interactive simulation modeling is the main way to simulate on a computer. This means that simulation can be easily used by any size organization, and by a wide range of individuals within the organization. Selecting software for simulation should therefore be based on ease of creating the screen image, and capturing the main features of the system, without the need for writing code. Of course, it is still important to understand that simulation rests on a time clock, a future event list, and a record of the current state, and is driven by pseudo-random number streams. Since its early days, simulation has come a long way, in tandem with the development of the personal computer. Simulation remains a dynamic field with new developments such as simulation-based advanced planning and scheduling, real-time decision support, and emulation.

Test your understanding

1. Describe a problem in which the decision-maker must consider a variety of criteria (multi-criteria decision model) in which simulation would be useful.
2. Describe a problem in which the visual aspect of a simulation would be the key motivator for using simulation tools.
3. Give examples of the following:
 - a) Static system
 - b) Dynamic system
 - c) Deterministic system

- d) Stochastic system
4. Describe the link between simulation studies and decision-making.
 - a) Who makes decisions?
 - b) Who makes simulations?
 - c) Why is simulation potentially powerful?
 - d) What other programs are useful to aid in making decisions? Which overlap and which can be integrated together?
 5. Describe a problem that could be simulated for the following:
 - a) Project Engineers
 - b) Six Sigma Black Belts
 - c) Plant Managers
 - d) Process Improvement Planners
 - e) Plant Design Engineers
 - f) Manufacturing Engineers
 - g) Business Consultants
 - h) System Analysis
 - i) Production PlannersTry to identify for each problem:
 - i. Who should develop the simulation?
 - ii. Where should they be positioned in the organization?
 - iii. What set of skills should the developer have?
 6. Name the first five events happening in a simple single ATM system. (Describe all states and events.)
 7. Describe the potential for APS in six different industries
 - a) Healthcare
 - b) Mining
 - c) Metal Production
 - d) High volume manufacturing
 - e) Low volume manufacturing
 - f) Coffee (from bean to mug)
 8. Describe how real-time simulation would affect the following:
 - a) Constraint analysis
 - b) Line balancing
 - c) Capacity planning
 - d) Workflow analysis
-

Chapter 2: Working with Simulation

Typical Simulation Study

Most simulation projects will have a client, whether a consultant is working for an external organization, or an industrial engineer is working for a Plant Manager. We will deal with the steps in a typical simulation study from this point of view. In practice, a simulation study is not generally a series of steps, but an iterative process where the model builder and client work together to refine the simulation model. However, the following aspects of a project should be included to ensure a successful simulation study.

Simulation study checklist:

- Identify the objective
- Determine the level of detail
- Determine the processes to be included
- Create a rough model
- Refine the model
- Run the model
- Verify the model
- Determine the warm-up time
- Explore the model
- Choose scenarios and run trials

Figure 2-1: Simulation study checklist

1) Identify a Need/Objective

Listen to the client to find out what issues they are interested in exploring and how their operations work. Their thoughts on what concerns them will provide a good idea of what variables and structure will help them to use the model of their system effectively. At this stage, a conclusion is reached whether simulation is even the best way to assist the client.

2) Determine Level of Detail

Consider the level of detail that is appropriate for the model. For example, is it necessary to include every part of every operation at each machine in the factory, or is it more appropriate to simply model the output of whole departments and how they interact with each other? Putting too much detail in a model takes longer time and can also cloud the issues that the decision maker is interested in.

3) Determine the Processes to be Included

Consider the scope of the model. For example, is it reasonable to limit the boundaries of the model to the factory itself, or do the systems that affect supply of raw materials to the factory also need to be included?

4) Create a Rough Model

Build a rough and ready simulation model as quickly as possible. It does not matter if some data is missing or if it crashes when it runs; the best attitude is 'to start before you are ready.' This rough model can then be shown as a prototype to the client. Experience has shown that even static drawings on a computer screen can do a good job of helping the client to understand the following:

- What information the client will get from carrying out the simulation study?
- What aspects of the need and objective mentioned above, have been misunderstood?
- What aspect of the system is of particular interest to the investigation now that a consultant has put some structure to the problem?

Creating a rough model is much more important than it may seem. The model builder's first idea of what is a suitable simulation model can be very different from the simulation model at the conclusion of the study. This is not because the model builder was necessarily wrong, but because the client's needs evolved in the course of the process.

Again, it does not matter how rough the model is, because, in most cases, it will be necessary to start again.

5) Working with the Client

Start working more closely with the client to build a more robust model. In fact, with the types of software becoming available now, it is possible for all the stages above to be part of one session with the client.

It is especially important to work with the client since the process of building a simulation provides a learning experience in which the client uncovers new facts about the system. Through this process, many experiments will be tried that challenge the assumptions of both the client and consultant. Both the client and model builder will learn a lot about the way the factory operates (and could operate) under different circumstances. If clients are not engaged in this development, then they will not understand how the end result has been reached. Without client involvement, implementation of anything other than an obvious solution could be difficult, as the client may not trust the results. The process of building models will be discussed in the sections on simulation technology, but it is important to realize that there are two key, but separate, skills involved in the model building process.

1. Being able to use the software to build a robust model.
2. Being able to design the display for a model that highlights the important issues to the client without clouding the root causes with information overload.

The second of these is not easy to learn, but this book is designed to provide a feel for its importance and what is likely to affect its success.

Working with the client breaks down into many sub-steps. This phase continues until the client feels they know what is best to do, in other words, until the problem is solved. The client/model builder relationship will be discussed in greater detail later in this chapter in the section Client – Model Builder Relationship on page 41.

6) *Running the Model*

Run the model (start the simulation clock and see the units moving around the system). This stage can provide many insights into how the system works and what changes would improve it. However, it is very important that certain key steps are taken to ensure validity of these discoveries.

7) *Verify the Model*

Verify that the model is running in the same way that the real world would work in the same circumstances, as the first step. In theory, there is a need to do this every time a change is made to the model, but clearly, this would be impractical. If the simulation is a model of an existing system, this verification stage is just a matter of ensuring the model behaves like the real system. For example, putting some actual customer orders into the model and seeing if they are handled in the same way and in the same time as they are in the real factory would accomplish this.

The only way to verify a model of a new system (which does not yet exist) is to carefully experiment with the model, watching both the animated screen and the statistics to see if the changes observed are reasonable in the light of changes made to the model input parameters such as demand, numbers, speeds of machines, etc. There is a methodological problem here because clearly, if these changes were known or expected, there would be no need to build and use the simulation model in the first place. Nevertheless, careful examination of the model's behavior will allow the identification and removal of most mistakes or misunderstandings in the model building.

It is very easy to omit this stage in the excitement and urgency of trying to help the client find a solution. Omitting it is also one of the easiest ways to lose a client's faith when they see some result which is not only intuitively wrong but proves to be caused by a mistake.

8) *Determine Model Warm-up Time*

Find a suitable 'run-in' or 'warm-up' time for the simulation model. Models of factories usually need a warm-up time because the simulation model is likely to start empty (no products at any of the machines), but real factories do not start each week without any work-in-progress. A situation in which a warm-up time would not be required in a simulation model might be

when the model represents the start-up of a new factory in which the client happens to be interested in the first day of operation, or where the simulation represents a situation that starts each day empty, like a shop, a car park, or an airport. However, even in these circumstances it might be preferable to separate off the results obtained during the early part of the day from the results under peak conditions because knowing the 'average' performance of an operation, which never works under 'average' conditions, is probably not worthwhile. Calculating an appropriate warm-up time is detailed in the Determining Warm-Up Period section on page 53.

9) Model Exploration

Model exploration can be considered the most important step in undertaking a simulation project.

Traditionally the next stage in using simulation was to design and perform a series of experiments with the model to see how the factory could be improved. Details of how to do this are in the next section, 'Choose Scenarios and Run Trials'. However, a much more important step in doing simulation (and one which only became possible when simulation became visual and interactive) is to explore the model visually with the client. This gives both the model builder and the client the opportunity to gain an understanding of how the different parts of the model interact with each other, and how the performance measures can be affected, and to gain insights into how the system can be changed and improved.

This 'visual exploration' is done by running the model and watching the products move around on the computer screen. For example, it is possible to see where inventory builds up and under what circumstances it is the largest. By changing the model and watching to see the effects, the model builder and client can gain knowledge and understanding of the way the system behaves. It is possible to get to know, in detail, the characteristics of the system.

Of course, exploring a model visually like this is not a rigorous or scientific testing procedure, and should always be followed by some careful tests. It is much better at giving insights into how to improve the system, however, than a series of controlled experiments. There are two additional, and perhaps unseen, benefits to these investigations. The first is quickening the user buy-in. The user will start to trust the model and seek to fully exploit its usefulness. Secondly, these investigations get the user thinking 'out of

the box', leading to some 'what-if' investigations that can be radically profitable.

10) Choose Scenarios and Run Trials

Once some insights have been gained from working with the model it is important to test the resulting ideas. This is especially true if there are a number of competing ideas and it is difficult to see visually which is best. In order to do this, distinct scenarios in which some aspect of the simulation has been changed should be run and the results evaluated.

It is important to remember that a simulation usually contains random numbers and if a week's production is being simulated, the results reported only apply to that one week (perhaps a lucky week when few of the machines broke down). A different week might provide slightly or very different results. For this reason it is important to run the model a number of times, and collect results, using a different random number stream each time.

- A computer simulation provides a risk-free arena to test various scenarios, so try many different situations including extremes. ●

Importance of the Simulation Steps

A simulation is a model of a system that is supposed to support the decision making process. The decision may be a one-off decision, or may be one that is recurring and is part of day-to-day operations. The model built should reflect the use for which it was designed.

It is entirely possible that in the process of building a model for a one-off decision, the client and the modeler may come to a decision before the model is even completed. One of the most important things to realize about simulation in practice is that much of the benefit of simulation comes from the model-building phase of the study. While building a simulation model, the model builder asks the client many questions in order to gain sufficient understanding of the process to build the model. This questioning process has the benefit of structuring, in both the model builder's and the client's minds, many thoughts about the process, which had not previously been pulled together. The simulation model then acts as a logical piece of documentation about the process. It is a 'document', which is extremely easy for most people to understand, being a moving picture of the process.

This was realized during the first uses of visual interactive simulation in industry. It was noticed that clients were very keen for models to be built

for them, but often before the model builder was ready to formalize the experimentation process, the client wanted the model changed. The act of building the model itself was sufficient in some cases to enable the client to see a new way of operating the plant that the client wanted to see tested in the model.

The consequence of this is that the model builder will spend most time in the first steps of the above process, and only dip into the more technical steps occasionally. It also means that the model building stage needs to be relatively easy and quick, in order to be able to be developed in session with the client. This is the area of software development where most attention has been focused over the last few years.

In the stage 'Working with the Client' above, it was stated that the stage continues until the client feels they know what is best to do, but there is another option that is becoming increasingly important. Simulation models are now so easy to use that the client may want to be left with the model and use it regularly to manage their operation. In this case it is particularly important that the statistical issues which were mentioned are understood by the client, and that the model is set up to aid them in dealing with these.

Client – Model Builder Relationship

Managing the relationship between the client and the model builder can be a complex task – but is important for the success of the project. There are several steps in the simulation project where involvement of the client is highly beneficial. This section will look at managing an effective Client – Model Builder Relationship.

Hidden Agendas

Every client of a simulation project has an agenda; this may be open or hidden, depending on nature of the relationship. It is the job of the model builder to establish the true agenda or objective of the project. If this is not done, it is possible for the client to steer the project to a preconceived result through selective disclosure of information pertinent to the project. A good model builder should be capable of establishing the scope of the project without input from the client beyond setting the model objective. In this way, the model builder establishes what information is required to answer the question at hand.

Models are used to support decisions. They should encompass all the information necessary to make the decision. Determining what information is required is the key to exploring the important elements of the entire solution space. If the model builder is not aware of client's agenda, they may not seek out all information pertinent to the project, thus building a poor decision tool. The model builder's job is to produce a reasonable model of the system, which provides all the necessary elements and produces accurate results. It is then the decision maker's job to do what they wish with the information. Agendas should be left out of the model and for this reason it may be necessary for the model builder to subtly manage the scope of the project.

Managing Scope Creep

Often during the course of a project, especially if this is the client's first involvement with simulation, there is a tendency for the scope of the model building effort to "creep." Many a model builder has heard the words "Wouldn't it be really good to see this area of the plant simulated..." Although it is great to have an enthusiastic client, in order for the project to be completed on time, and be successful, it is essential for the model builder to manage scope creep. When the initial objectives of the project are not met on time, it is unlikely that funding will be provided for further projects. Keep all extras for subsequent projects unless the payback for time spent is worth it.

Communication

Most modeling assignments should provide for periodic reviews of the work. This should be an open forum for the model builder to test any views or conclusions about the answer to the model's objective. It is amazing just how far and how quickly a project can go off track if this does not take place. Blind alleys can be fascinating places in which to carry out lengthy modeling assignments at the client's expense in either time or cost.

From a client perspective, it is reassuring to see that the project is running to schedule and that any problems are being dealt with. But this is also a good time to discuss views and ideas with the end customer. Whatever recommendations the model provides, it is important to have general acceptance of these early on within the project, or to establish that the objectives are unattainable. Usually, it is better to give a client a hint of where the results are leaning before giving the actual results. Allowing them time to get used to the answer will provide for greater acceptance.

Providing Acceptable Recommendations

The solution space the model explores should have reasonable boundaries. When working with the model, the user must find appropriate answers within the current project scope. These recommendations have to be acceptable to the client. There is no point in explaining the 20% throughput that could be achieved with a state of the art machine that runs exponentially faster than anything currently owned, if there is nothing left of the capital budget. That does not mean that recommendations should always be exactly what the client wants to hear, but should have been well thought out, considering all potential concerns of the client. Alternatives should be provided for flexibility. In order to accomplish this, it is important to understand the client's concerns and comfort zone surrounding expenditure and change. There is no reason why a comfort zone cannot be the subject of negotiation, but establishing it provides a framework from which to work. A good client-model builder relationship should establish boundaries, and identify hidden agendas while meeting the project's objective and deadline. While this may not always be achievable, exploring the alternatives available and providing reasoning as to why they cannot work provides a good argument and understanding for the client.

Focus on communication surrounding project objectives, ideas, plans, and recommendations. This will provide a good grounding for a successful client-model builder relationship.

Other Considerations in Model Development

Including Financials

Most simulation packages allow for some type of financial analysis. This is because most system alterations will require capital expenditure. The simulation must therefore provide a financial analysis for the return on investment (ROI) calculation. Two types of cost can be taken into account. These are capital costs and operating costs. By inputting information on the cost of running machinery, the resource costs, capital costs, as well as revenues generated from completed products, it is possible to generate a Profit and Loss Statement directly comparing two or three alternatives.

It would be difficult to imagine attempting to purchase the correct number of automatic guided vehicle (AGV) units in a system that has variable shifts,

demand, reliability, and production rates, without the use of simulation, on account of the computational complexity of this problem.

It is important to include financial information when assessing complex systems such as an automated storage and retrieval system (ASRS) and AGV due to the variation in demand or operating performance.

Some of the costs to consider for the simulated period are as follows:

- Parts and Supply
- Warehousing and Carrying Costs
- Equipment Running Costs
- Changeover Costs
- Resource Costs
- Capital Costs of Equipment, Storage, and Resources

If there are no financial options within the simulation package, results can be exported or copied into a spreadsheet package for further development of a financial case.

Coding Tips

There are many ways to make coding easier: use generic names for looping purposes, create generic code that can be called multiple times throughout the model, and generate components and templates for re-use, as provided for by many packages. The following are the three cardinal rules of good model development, and effective use of the project time:

1. Make it general – Re-use of code will reduce model development time by 20-50%
2. Use a naming convention – Time spent looking up names of objects, and de-bugging when wrong variables have been utilized in a certain piece of code, can be excessive.
3. Comment, comment, comment – Much time can be saved by merely documenting development steps during development.

Make it General

Developing a simulation model does not have to be a masterpiece, but there are some techniques that not only make it easier to understand, but speed up development time as well. Keep it general. Most simulation packages are moving towards Windows type copy and paste options. So for example, if there are several production lines within a plant that produce the same work, create one general line. Include all of the line parameters, write any code required, attached it to the appropriate areas, then copy. It is also possible to have multiple references to the same piece of code. Using a single piece of referenced code saves a lot of time should that code need to be changed. By changing just one section, it is possible to quickly reflect the change throughout the simulation model.

Another example is a plant which has over 20 machines built by the same manufacturer. They follow similar mean time between failure (MTBF) and mean time to repair (MTTR) patterns, so instead of inputting a distribution into each machine, create a generic distribution, and call it in all machines. If the distribution needs to be changed, a single change will be instantly reflected throughout the model.

Using input spreadsheets is another method for quickly and easily updating the simulation model for different what-if analyses. This requires more start-up effort, but is a worthwhile investment if several small alterations need be made, as they can all be made in one place. This also provides a convenient single reference point for the scenario tested, as the spreadsheet clearly shows which parameters have been altered.

Naming Conventions

It is recommended that a naming convention be used when creating large simulation models. By using a naming convention, it becomes easier to distinguish between variables and objects when using the internal programming languages of simulation packages. Development time can be reduced since the variables and objects within the simulation are far more manageable and easily identifiable, when a naming convention is used. This means that all different object types should have a discernable prefix. A spreadsheet could be prefixed with 'ss_' (short for 'spreadsheet'), or an integer loop variable that can be used anywhere could be prefixed with 'int_'. Sections of code should also be given names following an appropriate naming convention. Indeed, it is good practice to select a

■ Recommended naming Convention:
lbl_ = Label
dist_ = Distribution
ss_ = Spreadsheet
int_ = Local Integer
gbl_ = Global Integer
str_ = Text String
obj_ = Object
Variable ■

naming convention and apply it to the development of all simulation models across the organization. This ensures that models constructed by different developers are more easily transferable.

Documentation

The majority of simulation users are intermittent users. The software is usually purchased to help with a one-off decision, and is then shelved until another decision needs to be made. Often model developers have a change of priority and may not even be able to complete work on their simulation model and have to pass the work on or go back to it at a later date. As a result, many simulation models lie dormant for long periods. In fact, the actual user-developer might change over this period, and therefore it is extremely important to document any simulation model. What may be obvious to the current user at the time of development may not make sense to another user or even for that matter to the original developer in a year's time. To avoid duplication of work or long learning curves on subsequent projects, all simulation model developers should make use of the commenting or notes facilities provided by the simulation package. If this facility is not provided, separate notes should be made on the model development, all key areas of code, and specific object configurations and functionality of the model.

Chapter 2 Review and Questions

Chapter Summary

Simulation studies should generally follow a set of defined steps to ensure model validity and client satisfaction. In models built for a one-off decision, however, it is not unusual for the client to see the solution before all steps, especially the more technical ones, are complete. Looking further at how simulation is done in business settings, the model builder, whether an outside consultant or an internal expert, should be aware of some of the pitfalls of the client relationship. These include the possibility of hidden agendas, the tendency for clients to want to expand the scope of the project once it is under way, failure to carry out periodic project reviews, and the loss of trust that occurs when unrealistic recommendations are made. There are also technical considerations that the model builder should be mindful of. These include developing the financial side of the model (whether through internal financial functions of the modeling software, or through export to other applications), and good coding practices, such as using general, reusable code, using easily understood naming conventions, and finally remembering to constantly document the model, so the builder or someone who takes over at a later date can understand what the model does, and how.

Test your Understanding

Typical Simulation Study

A Case Study

Chatting with a friend, Bob, on the golf course, he begins to tell you about the headache that is his family's business. The business produces canned fruit for a variety of customers. It has been in operation for years and the family has not invested in improvements to their operations in recent memory. With your experience, you take some interest in his problem because you feel

you may be able to give him some direction and get him started on the right path.

The canned fruit business has not been as lucrative as it was in the past. Supermarkets can no longer get the same margin on the product. This has tightened available profits through the entire supply chain back to the farmers. In recent years, however, there have been some new, higher margin market possibilities opening up. The largest growth has been in frozen and organic fruit.

The traditional canned fruit market may still have a reasonable margin to be made. Each contract with customers guarantees a certain proportion of high-grade fruit and different mixes of fruit types. Bob figures that for each product run they overshoot their quality target by a large proportion. Additionally, over the harvest season the price of the fruit can vary depending on supply and demand for fresh fruit. The canning company pays the growers, not the end customer, so Bob feels this is an area in which they could improve.

Bob also recognizes that there are potential process improvements that could be made. The company has not taken the time to do involved time studies. Management has little idea where there are underutilized areas or where the critical bottlenecks occur.

The canners have little control over when fruit arrives at their docks. They schedule growers to make drops on one of Monday or Tuesday, but they do not specify time of day. This can cause congestion at the docks. There is even the case that sometimes several loads come in just before closing causing the dock workers to work overtime. On a few occasions, the production line has even become temporarily held up because of the lack of material.

Bob has explained a little about why they over sell the high-grade fruit. The fruit must be processed within 7 days of it arriving on the docks. Bob will agree to buy a certain amount of fruit from a grower and pay a market price but this cost always needs to be adjusted because what arrives at the dock is never the exact quantity or quality that was agreed upon. An additional complication is the limited capacity of the facility. There are limits to the amount of raw fruit they can hold, processing capacity and finished product storage. They do not have total control over the

mix and even if they get a fantastic price there is a limit to their ability to capitalize on the deal.

Bob's property is quite large; they have long had zoning approval to expand production. He has reached a point where he feels that if the business does not change they will quickly lose all room to maneuver and may not have the resources to adapt. Even worse, if several factors play against his business, he could eventually be faced with going out of business. He is excited about getting into the organic or frozen markets. The company already has relationships with farmers and the major chains. Bob has still not convinced himself that they have the experience to tackle this problem; he is worried that he does not understand the processes fully. The frozen food is bagged rather than canned and of course requires freezers, both technologies that Bob has never managed. Organic food product regulations require that the product be processed separately from the non-organic fruit. Organic fruit is presently marketed differently than canned fruit; the product will demand a jarring capacity.

Discussion:

1. What is the problem?
2. What is the required level of detail needed to address this problem?
3. Which processes need to be modeled in detail? Which can be approximated?
4. What would be included in the rough model?
5. Explain the importance of client involvement in different phases of the project.
6. How long should the model run and what are the visual elements?
7. Describe what set-ups and outputs could be used to verify the model's accuracy.
8. Model Warm-up time - how long would individual elements of this model take to warm-up before the numbers would represent the steady state numbers for the system?
9. Model Exploration - what type of 'what-if' analysis would be performed with this model? Who would be involved? Remember this should help develop a set of scenarios.

10. Choose Scenarios and Run Trials – which and for how long?

Managing the Client – Model Builder Relationship

1. Describe features of a simulation model that could help you, the developer, support your client while at the same time keeping the model robust.
2. If your client is pushing for the model to support one particular idea, you may, throughout testing the model, identify other potential avenues that may be reasonable solutions or identify potential problems with the client's plan. What preparation would you make before bringing these ideas to the table? What would you do with the model?
3. A project is underway and the client changes their needs – What would you suggest to them that they do?
4. When would you start from scratch and who would be involved in that decision?
5. When would you extend the scope of the project?
6. When would you trade off certain model features for others, why would this be an advantage to the client, and how could this effect the evaluation of the project?

Other Considerations in Model Development – Financial Considerations

In order to answer these questions, refer to the online model entitled Financial at www.visual8.com/demonstrations.

The first model, which uses SIMUL8's Finance tool, contains four scenarios. The user has the ability to choose which set-up is active and to see their financial effect. The scenarios are as follows:

- Scenario 1: No scrap
- Scenario 2: Some scrap but also a higher revenue per piece
- Scenario 3: Better trained workers, which cost more but incur less scrap
- Scenario 4: More expensive raw material and the same better workers, incurring even less scrap

Questions:

1. What set-up will allow production at the lowest overall cost?
2. What happens if the employees get a raise? (Requires changing model)
3. What if a different supplier supplies the parts – they are 10% cheaper but scrap is 10% more? (Requires changing model)
4. What if we now consider the cost of owning the building? How would you add this to the model?
5. How much part revenue would you need to generate to establish a profit if total overhead cost is the same as total raw material cost?

In the second online model, there are two input streams of products. Each stream has a different cost. Work Centers 1 and 3 are grouped, as are Work Centers 2 and 4, such that only one of each pair is working at any time. This is the same effect as having different processing times and different pay rates for the two products at the same station. There are two Work Exit points, each of which generates different revenue. Workers A are required for line A and Workers B are required for Line B.

Questions:

1. In your accounting – what proportion of overhead would you attribute to product A? Product B?
2. How could you find the average profit per piece for the existing system?
3. How could you set up the model to automatically calculate the profit per piece?

Other Considerations in Model Development - Coding Tips

Using only natural language statements, write example pieces of code that could perform the following functions:

1. Count the number of rows in a spreadsheet.
2. Calculate the average of several values in a spreadsheet.
3. Set the processing time for a product depending on product type.
4. Set the route out label.

5. Reference data in a spreadsheet.
 6. Calculate time in station.
 7. Extend function to calculate the cost for that process.
 8. Extend function to calculate the revenue and profit for that process.
 9. Extend function to record time and profit in detailed results report.
 10. Create code that updates input distributions (named distributions) from values in a spreadsheet.
-

Chapter 3: Statistical Considerations

A project is useful only when its recommendations are reliable. Thus, the statistical validity of the inputs and outputs of the model must be assured. This chapter deals with the most important aspects of ensuring that a model produces reliable results.

Determining Warm-Up Period

Depending on the nature of the simulated environment it is most likely that a warm-up period is required for the model. This is because there are very few processes that start each week with no work-in-progress (no work present at the different stations). Systems such as call centers; a grocery store, plant start-up simulations, etc are the exception to the rule, as there is no work present in the system at the beginning of the model run period.

Most simulation packages provide a facility to set-up a “warm-up” period during which the collection of statistics is usually switched off, or separated from the main results collection time.

There is a simple procedure for determining how long this warm-up period should be, which shall now be introduced.

1. Identify the key performance indicators (KPIs) for the system being modelled. For example a KPI could be Jobs per Hour (JPH), the utilization of a machine, or the length of a queue specified in time-spent waiting. If there is more than one KPI, it is important to carry out this procedure for all those measures of interest then use the longest identified warm-up period. For the purpose of this example let's assume the KPI is JPH.
2. Run the model for a short period of time. This 'short' amount of time is dependent on the system being simulated, but if the total

run period was a week, then a couple of hours should be adequate. It should be a sufficient amount of time to see items leaving the simulated system. So having run the model for 60 minutes, record the number of products that have left the system. *Depending on the system being modelled this is quite likely to be zero.*

- Run the model for another 60 minutes (or whatever time increment chosen) and record how many products left the system in the second 60-minute interval. i.e. the JPH for the second hour – not the total at the end of 120 minutes. Repeat until a table similar to Figure 3-1: Production Output is completed:

Time	Products
60	0
120	0
180	5
240	4 ¹
300	8 ²
360	23
420	15
480	22
540	21
600	16
660	21

Figure 3-1: Production Output

This table should then be plotted against time, enabling a view of what is happening in the system:

¹ This is the difference between the total output after 180 minutes and the total output after 240 minutes.

² This is the difference between the total output after 240 minutes and the total output after 300 minutes.

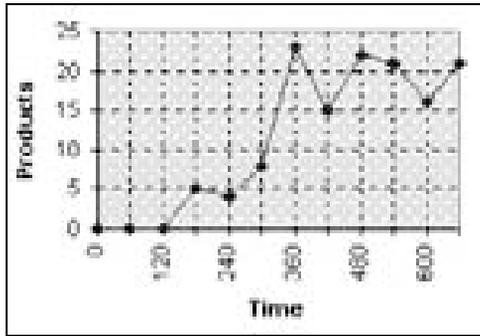


Figure 3-2: Output Chart

By plotting the graph while running each subsequent hourly period, it will be possible to identify when there are sufficient plot points. In the example above it can be seen that there is a fairly distinct difference between the JPH recorded prior to 360 minutes and the JPH recorded after 360 minutes. So the warm-up time for this particular system would be 360 and prior to that time the system was 'warming-up'.

Simulations attempt to model reality so a completely steady line will not be achievable or expected – however identification of a steady state is important. The simulation will use random numbers to emulate the variability in the real world, so variability is expected.

This example has been deliberately made clearer than often occurs. Quite often the performance measure being evaluated never looks at all stable. Sometimes during the warm-up time the key measure is very high and sometimes it is very stable - becoming unstable once the model has warmed up. It is important to identify a point in the model where the model emulates real-life.

A judgement will have to be made from looking at the figures. With several KPIs it is easier to be more certain about where the warm-up period should be. The principle is simply to ensure that the model is not in some atypical start-up state caused by the model starting from empty.

4. Once a warm-up time has been established most simulation modellers will add 20% to it, to ensure that the model has achieved steady state before any statistics are collected. The only potential

disadvantage with a long warm-up time is that it can take up a lot of time when the model is running. With today's simulation packages this should not be too much of a concern.

Remember when adapting the model further that significant changes to the model might affect how long it would take to warm-up. Repeat the above process if the simulation model has been significantly changed.

Determining Simulation Run Length

Once a warm-up period has been established the next element of the simulation model to be determined is the appropriate run length. A simulation contains random numbers and by simulating a specific period of time, the results apply to that period of time generated by one set of random numbers only. The random numbers in this period's production may have generated an exception; perhaps many machines broke down sequentially, and perhaps the bottleneck machine ran particularly well. A different period might provide slightly or vastly different results.

All simulation packages allow users to change the random numbers so they can also see what happens when the random numbers are different. This is accomplished by allowing the user to set the 'stream' of random numbers that will be used. Most packages have many thousands of 'streams' of random numbers built into them so there is no limit on the number of different weeks that can be simulated in the factory. By running trials of events, the results produced from the simulation model will represent several weeks of production all with different random numbers. To determine the length of the trial, please see Determining Simulation Run Length on page 56.

So far one week's production has been discussed. However many simulation models are interested in a month, a year, or sometimes only a day or an hour. Identifying the appropriate length of time is a function of the key performance measures used. The simulation period should be appropriate for meeting the performance measures.

Simulation run length is determined by one of two things. The simulation is either modeling a specific period of time or it is modeling a steady state system. When selecting a run length for the steady state system, the time required would be that to achieve statistical validity. Please see Determining Simulation Run Length on page 56. When modeling a specific time period, a run length that makes sense to the model objectives should

be chosen. For example if a factory is modelled to determine whether it can meet seasonal demand, the factory can either be modelled for the entire year including all seasonal variances in demand and shift patterns or the simulation can be designed to model the factory for the peak demand period and the opening state can be set by the user. These different approaches can be used to address the same issue.

Random Numbers

A simulation usually uses random numbers to generate timing for events. If a week's production is being simulated, results will be seen that apply only to one week (perhaps a lucky week when few of the machines broke down). A different week might provide slightly or very different results.

The procedure described here gives a step-by-step way to ensure the results are valid. Even if the user does not feel it necessary to go as far as calculating the statistical validity of the results, the first part of the process should be performed and the simulation model run with a number of different set of random numbers.

When using most simulation packages, if the time clock is set back to zero and the model re-run exactly the same things happen on the screen, in the same sequence as the last time it was run, despite the fact that the model contains random numbers to emulate 'real life'. This is because simulation packages use 'pseudo random numbers' which are generated mathematically and simply appear to be random. Each time the random numbers are re-started, the same sequence of numbers will be generated. This is very useful because it means it is possible to re-watch a model several times to understand exactly what is happening, without the issue being clouded by the random numbers changing each time.

All simulation packages allow the random number streams to be changed in order to see the effect this has on the behaviour and output of the model. They do this by allowing the user to set the 'stream' of random numbers, which will be used. Most packages have many thousands of 'streams' of random numbers built into them so there is no limit on the number of different weeks that can be simulated.

Confidence Intervals

Example:

A factory is simulated one week at a time and with each random number stream a different number of products are completed by the end of the week. This information can be really useful to the client - but it has to be presented in a useful and valid way for it to be of genuine use. This section is all about how to do this.

At this point in a simulation study sets of results are collected in order to compare two or more alternative decisions. In this example there are two alternatives and the simulation has been run 30 times for each of these alternatives. For each run of one week plus warm-up time different random numbers were used and the following output figures obtained:

Number of products leaving the factory in 30 different weeks (30 different random number streams).

Alternative			Alternative		
Week	One	Two	Week	One	Two
1	293	261	16	246	271
2	274	264	17	189	274
3	196	230	18	220	285
4	254	287	19	229	253
5	203	287	20	259	265
6	228	316	21	273	239
7	234	285	22	265	298
8	228	257	23	248	223
9	300	273	24	280	319
10	210	334	25	232	235
11	234	242	26	212	260
12	216	320	27	238	225
13	218	301	28	300	188
14	315	292	29	287	246
15	239	288	30	254	298

Figure 3-3: Output Variation

The results for alternative one are as low as 189 and as high as 315 with the figures for alternative two being a low of 188 and high of 334. Which is best? The averages for the two alternatives are 245.8 and 270.5, so perhaps

alternative two is best. There is so much overlap between the two that perhaps there is not really any difference between the two alternatives. Can the client really justify spending the extra money that alternative two will cost? What if the next 30 weeks (random number streams) average out the other way around? What will the genuine long-term average really be?

One option is to run the simulation model many more times. However, often, if there is a large amount of variability in the process, this will not improve the predictability of the results.

A simple statistical procedure can help here. In addition to the information shown above, the standard deviation of the individual results can be calculated.

	Alternative	
	One	Two
Average:	245.8	270.5
Standard Deviation:	33.1	33.3

Figure 3-4: Statistical Results

But this calculation only provides the variability of the *individual* results. The main area of interest is in how the *average* figures differ. If there were time to do another batch of 30 runs, would its average be different? If the model were used to run 30 trials of 30 runs, what would the variability of the averages be?

Fortunately there is a statistical relationship, which applies here, which provides a method of predicting the standard deviation of the *averages* from the standard deviation of the *individual* results - which has just been calculated.

$$\text{Standard Deviation of Averages} = \frac{\text{Standard Deviation of Results}}{\sqrt{\text{Number of Results}}}$$

In this case:

$$\text{Standard Deviation of Averages} = 33 / \sqrt{30} = 6$$

Confidence limits for the average can now be calculated to report to the client.

As 95% of normally distributed numbers are within 2 standard deviations of their average then:

$$\begin{aligned}
 \text{95\% confidence limits for our average} &= \text{Average } +/- 2 \times 6 \\
 &= 245.8 +/- 12 \\
 &= \mathbf{233.8 \text{ to } 257.8} \\
 &\text{for alternative \textbf{one}}
 \end{aligned}$$

and

$$\begin{aligned}
 &= 270.5 +/- 12 \\
 &= \mathbf{258.5 \text{ to } 282.5} \\
 &\text{for alternative \textbf{two}}
 \end{aligned}$$

The results show 95% confidence that the true average for alternative one lies in the range **233.8 to 257.8** and also that there is 95% confidence that the true average for alternative two lies in the range **258.5 to 282.5**. So with 95% confidence alternative two will produce more boxes in the long term (but not every week).

A picture of this can be useful:

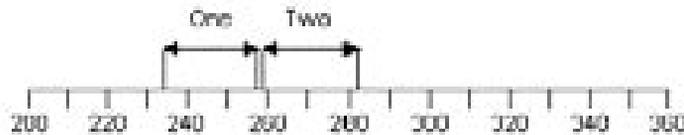


Figure 3-5: Confidence Intervals 1

Showing this type of picture to the client can help understanding especially when the numeric production count information is changed into profit or cost. The above picture shows that it is *just* possible to distinguish (statistically) between these two alternatives.

Of course, the picture might show the following:

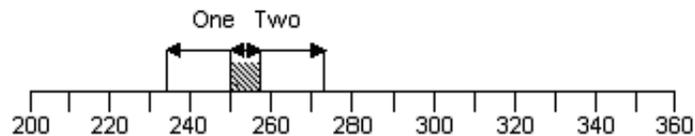


Figure 3-6: Confidence Intervals 2

There is an overlap between the two ranges, in which case the following two apply:

1. It **is not** valid to distinguish between the two alternatives. It is not reasonable to report any difference between them to the client because the average for alternative one could be as high as 257 and the average for alternative two could be as low as 254.
2. More simulation runs could be done because (take a look at the way the range is calculated) the larger the number of runs the smaller the predicted standard deviation of the averages: so the smaller the range. Of course this does not mean the two ranges will definitely separate by conducting more and more runs - it simply means that the figures are getting more and more accurate. The results may move towards something more like this:

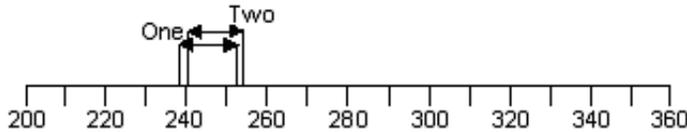


Figure 3-7: Confidence Intervals 3

If this happened, it would show there is no difference between the alternatives.

It is rarely necessary to do as many as thirty runs. By conducting five runs and then doing these calculations, a clear idea can be gained as to whether five is enough or whether it is necessary to do more. To summarize the procedure:

1. Do five runs of each of the selected alternatives and each run using a different random number stream.
2. Calculate the average and standard deviation for each of the alternatives.
3. Calculate the 95% confidence limit ranges for each of the alternatives

$$= \text{Average} \pm 2 \times \text{Standard Deviation} / \sqrt{\text{Number of Result}}$$
4. Draw these on a graph like the one above to see which alternatives differ significantly from one another.
5. If ranges overlap, do more runs to see if they separate.

A bit of statistical theory: This procedure only works if it is known that the averages are going to be 'normally' distributed. If there are at least 25 runs to calculate the average, this will then be the case. Fortunately, for simulation users, this is usually the case for smaller numbers of runs, because when the individual run results are normal the average will also be normally distributed. These are usually normally distributed because they are, themselves, the combination of a large number (more than 25) of individual events, for example, the times between products leaving the factory. A statistical theory called 'central limit theorem' says that any number which is the total (or average) of a large number of other numbers will be normally distributed, whatever the distribution of the original numbers.

Chapter 3 Review and Questions

Chapter Summary

Obtaining valid results from a simulation model is dependent on understanding some of the key features of simulation software. Without specifically putting Work Items throughout the model, in a manner consistent with reality, most simulations will need a warm-up period. While some systems start empty at the beginning of the day or week, which is the start point of the simulation run, most have work in process at this time. It is the function of the warm-up period to put the simulation into a statistically valid condition before results are collected. Likewise, selection of a run period is critical to getting valid results. This is especially true if there are long-term or seasonal variations in demand or performance that must be accounted for. Since the variation in a simulation model is the result of using pseudo-random number streams, it is important to make an adequate number of runs with different streams, in order to understand where the probable system averages and other measures of performance really lie. This is especially important when comparing alternatives. It may be necessary to calculate confidence intervals for results, in order to determine if the alternatives are actually distinguishable, before selecting one over the other.

Test your Understanding

Statistical Validity

Case Study

A typical decision in a factory environment that requires some treatment of statistical certainty is the purchase of equipment. Machines from different manufacturers or models will have different properties. Some machines will produce more scrap. Some take longer to repair than others. Some will breakdown more frequently.

A continual headache in the factory is Machine X. It is the bottleneck in the process. If it is fully operational and producing good material, it is capable of meeting the demand. However, demand is not being met and something needs to be done.

Unfortunately, the machine seems to be plagued with problems. It is not entirely reliable and produces a certain quantity of scrap. Adding another machine would seem a clear choice but is not a possibly because of space limitations. The only other choice appears to be replacing this machine with one that is more reliable.

By talking with sales associates from various companies, a replacement machine that is claimed to satisfy the plant's needs is found. Fortunately, there is the opportunity to verify the manufacturer's claim. Another facility in the organization uses this machine and has been keeping detailed maintenance logs.

A simple simulation model was built to illustrate the statistical analysis of this problem. On the top is the line set-up to run as the manufacturer claims. The second line uses probability of breakdown, repair time and scrap numbers from the other facility. The last line is the current line operating in the factory.

Discussion:

1. Does the simulation support the manufacturer's claim?
2. After 10 trials is there conclusive evidence that the machine from the other facility is significantly better than the current machine? What about after 40 trials?
3. What would the new machine be worth to the organization? What additional features could influence your decision?
4. Describe a different problem in which the statistical validity of the simulation could be a critical feature.

Warm-up period

1. What would be the difference between results with a warm up period and results with no warm up for:
 - Efficiency of a workstation?
 - Average time in system?

2. For each of the following cases identify 3 Key Performance Indicators (KPI) and give a reasonable estimation of the warm-up period required for the system and give an explanation of this warm-up (making reference to those KPI's).

Power plant:

- A system of conveyors transports the supply of coal from the coal yard to the boilers.
- The coal is fed into furnaces and, over a period of time, will heat up and begin to produce steam. Steam is then moved through high-pressure pipes to turbine generators.
- Generators coming on line and off line as, demand changes, scheduled and unscheduled maintenance, etc.
- Daily and weekly there are differences in operations across the facility in shifts; coal deliveries etc.

Car assembly Factory:

- Each station has a cycle time less than or equal to 48 sec.
- 75 stations
- 170 pallets that are recycled through system (two different types in different areas of the factory).
- Damaged parts are inspected and a decision is made if they are to be reworked or scrapped.
- Shipping is done by rail and receiving uses both rail and trucks.

Emergency Room:

- Daily arrival rates for different admittance codes.
- Different admittance streams – walk in and ambulance.
- Patients who are admitted need to be moved to empty beds in other wards. Beds in these wards are freed only when their doctor discharges one of the existing patients (doctors are in the hospital at various hours).
- Availability of tests – technicians may work different hours.

Simulation Run Time

For the following cases, identify two potential problems the manager may wish to simulate. Describe the problem and give an explanation of what run time you feel would be appropriate. Determine if it would be a better option to run for several periods or to run repeated trials of the same period.

Major Hardware Retailer

This retailer wishes to analyze its supply chain. They suspect that they could work on improving their supply chain to reduce the inventory they carry. The business carries a huge array of products. These products range from high cost to low cost, high volume to low volume and can be very large to very small.

They also feel that they could gain market share by making their seasonal sales more attractive (i.e. fertilizer or artificial Christmas trees). In order to do this, they must have lower advertised prices than the competition and must avoid stock outs during these special offers.

Ski School

The managers of a ski school at a major Canadian ski resort have an agreement with their instructors that they will give them a schedule of their hours for the upcoming week every Saturday. In order to meet the demand of their customers the ski school must have enough instructors on hand. However, demand is largely variable.

The ski school has identified several factors that they suspect may have an effect on the demand. A shortened list of those factors is as follows: day of week, date, exchange rates, snowfall, forecasted snowfall, the temperature, and potentially even the terror alert level.

Business Applications

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This section focuses on the application of simulation to a variety of business issues.

The role of simulation in business has grown significantly over the past ten years with the advent of cheaper, flexible, and more intuitive software modeling tools available on the market. In the past, simulation was a tool far too cumbersome to be used on a widespread basis. It is useful to understand how simulation modeling evolved, where it was used, and why it has become such a popular problem-solving tool.

There is a significant amount of literature that describes the early days of simulation. Available simulation packages were both costly and difficult to program. Simulation analysts would spend weeks and months putting together models that were approximations of the real system. These relatively inflexible models were slow in execution and limited in results. Much of their time was spent on the graphical animation of the system as opposed to the underlying procedures and controls. Results were churned out by large mainframes in the form of reams of numbers to be translated by mathematicians into terms and results understandable by the decision-makers. Aids such as a physical model of the real system, which would be manually updated to show the results of the simulation, were helpful but extremely cumbersome methods used to communicate the output from these computer models. In spite of their shortcomings, these models were valuable for both selling new or modified manufacturing designs to management and for proving systems before they were built. Therefore, simulation was successfully employed in increasing the understanding of a

complex interdependent system in order to reduce risk and increase performance.

With the advent of capital-intensive factory automation in the automotive industry and general manufacturing in the late 70's and early 80's, the value of risk avoidance and efficient design was paramount. At the same time, the first visual interactive simulation products – See Why, Foresight, Siman/Cinema, and AutoGram – emerged onto the market. These early simulation-modeling tools provided the analysts/engineers with simplified means of producing graphic animations of a system. The combination of these two events spurred management's interest in this technique for examining the design and workings of complex and costly manufacturing systems.

Since that time, simulation-modeling products have advanced significantly due to both computer hardware and software developments. The performance of these modern-day tools, such as SIMUL8, far outstrips the speed, ease-of-use, flexibility, and graphical animation capabilities of their earlier counterparts. Their range of application has also broadened from the design of systems outside of the manufacturing world into the service sector and general business processes.

The following sections of this book provide an overview of how simulation is being used in a number of key areas – manufacturing, the service sector, supply chains, production scheduling and control. Each section includes a number of case-examples with viewable simulations to demonstrate the benefit of this approach in these areas. For most worked examples there are SIMUL8 models available for download from the following page: www.visual8.com/demonstrations.

Chapter 4: Manufacturing Case Studies

Overview

The complexity of manufacturing operations today requires more than a CAD drawing or process layout of the facility to understand the behavior or performance of the system as it may operate under various changing conditions. Availability of equipment, materials, people, storage space, and rules of operation, all add to the difficulty of predicting the output of the system. However, management needs a way to understand how a complex process will operate under alternative plant designs to ensure that financial and operational targets can be met reliably before proceeding with construction of the facility. Similarly, to analyze an existing process and identify areas for improvement or expansion, decision-makers need a means to “play” with the existing system off-line and examine the before and after effects of potential changes to the system.

Spreadsheet analysis, while good at static problem solving, cannot capture the dynamic interdependencies of products, resources, and equipment over time. Understanding the rate of flow of products through a series of machines with different change-over times, processing times, and materials handling requirements requires a discrete-event simulation to show the workings of the process. CAD drawings are helpful in defining the layout of the manufacturing process with the proximity of machines, storage areas, and materials handling systems, but they fail to show the product flow through the plant, the use of resources, and the use of buffer areas over time. But what if we could import the CAD drawing and show an animation of the workflow according to the process rules and resource availability? This is now available with simulation tools such as SIMUL8. Several examples will demonstrate how this has been accomplished.

There are many areas in manufacturing that can benefit from the use of simulation - from the design of new processes and the review and improvement of existing operations, through to the adaptive planning and scheduling of work within a production environment. The range of simulation applications in this area are manifold but there are a number of common areas of use such as facilities design, capacity planning, quality control and reliability analysis, process improvement, and more recently real-time planning and control.

The benefits of simulation applied in these manufacturing areas include cost-avoidance, reduced commissioning ramp-up period, increased throughput, reductions in production costs, lower inventories, and increased customer service levels. Using simulation to support the execution of production schedules through shop-floor monitoring and adaptive controls has also led to significant plant performance improvements.

The following examples are provided to show both the value and utility of simulation applied to general manufacturing applications. They serve to highlight the scope of these models, the type and source of data inputs, the various screen displays, and importantly, the results that can be derived from these simulations.

Case Study: Automated Lines

Background

In the early days of simulation, platforms required a large amount of user knowledge and the outputs were less than visually appealing. Many manufacturers that were using simulation in its previous forms had bad experiences with the technique as it proved expensive and difficult to use. In recent years, some of these early users have been picking up the technique again with the advent of easy-to-use software and changing attitudes towards the technique. Visual interactive simulation has been instrumental in helping to make the technique mainstream.

One furniture manufacturer reintroduced the use of simulation in the nineties, as it became more intuitive and yielded valid results. One of the main reasons for taking up the technique again was the ability of the user, with minimal training, to visually see the interaction of subtle process variations, particularly in the area of product mix analysis. Software advances permitted the user to actually simulate the production lists in exactly the same sequence as they would run on the machines.

Problem

An office furniture manufacturer wished to evaluate complex processes that existed in the plant involving multiple Work Centers or production cells, comprised of any combination of machines working together. Simple one or two machine cells operated by a single operator can normally be evaluated mathematically and tend to be intuitive in nature. However, the area of interest, the press line, has many systems working together. The interaction is a dynamic relationship, impacted by several factors in addition to having high manual labor content. The effect of the manual involvement is most influential on throughput when it is at the infeed to a machine or cell. Manual unloading of a machine has fewer variables since the process is regulated by the pace of the machine.



Analysis

A simulation was designed to investigate the output requirements of a new automated short-cycle through-feed press line that produces both HPL and wood veneer products of multiple thicknesses for five subsequent production lines and cells. These production lines or “customers” operated at different operating speeds and produced a wide variety of products. The average output of these lines was material for less than 10 products, resulting in continuously changing demand on the press line.

To perform a valid simulation of machine lines, it is necessary for the engineer to have a detailed understanding of both the equipment and the realities of the shop floor. Factors affecting throughput, such as breakdowns, paperwork, tool changes, and material handling, all must be defined and entered into the simulation to yield valid results.

Recommendations

Simulation modeling offered the ability to simulate the “customers’ demands” from actual production runs and develop the demand on the press line in a pull-through process. Once the demand was developed for

the press line, required cycle times could also be determined. These required cycle times then became the basis for the design of the automation of the lay-up as well as infeed and outfeed designs. This is an example of using simulation not only to evaluate an application, but also as an aid in defining and evaluating design criteria.

The same model was also used to determine conflict areas for the infeed of the multiple cores, faces and backers being used, as well as to define the required sizes of work-in-process surge areas between the press line and its “customers.” The conflict (contention) areas, as well as surge area issues, become apparent as soon as the animation is run. Data that defines the magnitude, frequency and duration of any conflicts is collected by the program over the length of the run simulation and this information can then be used to run “what if” variations as an aid in resolving any issues.

Payback for equipment implemented in this example was just under three years.

Simulation was also used internally by the company as a sales tool when competing for capital funding. It provided the ability to show management and union leaders process alternatives and results, in both animation and numbers.

Discussion

1. What are the key performance indicators that this simulation is designed to examine?
2. What is the most efficient way of simulating the “conflicts?”
3. Once the demand for the press line has been determined, what are some methods of inputting this data into SIMUL8?
4. Name another industry that can be simulated using an identically structured simulation model.

Case Study: Cell Manufacturing

In the world of cell manufacturing, different facets of an operation affect one another in interdependent ways. For this reason simulation is an excellent tool for analyzing how manufacturing cells operate. Whether the issue is establishing design proof or the method of cell operation that will satisfy the necessary operational requirements, simulation captures the necessary variables.



Background

One common issue is the allocation of resources to different tasks within a cell. A major Midwest automotive parts manufacturer is having trouble meeting demand. The specialized parts that it produces preclude the sole use of production robots and require human operators. The company assumes that more operators would decrease cycle time and increase throughput. They have chosen to use simulation to address the allocation of staff to the manufacturing cells. Although the problem is extremely difficult to analyze in a static environment, it is a simple simulation model.

Problem

The company’s allocation options include the following choices:

- Assigning operators to a particular Work Item and following it around the cell,
- Randomly assigning operators to the next Work Center requiring operation, and
- Allocation of resources/operators to individual operations within a cell.

The challenge is to select the option that maximizes the company’s ability to meet demand.

Analysis

For this case study, assume that there are six operations within a cell and two operators, so the options are limited to the first two on the above list as there are insufficient operators to staff the entire cell. Assigning each Work Item to a particular Resource ensures minimization of cycle time to complete each individual Work Item, whereas allowing the resources to move to the next available operation maximizes Resource utilization, especially if any of the stations within the cell only require loading and unloading by the operator.

In this example, we will assume that only one automated station, Station 30, requires load and unload by the operator. The simulation in this example has the following parameters:

Scenario	Station 10	Station 20	Station 30	Station 40	Station 50
I	20	25	30	20	23
II	20	25	5(R), 20, 5(R)	20	23

Figure 4-1: Cell Manufacturing Simulation Parameters

In Scenario 1, attach the operator to the Work Item as it moves around the cell. See the reference section topic

Resource on page 197 to learn more about this. Scenario II, would allow any operator to work on any Work Item at any station at any time. This scenario, which breaks out the unload and load functions at Station 30, means that the operator is not required to remain at the Station as it processes work.

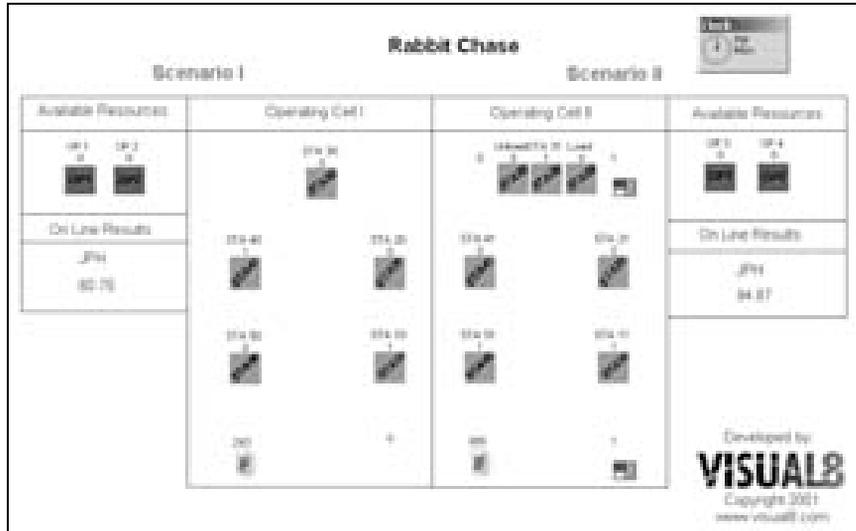


Figure 4-2: Cell Manufacturing Simulation

Recommendations

The Key Performance Indicators for this simulation study are Jobs per Hour, Cycle Time, and Resource Utilization. The following provides a summary of the simulation results:

Scenario #	Average JPH	Ave. Cycle Time	Resource Utilization %
I	60.75	119.22	99.89
II	94.88	169.42	97.62

Figure 4-3: Cell Manufacturing Simulation Results

It is possible to see from the results above that although, in Scenario II, parts will remain in the system longer as they wait for a Resource, the overall throughput of the system will increase by 56%.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. What manufacturing KPIs are represented in this model? Which perform better in Scenario 1? Which perform better in Scenario II?
2. Some of the results of this model seem contradictory. Explain.
3. Which policy would you suggest in the following scenarios:
 - a. The product is very delicate?
 - b. The turnaround time required is very tight?
 - c. The margin on each part was very low?
4. This model uses fixed processing times to illustrate the impact of different policies more clearly. What would you expect to find if there was some variability around the processing times? Change the model and test your assumptions. Does the utilization on Scenario 1 stay the same?

Case Study: Quality Control/Rework

Although Six Sigma is used across virtually every industry today as a problem-solving approach, its birthplace was in the manufacturing environment. More specifically, the methodology was used to measure quality and its effect on system output.

The following simulation example models a manufacturing facility in which quality is an issue. It includes a rework loop after a quality control inspection process. Although the process is simple, the effects of quality control initiatives may not be apparent through quick back-of-the-envelope calculations. Instead, a simulation model allows the user to evaluate the effects of a probabilistic event on the system. This event can range from inherent variability in the process to machine breakdowns.

Background

The simulation focuses on a specific set of operations (metal stamping and trimming) as part of a greater manufacturing process. Pieces of sheet metal that have been prepared from upstream operations are stamped at a press machine and then trimmed. Some of the pieces, however, are not trimmed perfectly and must be inspected to identify this flawed work then sent back for rework. If the pressed and trimmed parts are of sufficient quality, they are packed and shipped. Each operation in the process has a certain labor and energy requirement and thus, costs can be associated with each process as well as estimated revenue for each piece shipped. The problem is to determine the costs and benefits of different levels of quality of the press machine.

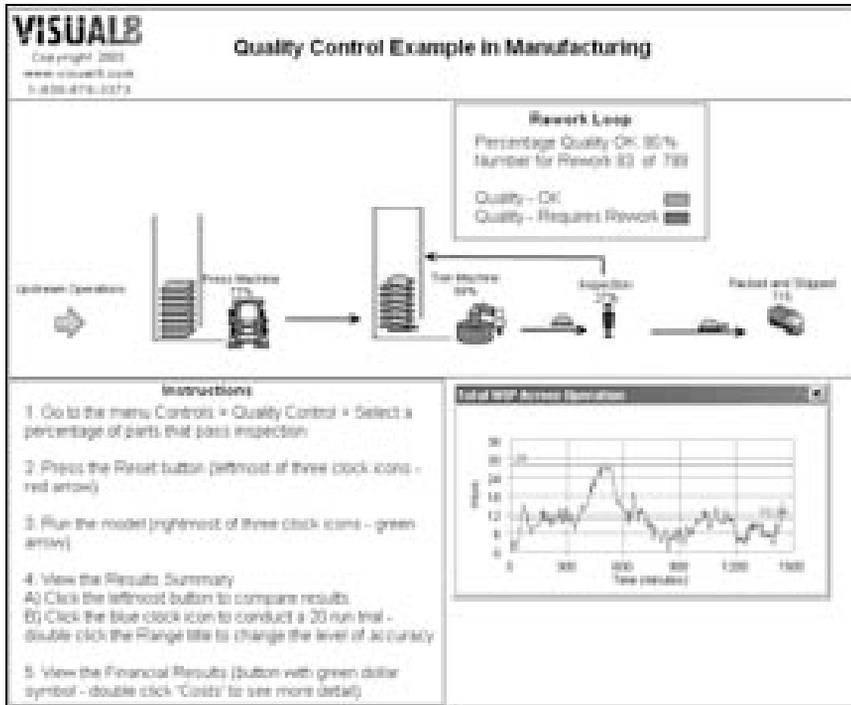


Figure 4-4: Quality Control Example Screen Capture

Analysis

The simulation model is non-complex. Processes are inline, each has a respective buffer, and cycle times are normally distributed. The rework has been implemented by routing out of the Work Center with the percentage discipline (See Route Out Percent on page 268). A specific percentage is sent to Packed and Shipped (a Work Exit Point) while the rest of the Work Items are routed back into the queue for the Trim Machine to be reworked – hence a Rework Loop.

The custom dialog box in the Controls menu is available for quick changes to the percentage of imperfect parts to evaluate the effects of various levels of quality on the specified performance measures. Additionally, the Finance features are used to provide an economic analysis of the system.

The simulation may be run multiple times (a trial) to obtain more statistically significant results than those obtained through a single

simulation run. Scenarios with 90% and subsequently 95% quality parts were tested in trials to obtain the following performance results.

		Total Average	Trial Average
WIP	Average	23.96508	12.81932
Packed and Shipped	Number	1170.95	1150.0

Figure 4-5: Quality Control Example Results Comparison between Trials (on page 321)

- This tells the user that a quality initiative would cut the system's WIP in half as well as increase the overall throughput. Financial results were obtained using the Finance feature within SIMUL8. ●

Category	Item	Value
Costs	Costs for Tool Machine	\$ 2,100.00
	Tool Machine	\$ 2,540.00
	Inspection	\$ 1,320.00
	Press Machine	\$ 2,700.00
	Costs for Press Machine	\$ 780.00
		\$ 9,240.00
Revenue	Packed and Shipped	\$ 9,650.00
		\$ 9,650.00
Profit		\$ -410.00

Category	Item	Value
Costs	Costs for Tool Machine	\$ 1,470.00
	Tool Machine	\$ 2,540.00
	Costs for Inspection	\$ 0.00
	Inspection	\$ 1,320.00
	Press Machine	\$ 2,430.00
Costs for Press Machine	\$ 241.00	
		\$ 7,701.00
Revenue	Packed and Shipped	\$ 9,210.00
		\$ 9,210.00
Profit		\$ 1,499.00

Figure 4-6: Quality Control Example Finance Results

In terms of bottom line, the change in the percentage of items that require rework results in a positive income instead of the predicted loss.

Recommendations

The simple manufacturing simulation example above provides a strong economic, operational, and visual argument for any decision-maker to justify the implementation of a quality initiative within this production process. The simulation was useful for predicting how the system would react under various scenarios. The ability to simulate and analyze a rework loop is particularly valuable for Six Sigma professionals. The above example would be used to test out several scenarios during the Improvement Phase of the Define, Measure, Analyze, Improve, and Control cycle.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. Does the simulation run long enough to determine if the system is going to be profitable in the long term? How do you know? What is an appropriate length?
2. What are the key performance indicators that change when process reliability is improved?
3. What are the increased costs of the QC initiative?
4. What do you think is the best way of presenting the results?
5. Expand this model to send all pieces that do not pass inspection the first time to a special rework bin and only draw from it when the operation is starved of work. What is the maximum level the bin reaches?

Chapter 5: Service Industry/Business Process

Overview

Outside of manufacturing there are a wide variety of applications wherein simulation can be applied. This section discusses a major group, namely service and business processes. Included are areas such as the processing of applications or transactions in a bank or insurance company, the handling of calls within a call center, the treatment of patients in a hospital or clinic, and the serving of customers in a retail operation. Indeed, a significant proportion of simulation work today relates to non-manufacturing applications.

With the emphasis shifted more on people and procedures rather than product and machine routings, business process simulations are being used to streamline delivery and service systems. These models can be used to investigate staffing requirements to satisfy projected customer demands; to examine alternative ways of processing applications or requests; to measure the impact on the system of changes in policy and procedures or with the introduction of new technologies such as image processing or ATMs in a bank.

Simulation in business services is a fast growing field because it can look at more efficient ways of handling transactions or servicing customers with the emphasis on service levels and processing costs. Extending the business analysts process mapping and documentation tools with the capability of simulating the process adds greatly to the questions that can be addressed. Business process simulations help to show how efficiently documents flow within an office system, how people are utilized, the level of customer service that can be attained, and most importantly, the cost of doing business and the opportunities for improvement.

To define a service process, decision-makers typically draw a map or flow chart of the process using tools like Visio or ABC Flowcharter. Much like a CAD drawing in plant layout applications, this information only provides part of the story. On its own, it does not help determine the volume of work a set number of staff could handle, nor does it show the physical layout of the process. Simulation of the process can reveal the flow of work through the system with the utilization of staff or equipment and the timeliness of the service being delivered.

SIMUL8 offers a link to a number of popular flowcharting packages that can speed up the time required to define the process steps within the simulation model. In addition, the product allows the user to specify the cost of the service being delivered at each step of the process. Simulations of fast food restaurants, tollbooths, emergency clinics, gas stations, call centers, car service shops, and government departments are all examples of valid and useful applications.

The following examples help to demonstrate the diversity of business process and service industry simulations. They are a small set of case studies drawn from our experience with a wide range of companies in the service sector and they highlight the emphasis on modeling demand profiles and service costs.

Case Study: Call Center

Call centers have been an interesting area for simulation modeling over recent years. The financial constraints of keeping costs reasonable factored against outside pressures to meet service level agreements, and the threat of lost business from poor performance put the system's managers under scrutiny. The goal of any call center investigation is to learn what staffing level, schedule, and training is required to meet the expectations of the system's performance.

As simulation packages become more generic in nature, it has become easier to build simulation models of call centers. Several tools exist to assist in the planning of call centers, but simulation provides an excellent method for quickly and relatively simply creating an accurate representation of the real flow of calls, agent utilization, and performance standards, while getting around the limitations of static analysis tools.

Most simulation packages provide a call center template that allows the user to build their call center through build wizards. The wizards provide structure to the problem, which speeds up the development time. The call center problem is a relatively common application of simulation and is easily understood, so often the template requires minimal additional work to model the specific problem.

Typical studies on call centers have included the following:

- Justification for less or more staff across a daily, weekly, or monthly profile;
- Revisions of shift patterns and break allotments;
- Acceptance of new call types based on identifying extra capacity;
- Training of personnel for multiple skill types; and
- Justification for more trunk lines to ensure no lost calls.

As operations grow and business environments change, managers are required to evaluate issues such as the following:

- Increases in call volumes,
- Increased call mix,
- Improved customer service level requirements,

- Call escalation, and
- Outbound / Inbound Combinations.

All call center simulation models will have a similar set of input and outputs required. Inputs are as follows:

- Call Arrival Patterns, typically expressed as calls per hour, half hour, or quarter hour.
- Staffing Shift Pattern
- Call Types and Profiles

Outputs:

- Service levels profiled across the simulation period – expressed as # of hang-ups, lost calls, and calls serviced within service level target.
- Agent Utilization profiled across the simulation period – match over-utilization periods with lost calls, and poor service.

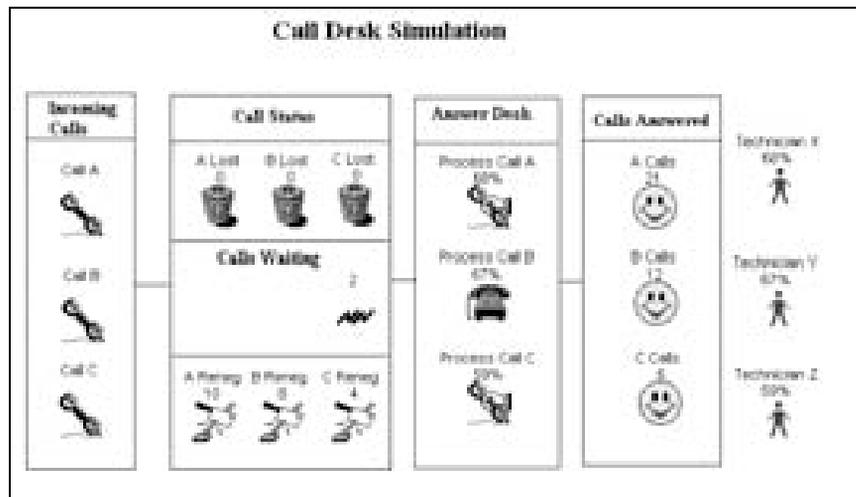


Figure 5-1: An Example Call Center Simulation Model

Most simulation studies on call centers will include more detailed information, such as the following:

- Average customer wait times by call type,
- Trunk Line capacity,

- Call escalation, and
- Outbound calling.

Background

A call center for a growing IT firm provides technical support for the firm's products including its brand new line. As an expanding IT firm, it is crucial to develop a good reputation for outstanding customer service. Thus, one of the company's main objectives is to ensure that no calls are lost. The secondary objective is to ensure that service levels are met across all call types within the center.

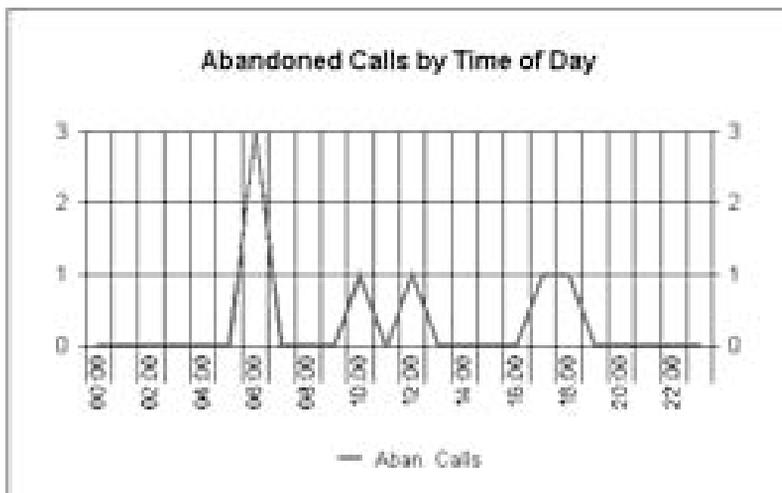


Figure 5-2: Abandoned Calls across a Daily Profile

Analysis

Data described above was input into the model for simulation. The model was then validated, ensuring that it actually reflected the call center. The following issues were analyzed:

- Can the system handle an increase in certain call types?
- Under what conditions does the system lose more than 20 callers per day?
- If a different mix of trained staff were available, would the center meet service level targets?

By studying an incoming work profile, it is possible to correctly predict staff requirements by skill type to ensure sufficient availability such that the target service levels at the service center is met.

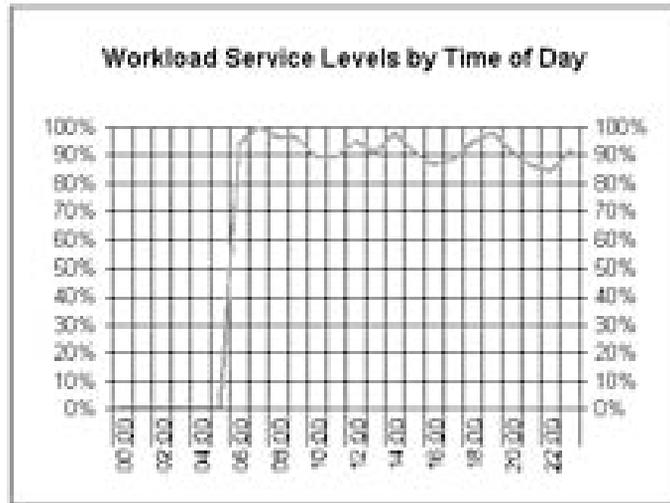


Figure 5-3: Service Levels Profiled across a Simulated Day

Recommendations

Results from the model demonstrated that trunk capacity does not need to be higher than approximately 25 lines, for the given incoming call profile. As this is the case, more than 25 total staff members would be superfluous, assuming they are all capable of handling the various types of calls. In fact, increasing the abilities and skills of operators is clearly shown to lower the number of staff necessary.

Discussion

1. What increase in call volume (even proportion across the call types) can the model handle before the total lost calls reaches 10? What if trunk capacity was increased by 3?
Starting with the default call volume, what possible changes to the set-up would cause the system to lose more than 20 calls?
 - a. Different mix of staff?
 - b. Different service times?
 - c. Different caller tolerance times?
2. If a contract says that you can handle x % of the customer calls within Y amount of time Z % of the time, what service level can you guarantee for Call A? (hint: look at Work Complete Results)
 - a. Now increase the caller tolerance time by 50% and state the new statistic.
3. Change the caller tolerance time back and decrease the service time by 25% and state the new statistic.
4. If the client is expanding the organization and expects that call volume will increase by 5%, how would you change your set-up?
5. What if the company also wanted to decrease the expected time in system by 10%?
6. How would you augment the financial aspects of the model to improve its results?

Case Study: Process Simulation and Six Sigma

Six Sigma has become a very popular process improvement methodology in recent years as demonstrated by GE and many other leading organizations. The Black Belts' approach to Define, Measure, Analyze, Improve, and Control processes has been successfully applied to a wide variety of business and manufacturing processes. Static analysis tools like Statistical Process Control are effective for supporting operations that are relatively simple and easily observable. However, in cases where the process is more complex with interdependent operations, Six Sigma professionals are turning to Process Simulation.

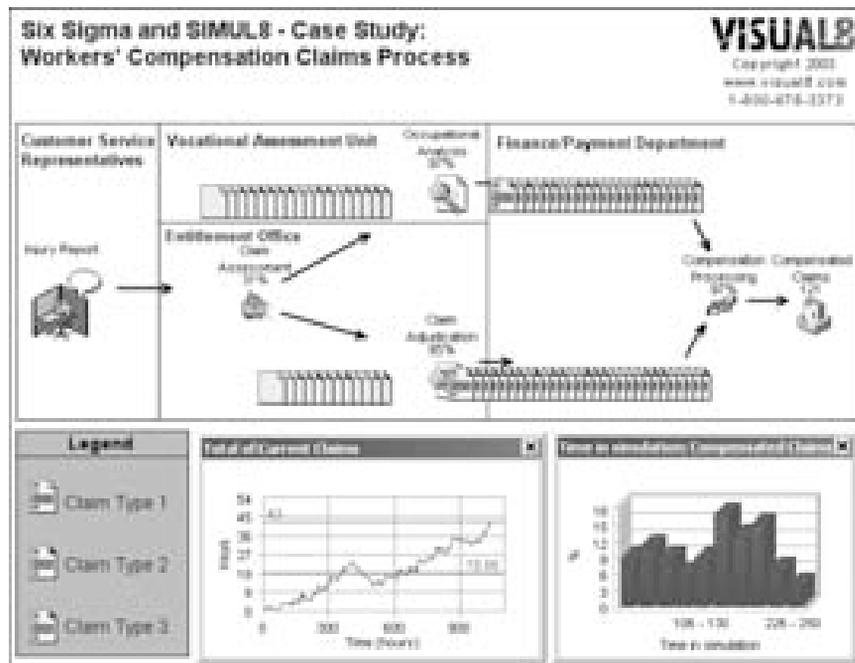


Figure 5-4: Services Simulation Screen Capture

Process Simulation lets the user capture and display the inner workings of operations no matter how complicated the system. It is similar to Process Mapping in that it provides the visibility often required to understand involved processes. Simulation, however, contributes another valuable

dimension to this Quality Tool by being able to demonstrate the effects of modifications to the system dynamically. The following example shows when and how SIMUL8 can be an effective Process Simulation tool to address these time-dependent issues.

Although Process Simulation is another potential tool within a Black Belt's kit, not all Six Sigma projects require the technique - knowing when to apply simulation is crucial. Here is a simple guide:

- If the process is complex and provides little or no visibility for review, simulation provides the opportunity to observe and analyze the working system.
- If a process has many decision variables such as product types, routings, resources, shift-patterns, task times, or rework, simulation offers a dynamic platform to examine the performance of the system and to determine how it can be improved.

Background

Claims processing at a workers' compensation center is an appropriate application of this simulation approach. The process provides little to observe, has intricate routings, and alternative processing rules based on the claim type.

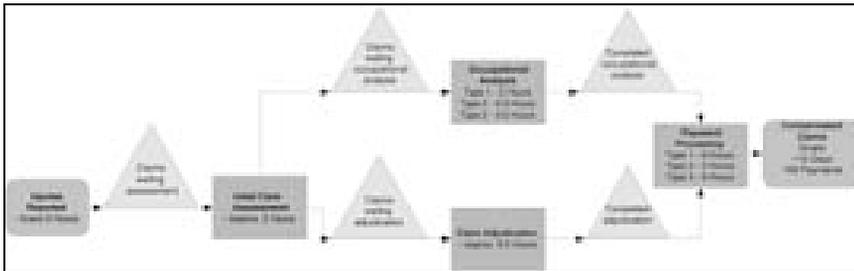


Figure 5-5: Services Simulation - Process Map of Claims Processing

Problem

The goal of the study was to identify and eliminate constraints within the operation. In the process shown above, the proportion of claim types changes daily, but it is not immediately apparent that the bottleneck in the claims process continually shifts.

A Process Simulation of this claims processing center can assess the system as a whole to evaluate current operational Key Performance Indicators (KPIs) and to verify the impact of changes to the entire system's throughput.

One KPI of the process is the application turnaround time – target 90% of claims in less than 15 days. Other KPIs are the average number of claims in the system (target under 15 cases), Resource utilization, and claims processed (target 140 payments). The simulation allows us to measure these indicators directly.

Analysis



Figure 5-6: Services Simulation Results

After simulating the process, it was discovered that the claims processing center could only complete an average of slightly over 120 cases with an average of 18.66 open claims and only 38% completed in less than 15 days.



Figure 5-7: Services Simulation Scenario 1 Results

Several scenarios were tested using the simulation, such as changes in case process times and increasing number of resources available, but these had little to no impact on the KPIs. Instead, results indicated that the mix of claim types had the most significant effect and, in particular, the volume of Type 3 claims.

A suggested improvement to the process was to use a dedicated team to handle all Type 3 claims. To test this, a simple change to the simulation model was made to replicate this scenario. Then a trial of 20 runs was used to obtain the confidence limits as shown below.

Item	Result
Compensated Claims	
Number Completed	113.00
Average Time in System	128.88
SD Dev of	62.89
Average Time in System (1)	88.86
SD Dev of (1)	65.94
Average Time in System (2)	118.88
SD Dev of (2)	66.47
Average Time in System (3)	138.00
SD Dev of (3)	69.25
Current Claims	
Average queue size	18.88

Figure 5-8: Services Simulation Multiple Run Trials Results

The results from the simulation could also be exported to Minitab™ for further post-processing analysis (Results > Results Export > Minitab).

Recommendations

The process change had the net effect of decreasing the total claims processing time for all three claim types and, through familiarity of claims, was expected to reduce the number of staff required.

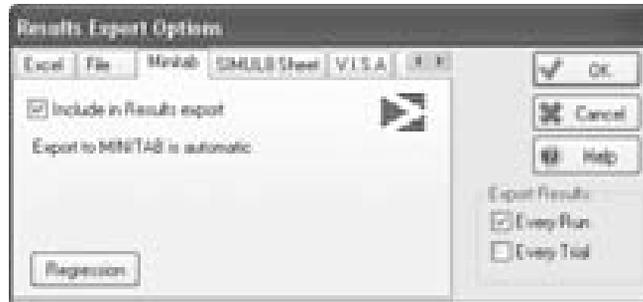


Figure 5-9: Services Simulation Minitab Export

The turnaround time no longer exceeded 13 days and now averages less than 10 days, with a reduction of average open claims to 5.7 and throughput in excess of 150 cases!



Figure 5-10: Services Simulation Scenario 2 Results

The value of Simulation lies in its ability to dynamically show the entire process in operation. Running “what-if” scenarios quickly revealed the relationship between process times and the mix of claim types that static analysis would have failed to uncover. In addition, the Process Simulation proved useful for monitoring the system’s performance and assessing the impact of policy and procedural changes, for example the automation of specific operations at the workers’ compensation center.

Regardless of the industry application, Process Simulation with SIMUL8 is an invaluable tool for any Six Sigma professional.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. What are some other KPI's that could be examined in order to improve the efficiency of the claims processing center? Are there any necessary modifications to the model that must be made to incorporate these additional KPI's?
2. Aside from our recommendations, what other approaches would you consider?
3. Explain how you could use the simulation to answer the following question: What percentage of time can you answer a specified percentage of calls within a specified number of minutes? Which SIMUL8 function does this for you?

Case Study: Airline and Airport Simulation

The airline and airport industry has been taking advantage of operations research techniques for many years. Airlines must ensure that their booking policies and schedules are able to generate maximum revenue with minimum cost. The complex layouts, customer service tasks, and security responsibilities within large airports present a huge logistical challenge that is often addressed using simulation.

Background

The check-in process at an airport is quite difficult to model using algorithms and spreadsheets. Factors such as the flight schedule, passenger arrival patterns, different customer profiles and processing time of customers by check-in staff all add to the complexity of the system. Simulation can be effectively used to model airport check-in as each of the factors can be quickly set up in the model and examined together or independently.

Problem

The following example provides a model of an airport check-in area. The objective is to identify the impact of various increases in efficiency in serving customers at the check-in.

Analysis

The simulation runs for one day of the check-in operations. It is assumed that check-in operates for twelve hours with a constant number of resources available and with a steady arrival of customers. In a more complex model, it is possible to correlate the arrival of passengers to a flight schedule and also to incorporate recommended check-in times. It is assumed for the purposes of this example that customers will stop arriving 2 hours before the end of the day.

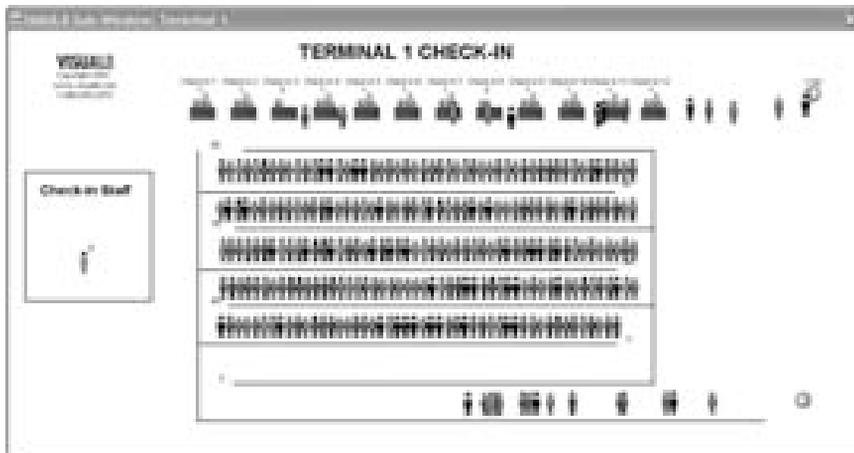


Figure 5-11: Airport Queuing Example Scenario 1 Screen Capture

Scenarios

A number of scenarios are examined. In the first scenario, the input parameters shown in Figure 5-12 are used. The model shows profiles of eight different customer types. Each type of customer has a different average check-in time and a respective proportion of the total number of customers. The model makes an approximation of the arrival rate of people based on the number of flights per day and customers on each of the flights. There are twelve staffed check-in desks.

The second scenario evaluates the impact of a small process improvement on the customer queuing. The improvement is a mere 15 second reduction in service time for each customer to simulate increased staff efficiency.

Sheet: Input

Customer Servicing Time

Customer Type	Ave Check-in Time (min)	% of Total Customers
1	2	15
2	4	20
3	5	10
4	15	2
5	3	15
6	4	20
7	6	10
8	7	5

Flight Information

Flights per day	Customers per Flight
6	100

Resources

Check-in Resources
10

OK
Cancel
Help

Figure 5-12: Airport Queuing Example Scenario 1 Inputs

The simulation model uses a Probability Profile distribution to set the profile of customers arriving. Labels are used to represent the different customer types and a named distribution is used to assign a process time as the different customer types arrive at the check-in desks.

Results

Shown below are the results from running the model under both scenarios, with and without the small process improvement. The buildup of customers queuing under both scenarios can be seen as the day progresses. The following charts show the profile of customers queuing throughout the twelve-hour day. The first chart shows that under scenario 1, the buildup of customers reaches a peak of almost 320 and the customers cannot be cleared by the end of the day. The second chart shows scenario 2 has a much smaller queue size and all customers can be served by the end of the day.

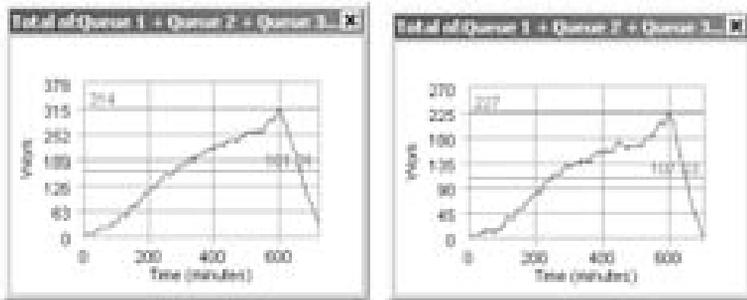


Figure 5-13: Airport Queuing Example Queue Size Charts

The following results from scenario 1 show long queues and waiting times. There are also some customers who have not been serviced by the end of the day. This would mean that staff would have to continue working overtime in order to deal with those remaining people.

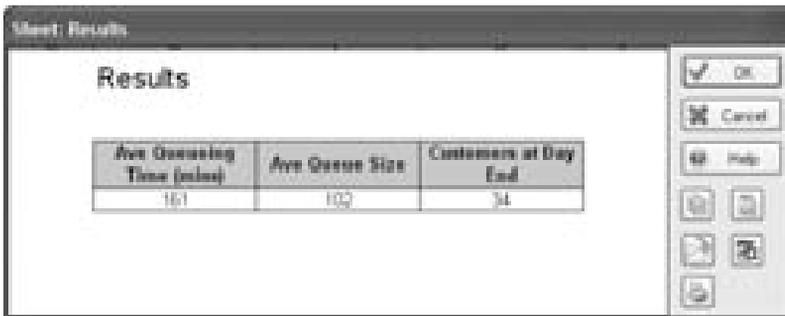


Figure 5-14: Airport Queuing Example Scenario 1 Results

Scenario 2 shows that speeding up the processing of customers has significantly reduced both the queuing time and queue size.

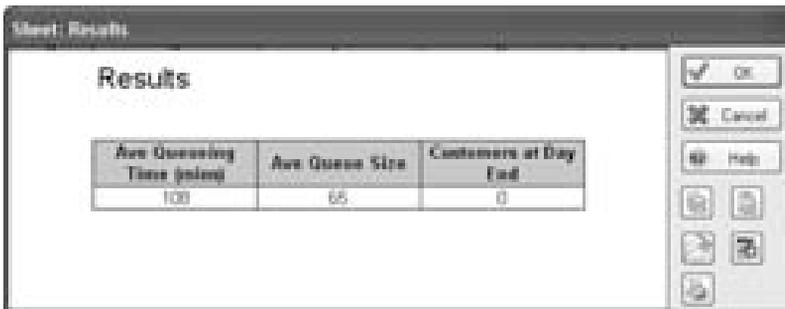


Figure 5-15: Airport Queuing Example Scenario 2 Results

Recommendations

The example simulation of queuing at an Airport Check-in demonstrates how small changes in procedures can have a large effect on customer wait times. The model results make a strong case for the implementation of even minor improvements to the check-in procedures. The model could be further enhanced to provide a more detailed profile of customer arrivals according to flight times, capacities, and destination (recommended check-in times). The same type of modeling techniques could be applied to other areas around the airport such as security checking or customs.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. What else can be done to decrease customer time in system without decreasing service time?
2. Name at least three improvements to the check-in process that would lower the service time of travelers. Of these, which can be included in the simulation without making any changes to the model? What changes must be made in order to incorporate other changes?
3. How can we refine the arrivals schedule to more accurately reflect reality?

Case Study: Modeling ATMs

Financial institutions have traditionally relied on a full-service branch system wherein all financial transactions are completed within the physical bank building. With increasing customer demands for 24-hour per day availability, a desire for more locations, and cost-reduction initiatives, Automatic Teller Machines (ATMs) and internet banking have become much more prevalent. This example focuses on ATMs in terms of daily operations and evaluating different geographic networks of ATM locations.

Background

An expanding bank is growing quickly and expanding into new geographic markets. The manager responsible for ATM deployment at the financial institution wishes to analyze the daily operational performance of placing five ATMs into a new metro market. Instead of using the traditional model that dictates where the machines should be placed and evaluating their performance post-deployment, the manager has wisely decided to perform a simulation analysis of the new system to answer several questions:

- How much will the ATMs be used?
- Is there sufficient capacity at the ATMs for the number of transactions?
- Will the ATMs support an adequate level of service?
- What is the financial benefit from deploying the ATMs?

In this simplified example, customers use ATMs to withdraw cash, deposit cash or checks, and pay bills (or other miscellaneous transactions) throughout the day. Concurrently, armored trucks make regular visits to the ATMs to replenish the stock of available cash and to pick up any deposit, bill payment, or other transactional envelopes. The ATMs are either located at a grocery store or near the front entrance of an existing bank.

Problem

The manager's primary concern is whether the five proposed ATMs could meet a certain level of service. Service level is defined as the percentage of satisfied customers who use or plan to use the ATM. In the model,

potential reasons for causing a customer to be dissatisfied are waiting in line too long, lack of capacity to deposit envelopes or make bill payments, and insufficient cash available for withdrawals.

Analysis

The simulation model uses three levels of hierarchical modeling for each location through the use of sub-windows. See the Reference section for more details on this useful feature that enables the user to display further detail in addition to the macro level view:

1. The main screen that shows the placement of the locations on a map,
2. The layout of the store or bank location, including a detailed view of the ATM queue area, and
3. The contents of the ATM itself.

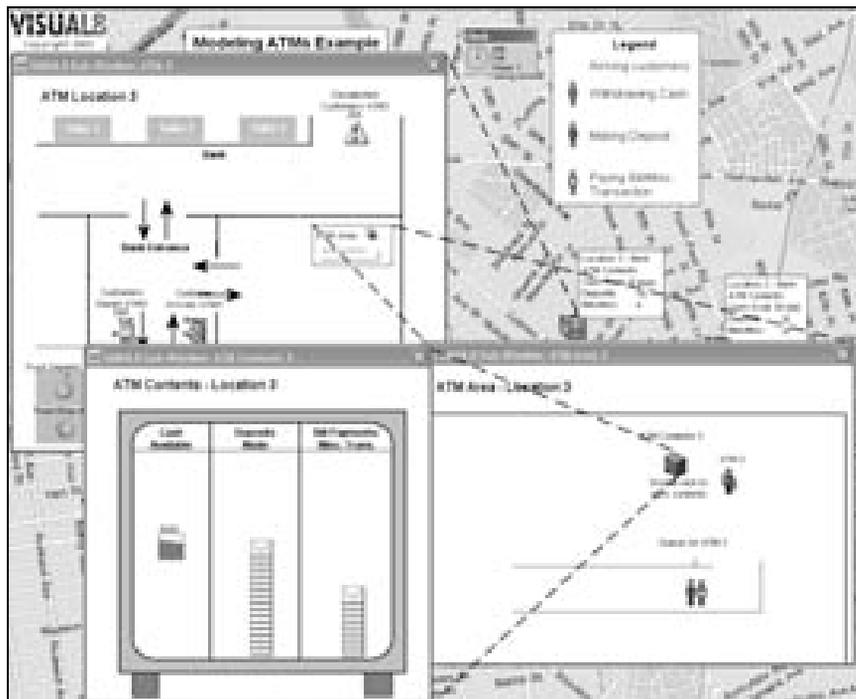


Figure 5-16: Modeling ATM Example Hierarchical Structure

For each ATM, the user can specify the ATM capacities, processing times, customer arrival rates, action types available (i.e. withdraw, deposit, bill payment, etc.), costs and revenues associated with operating the ATM, and customer service threshold (i.e. amount of customer patience).



Figure 5-17: Modeling ATM Example Model Input Parameters

The example model uses graphics and animation extensively. Background maps, layouts, and drawings are used within each Sub-Window along with icons for each on-screen object. Work Items (customers, armored truck and guard, cash, deposit envelopes, and bill payment envelopes) are all assigned different images to visually differentiate between them. Visual Data is shown on the main screen to dynamically display the contents of the ATM. (See Graphics Palette on page 182 for more information.)

The simulation model indicates how much of the ATM's carrying capacity was actually used, the amount of utilization of the ATM itself, the service times, the service levels, and the financial results. This information is presented in an organized fashion using the wizard option of SIMUL8's dialog box feature, shown below.



Figure 5-18: Modeling ATM Example Model Results

Recommendations

The model was run for a simulated week to obtain the following summary results.

Result	Overall	Location 1	Location 2	Location 3	Location 4	Location 5
Capacity Utilization	59.7%	68%	37%	62%	65%	68%
ATM Utilization	45.1%	41%	53%	40%	46%	46%
Average Service Time (min.)	1.4	1.4	1.9	1.2	1.5	1.6
Customer Service Level	73.1%	80%	60%	76%	78%	82%
Net Income(Loss)	1,034	231	(100)	185	352	386

Figure 5-19: Modeling ATM Example Summary Results

As shown above, none of the ATMs achieve a very high level of customer service and further investigation into the cause of the dissatisfied customers is required. The manager can conduct a more detailed analysis by investigating the capacity utilization, the processing times, the interference with armored truck drops at the ATMs, etc.

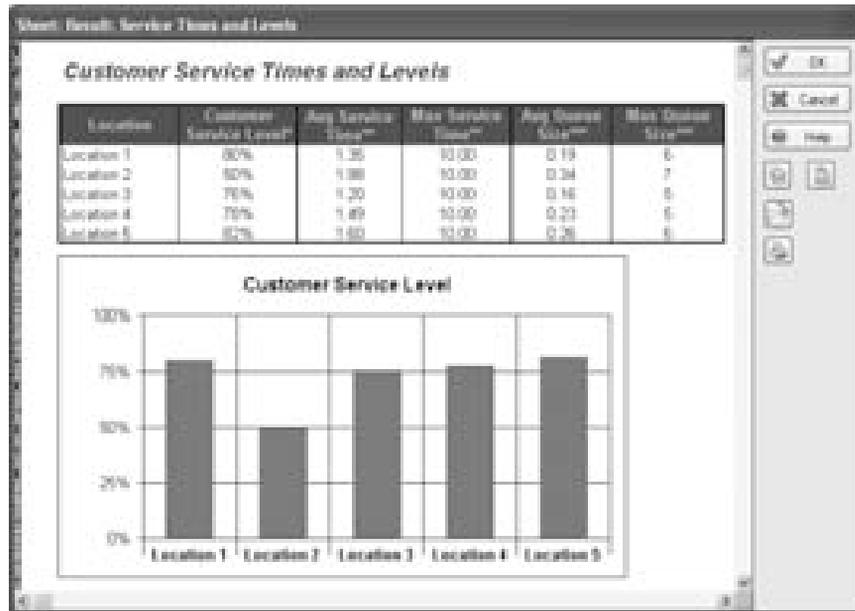


Figure 5-20: Modeling ATM Example Model Results

The simulation analysis, as shown above, provides a sound basis for decision-making before deploying the proposed ATMs. Instead of placing the new ATMs with little information regarding how they will perform, the

model allows the user to make adjustments to the proposed deployment since she has a better understanding of the system.

Several options exist for extending the current simulation model. The potential future area of expansion for the current simulation that would provide the most value and insight, however, is to convert it to a metro network configuration tool. More specifically, link the current simulation to a GIS database to obtain geographically based demographic data pertaining to specific locations and show the interactions between them. By providing this feature, various metro ATM network configurations can be tested for appropriate coverage when placing new or removing old ATMs. Therefore, while the current model is used to examine individual ATM performance, a network model can help evaluate the system as a whole with all the requisite detail.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. What method should be used for determining customer service threshold?
2. Can you explain the relationship between customer service level and the other KPI's in the model?
3. Are there any other issues involved in deploying additional ATM's to satisfy customer demand? Include these in the model and produce a new set of results.

Case Study: Healthcare

Healthcare is the single largest industry in North America. It is constantly developing and changing as technology advances and new modes of delivery become available. The consistent evolution of the processes means that there are always potential gains to be had from OR studies. Healthcare is a unique industry because it does not conform directly to the economics of supply and demand. Health providers strive to deliver exceptional care at a reasonable cost. Organizations are constantly trying to determine how funding should be allocated in order to provide the best patient care. For this reason, the benefits of an OR study are very valuable in terms of providing better patient care. From a business process or services sector standpoint, healthcare is a potentially contentious area to quantitatively evaluate. What are appropriate measures of patient care? Should service level, like transaction-oriented businesses, be used to determine how an HMO, hospital, or clinic is performing? If service level is chosen, an appropriate definition and method of assessment must be established. These are just some of the issues that arise when analyzing a 'human' system. The following example describes a basic application of simulation analysis to a healthcare setting.

Background

Simulation studies can be applied to nearly every aspect of the healthcare industry. Some studies become politically sensitive when they end up directly comparing service levels and finance constraints. Often internal structures and policies become invisible constraints to the progression of change.

This example models the simplified operations of a hospital's emergency room (ER). The administration has several concerns: budget, staffing, space, and process times. In this model, we examine the possible benefits that could be gained from a simple reorganizing of patient activities.

Problem

Two scenarios are modeled in the example simulation. Common to both scenarios are the process times required for each task, the requirement that all patients must pass through each process before being discharged, the personnel, facilities available, and the arrival rates of patients at the ER.

The first model shows the emergency room before a proposed process improvement recommendation is implemented. When patients enter the ER, they first proceed to the area of the ER that they feel is appropriate (i.e. a random routing).

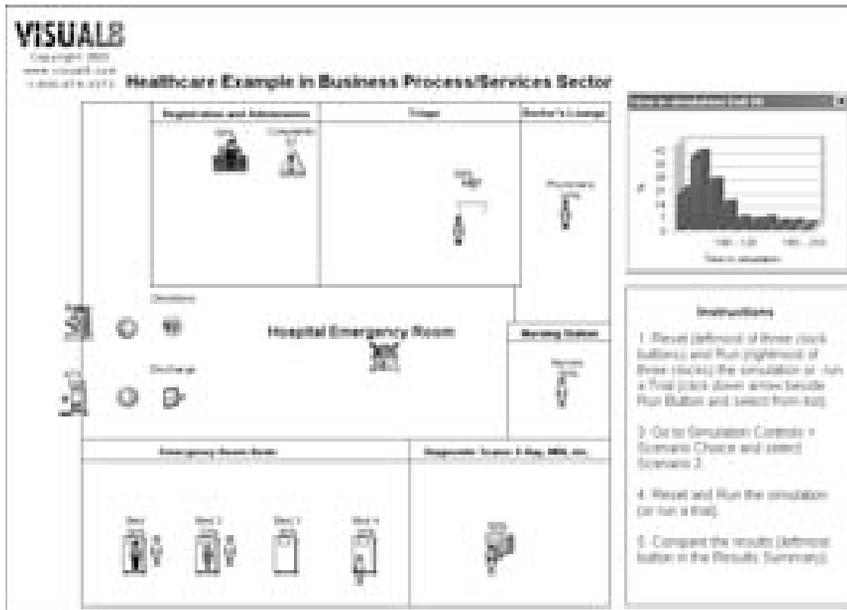


Figure 5-21: Healthcare Example Scenario 1 Screen Capture

In the second scenario, patients are given instructions to go to Registration and Administration area first, at which time patients are told exactly where to go (i.e. clockwise through each area in the ER). See the figure shown below.

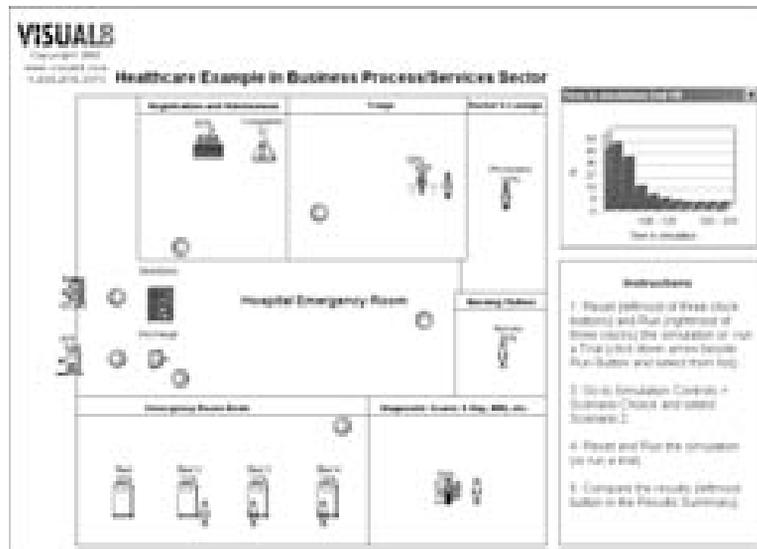
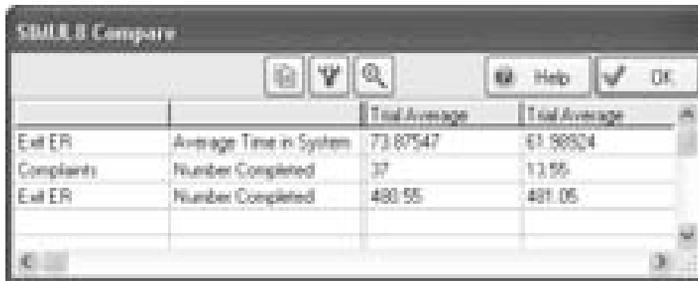


Figure 5-22: Healthcare Example Scenario 2 Screen Capture

Analysis

The simulation model makes use of the Jobs Matrix feature in SIMUL8 (See Jobs Matrix on page 275). The Jobs Matrix enables multiple Work Item types, routings, and processing times at each station, without using complex coding. The Resource feature is used to provide the appropriate number of personnel required at each of the various processes. Other features of note are the *Image* label and the use of a Rounded Uniform Distribution in Label Actions, which are used together to quickly and easily assign various images to patients. The primary indicators of service level, for this case, are patient time spent in the ER system and individual queuing time at each process. Patients are expected to never wait for more than half an hour for any one task in the ER. Otherwise, a complaint is filed. The figure below shows these indicators after a trial of 20 runs.



		Total Average	Total Average
Exit ER	Average Time in System	73.87547	61.96924
Complaints	Number Completed	37	13.55
Exit ER	Number Completed	480.55	401.05

Figure 5-23: Healthcare Example Results Comparison

The left column shows Scenario 1 results (disorganized routing) and the right column shows Scenario 2 results (specific routing). Comparison of these results clearly shows that patients in the second scenario spend considerably less time in the ER. These results can also be seen in the histograms shown below.

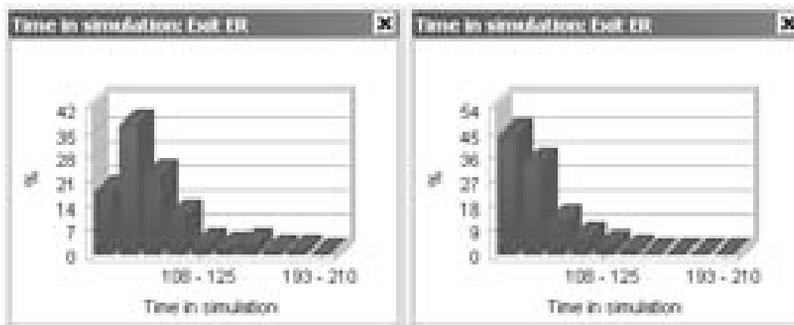


Figure 5-24: Healthcare Example Time in Simulation Charts

An additional result of the process change is that the number of complaints filed is nearly two thirds fewer than the number in Scenario 1. This translates into a service level increase from 90.8% to 97.3% after the patient flow process improvement.

Recommendations

The Emergency Room simulation example above provides a convincing argument for implementing the proposed process improvements to the existing system. The simulation was particularly useful for comparing the two scenarios against specific measures using statistically robust techniques. The simulation model can be expanded to provide further insights into various healthcare projects in many ways. One example is providing more

detail within the simulation, such as by using different service levels for different injury types or ICD10 codes. Another example is to change the scope of the simulation to evaluate ER coverage within an entire metro area. Regardless of the specific area of study, simulation analysis is a tool that is scalable, flexible, and practical and can be applied to a variety of healthcare issues to provide hard evidence to back proposed improvement projects.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. Can you find any major costs in switching from scenario 1 to scenario 2?
2. Which results remain similar in both scenarios?
3. What improvements would you propose to improve upon these results?
4. How would you expand this model to include a second stream of incoming patients?

Chapter 6: Supply Chain Case Studies

Overview

The term Supply Chain is used loosely to denote any or all aspects of the product procurement cycle from sourcing raw materials, managing the production of parts and finished goods, transportation of goods to warehouse and/or distribution center, and final customer delivery areas. What was once termed physical distribution and manufacturing has expanded to encompass a wide range of interdependent operations within the supply process and with it the complexity of maintaining efficient and focused systems.

Simulation offers the potential of looking at the dynamic working of the supply chain from a very high level, examining the flow and cost of moving products across the entire supply network. From this viewpoint, it is possible to examine the adequacy of the fill supply system from a response or service level standpoint with respect to the cost of providing this level of product fulfillment. This type of analysis may reveal problem areas in the network, which may be candidates for more detailed or low-level simulation analysis.

Any segment or part of the supply chain can be simulated in more detail. Examples are the internal working of a distribution center or the physical transportation of goods from producing plants to storage centers. The performance issues that can be discovered include inefficient storage and retrieval systems, inadequate materials handling equipment, or even excessive stock levels. Improvements can easily be studied through adjustments to the model parameters, revealing their specific contribution to the system's increased performance. In this way, a cost-benefit analysis can be performed to "fine-tune" the supply chain network with respect to service level objectives.

As described earlier, supply chain simulations in SIMUL8 can be shown across a geographic area, using bitmaps, depicting the location of plants, warehouses, distribution centers, and customer demand areas. The level of graphic animation in the model could include truck shipments delivering products from source to demand points in the network with the simulation keeping track of freight costs and delivery times. Typically, a simulation of the supply chain will manage inventory levels at each stocking point and automatically generate replenishment orders based upon inventory management rules for the product(s) that are being controlled.

Supply Chain models can be very data intensive and the analyst has to be careful about the combined level of detail and scope of the simulation to avoid building a tool that is cumbersome, slow, and impractical for addressing operational issues. The following examples provide a practical view of the way in which SIMUL8 has been used to address warehousing, physical distribution, and product supply issues under the general umbrella of supply chain applications.

Case Study: Warehouse Workflow Modeling

The use of simulation to explore the workings of warehouse operations is a common application. These models allow the analyst to examine issues such as the warehouse layout, materials handling requirements, staffing levels, storage and retrieval systems, stocking policies, picking and packing operations, type and size of racking systems, product storage needs, space requirements, etc. The more complex the materials-handling system, the more valuable simulation models can be in helping to determine the flow of product or pallets through the system.

Background

Simulation models can be used to examine warehouse design issues as well as on-going operating practices to improve efficiencies and productivity levels. Indeed, a popular application of this technique is to examine the capacity of the warehouse operation to handle a predicted volume of received goods or shipment of orders within a specific timeframe. These performance evaluation models typically lead to changes in the operation that eliminate bottlenecks that constrain the system's ability to meet planned or predicted workload levels.

Similarly, simulation can help decision-makers determine staffing levels where there are stock pickers and shippers or receivers handling the daily inflow and outflow of goods from the distribution center or warehouse. The timing of shipments both inbound and outbound can significantly affect the staffing profile required to handle the workload in a timely and cost-efficient manner. Physical characteristics of the warehouse can also come into play such as the number of shipping and receiving docks, the number of fork lift trucks available, and available space to build outbound orders or inspect incoming goods.

The animation provided through the simulation model offers a unique bird's-eye view into the workings of the warehouse's operation. Problems that may arise such as a build-up of pallets on the floor or trucks waiting to be off-loaded can be quickly seen. This feature, coupled with the power to test-out alternative ideas or workload conditions by simulating "what-if" conditions or changes quickly in a risk-free setting, gives decision-makers a powerful analysis and project marketing tool.

Problem

A pharmaceutical company must redesign its existing warehouse operations in order to accommodate a planned increase in production that will result in an increase in material handling tasks. Naturally, management would like to minimize capital expenditure and continue to operate within the current building, which is directly linked to the production area. Although management suspects there will be a need for large investments, they would like to support their decisions with hard evidence. They have wisely elected to use simulation to examine the problem and provide them with clear numbers.

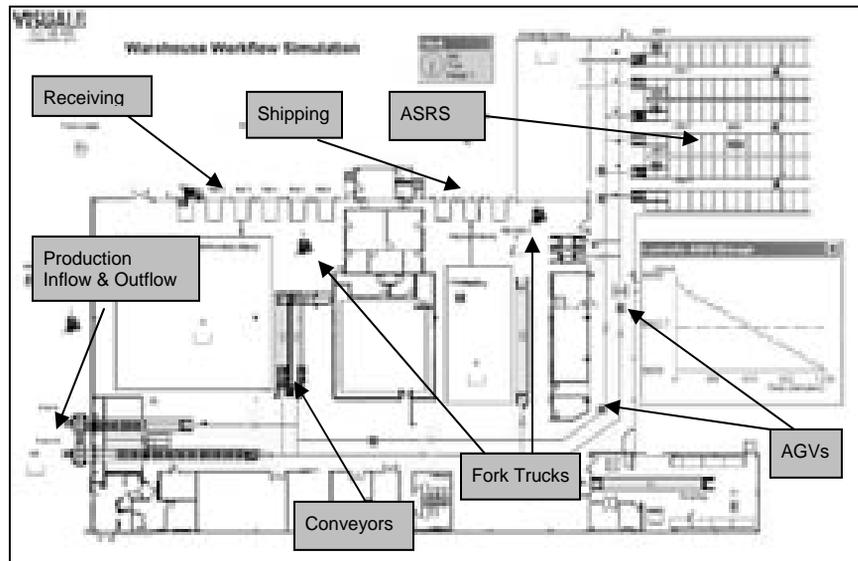


Figure 6-1: Warehouse Simulation Layout

The current warehouse employs forklift trucks to unload pallets of materials from trucks at the receiving docks. These in-bound pallets are fed to power-and-free conveyors, which in turn are moved by automatic guided vehicles (AGVs) to an automated storage and retrieval system (ASRS) that can hold up to 10,000 pallets at any one time.

Throughout the day, production issues requests to the warehouse for materials that are retrieved by the AGVs and transported to the conveyors feeding the production area. Pallets of finished goods are output from production to shipment and the AGVs move the pallets to the outbound shipping conveyors.

Analysis

Given the demands on this project the study team elected to use a simulation model of the current warehouse operation and examine where the “pinch-points” developed under increasing workload levels. The design of the simulation model was to provide a bird’s-eye view of the warehouse layout with the current materials handling systems. The model was to be controlled by a single input sheet that defined the volume of work in and out of the warehouse along with the type of equipment and rate of operation. The results from the simulation were distilled down to a number of key performance measures that were also presented on a single output sheet.

Input to the simulation model was provided through a spreadsheet of key operating parameters. As shown below, the user could control the number of receiving or shipping bays that could be employed, and adjust the rate of loading or unloading trucks. Note that these rates were input to a normal distribution, which provided a realistic range of process times.

Of particular interest to the user was the ability to adjust resources, such as forklift truck and AGVs, and the demand levels from production in terms of the inflow and outflow of pallets.

Warehouse Configuration					
Receiving		Inventory Locations		A&B's	
Bay #	Access	Unload Rate	Location	Capacity	Opening
Bay 1	1	15	Receiving Bay/In	200	0
Bay 2	1	15	Commodity 1	50	0
Bay 3	1	15	Commodity 2	50	0
Bay 4	1	15	Commodity 3	50	0
Bay 5	1	15	Commodity 4	50	0
Bay 6	1	15	Shipping Bay/Out	100	0
(* Pallets per hour)			AGV's	1000	1000
Shipping		Resources		Production	
Bay #	Access	Load Rate	Description	Available	Maximal
Bay 1	1	20	AGV's	0	50
Bay 2	1	20	For. Forklifts	8	50
Bay 3	1	20	Ship Forklifts	2	50
(* Pallets per hour)			Truck Forklifts	3	50
(** AGV's parameters need to be set within the software being in the simulation model)					
Truck Movements		Production			
Inbound	Trucks	Loads	Location	Capacity	Rate
Outbound	1	20	Inbound Commodity	50	50
	1	40	Outbound Commodity	15	30
			Production Commodity	50	15
			Production Outflow	50	20
(* Trucks per hour = Volume of Pallets) (* Pallets per hour)					

Figure 6-2: Warehouse Simulation Input Parameters

Once the user was satisfied with the configuration of the warehouse in the spreadsheet, she would reset the model to set the simulation model parameters. Running the simulation model would automatically generate inbound truck shipments to the warehouse at the rate specified as well as

the volume of materials ordered and produced by production (pallets per hour) for the warehouse.

The ability of the warehouse to keep up with the inbound and outbound volumes was a function of the number of resources provided and their efficiency or speed of operation. Adjusting these Resource levels had a significant impact on the overall performance of the warehouse operation.

Recommendations

The key performance results were captured in a formatted spreadsheet, as shown below. This shows the number of trucks that arrived during the simulation and the number of pallets that were offloaded. As can be seen, only two receiving bays out of the six available were used. Similarly, only one shipping bay was required to load 31 trucks with 1,240 pallets. No trucks, inbound or outbound, were required to wait.

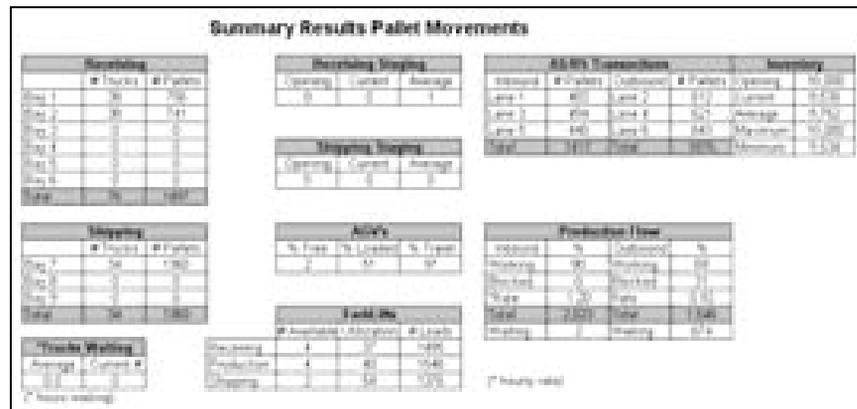


Figure 6-3: Warehouse Simulation Summary Results Run 1

Of particular interest was the ability of the AGVs and forklifts to keep up with the volume of work as dictated by the production area. As shown, production required and received a total of 2,017 pallets of materials but only managed to ship out 1,429 pallets of the 2,216 it produced. There is an unacceptable backlog of 787 pallets sitting in production waiting to be handled by the warehouse.

Looking at the utilization of the resources in the warehouse it is easy to identify the problem. The forklift trucks appear to be operating within their areas at an acceptable work level but the AGVs are close to 100% utilized either loaded or traveling to a pick-up location. The question, therefore, is

“what-if” we added another AGV into the system. The change is simply made in the input spreadsheet, adjusting the number of AGVs to 8, and the simulation is then re-run with this new level of Resource.

The results are now shown from running the warehouse for a one-week period with one extra AGV – a modest capital investment – providing a total of 8 available vehicles.

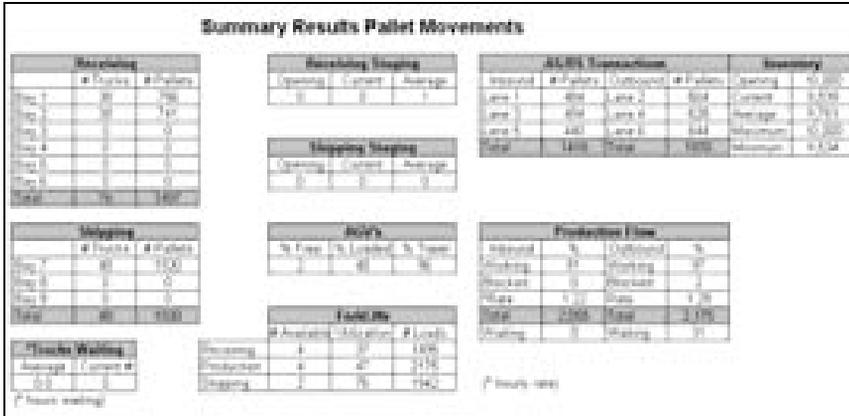


Figure 6-4: Warehouse Simulation Summary Results Run 2

The impact of this one additional AGV is evident. The production backlog has been eliminated and there has been an increase in truck shipments from the warehouse, offsetting the cost of the extra AGV.

This simple but effective use of simulation demonstrates the power of this technique in a warehouse setting. One can conduct sensitivity analysis on the results by running a number of trials or by adjusting the parameters in the warehouse simulation. These experiments take no more than a few seconds to run but provide valuable insight into the efficient running of the operation to satisfy projected workload levels.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. What issues are involved in introducing a new AGV into the warehouse?
2. Are there other solutions to the order backlog problem that avoid these issues?
3. For what minimum volume level is our recommendation valid? At what level must further changes be made? What would you recommend?

Case Study: Warehouse Sizing

The correct configuration, racking setup, and sizing of a warehouse are vital issues with respect to supply chain management. Even when demand can be predicted with some level of certainty, determining warehouse specifications can be a daunting task. When supply is then considered, in which various options for reordering policies (i.e. EOQ, JIT, Kanban, Push, Pull, etc.) must also be established, determining the correct configuration of a warehouse can become even more complex. In most cases, a warehouse-sizing project is undertaken when building a new facility or renovating/expanding an older one. Because of the large capital expenditure associated with new construction and purchases of storage racks, assessment of warehouse sizing requirements must be done correctly.

Simulation is the perfect decision support tool for warehouse sizing, since it can take into account dynamic product flow interactions and stochastic events. Whereas static analysis performed in a spreadsheet may yield rough results in a matter of minutes but will never attain the required level of sophistication, a SIMUL8 model can be developed relatively quickly and can include as much or as little detail as needed.

Background

The following example model is used to determine the amount of space and racking required for work-in-process (WIP) and for finished goods at a plastic injection molding plant. The process involves two steps: molding blank product and printing onto the blank product. The primary statistics that the decision-maker requires are the average and maximum levels of inventory, the variety of products, and service levels (i.e. on-time deliveries) given various scenarios (i.e. number of machines, demand volume, re-order policy changes, etc.). The study cannot easily be completed using static analysis since a pull system is used for re-ordering, multiple product families and SKUs exist that can only be produced on specific machines and require different pallet sizes, and all of this must coincide with a fulfillment schedule that includes some uncertainty.

Problem

Allocating a large space for WIP and finished goods inventory will, over time, cost the company a great deal of money. The problem at hand,

- Split up batch orders into smaller, suitable portions if it cannot be finished on time as one order,
- Cannot have more than a specific number of machines working on a particular product family type,
- Must meet a minimum order quantity,
- Minimize number of changeovers from one type to another, and
- If assigning an order to a machine based on changeovers will make the order late, find the machine with the shortest queue.

All of these rules are modeled in this example simulation. Each simulated day, the model determines what and how much to produce based on the input parameters and shipping schedule.



Figure 6-6: Warehouse Sizing Model Parameters

Even with over 6,000 finished product SKUs, 50 product families, and up to 100 mold and print machines, the simulation only takes a few minutes to complete an entire simulated year and to obtain results.

The simulation provides various reports detailing machine utilization, order fulfillment times, inventories, and service levels. All this information is

used to evaluate the various options available to the company for facilities planning with a particular focus on warehouse sizing.



Figure 6-7: Warehouse Sizing Result Options

The results of the simulation help determine the necessary size and configuration of the warehouse along with the types of racks to be purchased, based on the specified input parameters provided. Along with calculating the amount of inventory and the size of the storage area, other performance measures relating to various aspects of the plant are analyzed.

Product Type	Avg Order Cycle Time (days)	Service Level	Production Rate	Machine Util.	# Workstations Available	Storage Capacity	Warehouse Cost
Product A	1.5	95%	1000	85%	10	1000	\$100000
Product B	2.0	90%	800	75%	8	800	\$80000
Product C	1.0	98%	1200	90%	12	1200	\$120000

Figure 6-8: Warehouse Sizing Summary Results

Recommendations

From this simulation analysis, the company was able to construct a Greenfield production plant with confidence in its specifications. Instead of making rough estimates of how the plant would operate under given conditions, and thus how much storage space was required, the warehouse sizing simulation was applied as a sound basis for testing various scenarios and decision-making. The simulation can be further expanded and continues to be used even after the physical construction/expansion of the warehouse is complete for ongoing management of the production plant. Testing shipment schedules, evaluating machine acquisitions, establishing new re-order policies, and labor/resource scheduling are just some of the different areas in which this decision support tool can be of further value.

Discussion

1. What feature of SIMUL8 can be used to quickly view financial details of various configurations?
2. Are there other methods of displaying simulation results? Design a different output spreadsheet for comparing results of various configurations.
3. How would this study change if only a push system was available for the company's inventory?

Case Study: Network Supply

It is important to look at a supply chain in its entirety to ensure that all parts of the network are working well together. For example, ordering patterns have a huge impact on inventory levels and carrying costs. They can affect the delicate balance of the supply network. Shipping costs also vary greatly depending on the quantity and frequency of shipments. Many different policies can be used when ordering product including Reorder Point/Reorder Level based on forecasted day's supply, fixed frequency and quantity, and Economic Order Quantity (EOQ). The following example illustrates the impact of ordering patterns on inventory levels. A basic policy of Reorder Point/Reorder Level quantities will be used.

Background

The simple example of one distribution center (DC) ordering one product from a single source will be used. The DC places orders with the factory based on the level of inventory it is currently holding. Currently the ordering pattern at the DC results in stock-outs and poor customer service. Demand that must be met by the DC is forecasted as shown below.

Day	Demand	Day	Demand
1	4	26	7
2	0	27	4
3	10	28	0
4	13	29	0
5	4	30	6
6	7	31	7
7	5	1	3
8	0	2	8
9	0	3	9
10	6	4	11
11	7	5	10
12	3	6	7
13	6	7	0
14	10	8	6
15	11	9	9
16	9	10	4
17	7	11	0
18	0	12	10
19	6	13	9
20	9	14	4
21	5	15	7
22	0	16	6
23	10	17	0
24	13	18	0
25	4	19	0

Figure 6-9: Demand Profile

The reorder policy is shown below in Figure 6-10 with the DC placing an order when the inventory level reaches the reorder point. An order is placed to replenish up to the reorder level while taking into account what is already on order. The system is also constrained by a lead-time for the delivery of orders and the number of trucks that can be utilized at any time. An initial inventory of 30 units is assumed.

Reorder Policy	
DC Inventory	
Reorder Point	Reorder Level
30	60
Order Lead Time	
Days	
4	
Number of Trucks	
	3

Figure 6-10: Reorder Policy

Analysis

Given the demand profile and the reorder policy it is possible to assess whether the DC was able to meet demand over the 50-day period. On running the model for 50 days, the Inventory Chart and Stock Out Report below that the DC is not able to meet the demand placed on it. The Stock Out report shows that the DC was short of demand on many of the days in the simulated period by a significant number of units. The Inventory Chart also shows these stock outs and the large fluctuations in inventory levels. The reorder policy can now be reevaluated to prevent stock outs and smooth out inventory levels.



Figure 6-11: Stock Out Report and Inventory Report

Recommendations

By simply changing the Reorder Point and Reorder Level rules, it is possible to achieve no stock outs and meet demand across the period.

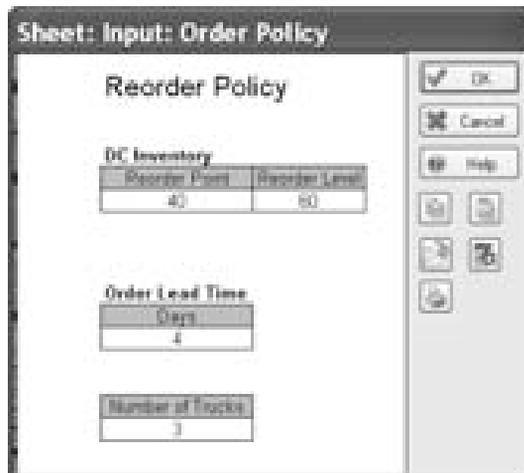


Figure 6-12: Reorder Policy – Revised

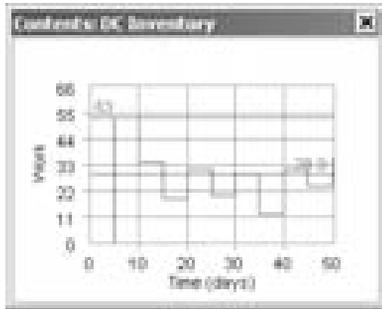


Figure 6-13: Inventory Chart - No Stock Outs

On running the model with the new ordering policy in place, no stock outs were observed. The inventory chart also shows that stock levels are more stable across the period thus providing a safety stock should any unexpected demand occur. Using the distributions provided in the simulation package, it is possible to generate further demand in order to test this new policy. It is easy to imagine how complex reordering issues can become when the supply chain network is expanded beyond this simple example. Many organizations have networks including many factories, distribution centers, and warehouses, moving hundreds of product, each of which has its own demand and ordering policy. Simulation can help to play out the effect on the entire supply chain of altering order policies, shipping lead times and capacities, and many other operating rules.

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. Aside from the reorder policy, what other reasons might there be for the DC being unable to meet demand? Which reasons can this model be used to investigate? What changes must you implement in order to study additional reasons?
2. What other reorder policies might benefit the DC? Design a spreadsheet that can be used to input its parameters to SIMUL8.
3. How can SIMUL8 be used to study the costs and benefits of various reorder policies? Design a spreadsheet that compares results of various reorder policies.

Case Study: Lean Manufacturing

In today's economy, lean manufacturing has become a widely used strategy. It involves reducing inventories while maintaining high service levels. This can be accomplished by adopting a "pull" method of production, with shorter batch runs and faster machine changeover times. However, the implementation of this methodology is no simple task and without careful planning, it can lead to chaos with missed orders, unbalanced workloads, excessive machine downtime, and increased production costs.

Lean practitioners advise that this "pull" method of producing goods takes a significant amount of time to implement and stabilize. In essence, what they are saying is that there is a lot of trial and error to go through before the correct batch sizes, buffer levels, and changeover frequency is worked out for each of the parts produced. One way to expedite this process is to use a simulation model of the manufacturing process.

Many consultants are now providing their clients with simulation models to demonstrate the potential benefits of introducing lean techniques and using the same tool to identify the optimal batch sizes and work-in-process inventory levels of intermediate stocks. These lean manufacturing simulation models can quickly show the flow of work through the plant and help to identify bottleneck processes and buffer level requirements between stations.

Simulation models can be used to examine warehouse design issues as well as on-going operating practices to improve efficiencies and productivity levels. Indeed, a popular application of this technique is to examine the capacity of the warehouse operation to handle a predicted volume of received goods or shipment of orders within a specific timeframe. These performance evaluation models typically lead to changes in the operation that eliminate bottlenecks that constrain the system's ability to meet workload.

Background

A large manufacturing company producing plumbing parts using high-grade copper material was keen to reduce finished goods inventory levels in the field by adopting a more responsive method of production.

In the past, the company manufactured finished goods in large product runs or batch sizes to replenish stock levels at their distribution centers and warehouses. Maintaining field inventories in this way helped them to achieve high customer service levels and low unit costs, but their stock holding costs were excessive.

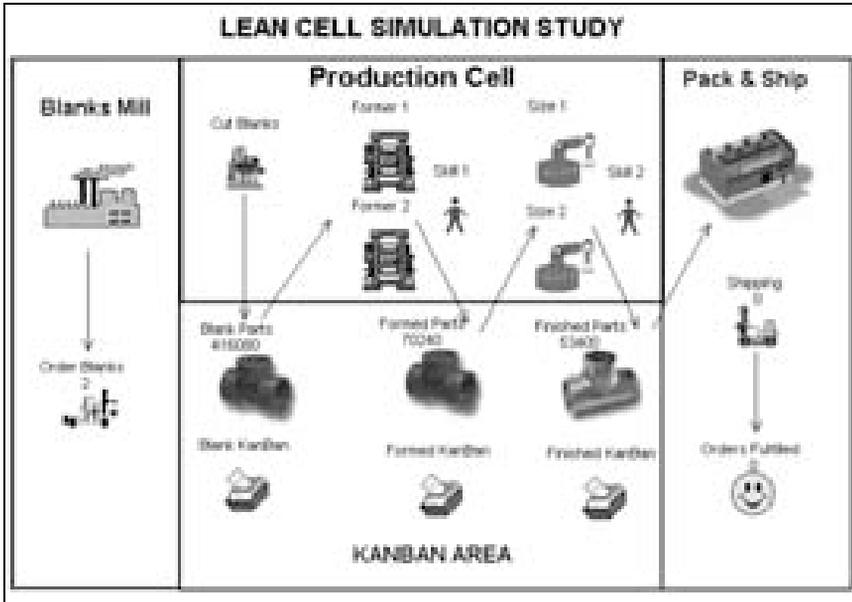


Figure 6-14: Lean Cell Simulation Screen Capture

Problem

In an attempt to reduce supply costs, management decided to adopt a lean cell manufacturing approach that could supply smaller quantities of product to the field at a much faster rate than before. This would mean more frequent machine changeovers and potentially higher levels of work-in-process.

Since certain finished products were produced from common formed parts and these in turn were produced from common blank parts, the idea was to stage product at different levels of completion across the manufacturing cells. Using a pull system the system was to be self-regulating.

External demands for product would be drawn from finished goods at the plant, creating an internal demand for their replenishment. These

manufacturing orders would ripple across the production cells, converting formed parts to final product, and in turn, blank parts to formed parts.

The challenge for the lean production team was to determine which parts should be staged at each level of production, appropriate buffer sizing, and the number of bins or Kanbans should be held at each manufacturing cell. A simulation model of the process proved to be extremely valuable for this analysis.

Analysis

Analyzing historical demand patterns for the various finished products and establishing their part families, the project team was able to develop a rough plan of bin size for each part type as well as the number of bins. By feeding this information into a simulation along with machine change-over times and finished goods demand, the project team could analyze the production flows across the manufacturing cells.

Part	Level	From	Start Qty	Range	BLANK	FORMED	FP	Monthly Sales	# Bins	Bin Size	Inventory Qty	% Operating	Repl. Qty
1	1	125	5129	2	2	1	1	53217	7	6500	45500	0.8	3
2	3	83	374	4	2	1	1	2671	4	1400	5600	0.8	2
3	3	42	1570	6	2	1	1	5451	4	1400	5600	0.8	2
4	3	3	4990	15	2	1	2	1290	2	5000	10000	0.8	1
5	3	7	694	9	2	1	1	396	20	50	1000	0.8	6
6	1	5	4300	13	14	2	3	1790	2	5000	10000	0.8	1
7	1	83	2729	2	3	3	4	18846	16	4500	72000	0.8	4
8	3	5	1690	14	3	3	4	863	40	50	2000	0.8	6
9	3	5	480	11	3	3	4	200	75	50	750	0.8	3
10	1	83	2318	2	5	4	5	16100	8	2800	22400	0.8	2
11	3	42	300	10	5	4	5	693	3	500	1500	0.8	1
12	3	2	600	24	5	4	5	700	2	400	800	0.8	1
13	1	83	2123	4	7	5	6	14736	13	1400	18200	0.8	4
14	3	6	377	16	7	5	6	167	4	300	1200	0.8	1
15	3	3	249	21	7	5	6	63	10	50	500	0.8	2
16	2	83	305	2	2	1	2	2077	3	5000	15000	0.8	1
17	2	4	7066	16	16	2	6	2333	3	5000	15000	0.8	1
18	2	26	2336	3	3	3	5	4885	2	2500	5000	0.8	1
19	2	26	2192	2	5	4	10	4516	12	50	6000	0.8	3
20	2	26	1666	3	7	5	11	3471	3	1400	4900	0.8	1
21	2	26	3000	3	1	10	12	7968	12	1000	12000	0.8	3
22	3	7	4058	10	1	10	12	2346	7	600	5000	0.8	11
23	3	2	700	20	1	10	12	117	2	600	1200	0.8	1

Figure 6-15: Lean Cell Simulation Model Parameters

Through repeated experiments with the simulation model, the team was able to establish the correct buffer level by part and replenishment bin size. Adjusting demand levels or changeover times would also show how sensitive the system was to small system changes or production delays.

Recommendations

The following results summary provides some of the performance information that the team used to measure the effectiveness of their recommendations. Reading from the top table down we see the number of external orders that were placed on the plant from the distribution center (DC) and the number that were fulfilled. The response time is shown by the production lead-time, which is measured in hours.

SUPPLY CHAIN SIMULATOR RESULTS										
LEAN CELL MANUFACTURING (16 Weeks - 8 day week)										
OPERIES										
Process	DC Orders	Orders Filled	Quantity Ordered	Quantity Complete	Average Leadtime	Maximum Leadtime	# Orders Late	% Orders Late	% Orders Filled	
Blank	10	10	10,000	10,000	1.0 hr	2.0 hr	0	0%	100%	
Coated	10	10	10,000	10,000	1.0 hr	2.0 hr	0	0%	100%	
Assembled	10	10	10,000	10,000	1.0 hr	2.0 hr	0	0%	100%	
Total	30	30	30,000	30,000	1.0 hr	2.0 hr	0	0%	100%	
MACHINES										
Machine	Cycle Time	Changeover Time	Current Job	Number of Changes	Time for Changes	Production Time	% Time Changed	Machine Utilization		
Machine 1	1.0 hr	4.0 hrs	1	20	80 hrs	80 hrs	80%	80.0%		
Machine 2	1.0 hr	4.0 hrs	1	20	80 hrs	80 hrs	80%	80.0%		
Machine 3	1.0 hr	4.0 hrs	1	20	80 hrs	80 hrs	80%	80.0%		
Machine 4	1.0 hr	4.0 hrs	1	20	80 hrs	80 hrs	80%	80.0%		
CONTO AREA(S)										
Location	Total # Bins	Holding Capacity	Floor Space	Bin Places	Average Holding	# Bins on Orders	# Bins on Filled	% Bins on Stock	Average Leadtime	Min. Time
Blank	10	10,000	1,000	40,000	4,000 hrs	1,000	1,000	100%	1.0 hr	4.000
Coated	10	10,000	1,000	40,000	4,000 hrs	1,000	1,000	100%	1.0 hr	4.000
Assembled	10	10,000	1,000	40,000	4,000 hrs	1,000	1,000	100%	1.0 hr	4.000
Total	30	30,000	3,000	120,000	12,000 hrs	3,000	3,000	100%	1.0 hr	12.000

Figure 6-16: Lean Cell Simulation Model Results

Machine loading is provided in the second table for each of the machines in the cells. We can see the number of parts produced and the utilization of each cell, and for each of the machines, the frequency and percentage of time they were in a set-up state.

Lastly, the table at the bottom of the report provides information on the number of bins that were required at each stage of manufacturing, their overall capacity, and the frequency of replenishment. The average lead-time to replenish the part bins is also provided along with the internal service level for the delivery of part bins measured against an acceptable supply lead-time.

This simple but effective use of simulation demonstrates the power of this technique in warehouse setting. One can conduct sensitivity analysis on the results by running a number of trials or by adjusting the parameters in the warehouse simulation. Running a simulation scenario takes no more than a few seconds but provides valuable insight into operations and how to satisfy projected workload levels.

Discussion

1. Would you have chosen the same KPI's as those used in this analysis? Why or why not?
2. How could you improve the power of this simulation by changing the way demand is simulated?
3. Aside from lean manufacturing, can you think of another area of application of a pull system? Can this model still be used? What would you change?

Chapter 7: Operations Scheduling Case Studies

Overview

As described earlier, simulation is a useful technique for analyzing the potential workings of newly planned or current operations. Having created a detailed simulation of the manufacturing operation, however, it is possible to use the same model to determine the best loading and sequencing of work across machines. Just as the tool can be used to answer “what-if” questions on machine reliability or resource availability, the tool can also be used to investigate the lead-time to produce specific orders or to help determine the best sequence of work to minimize changeovers.

In this way, we turn the use of the simulation tool from one that is used to examine the “what-if” probabilistic outcome of a system to one that is more deterministic and helpful to predict the timing of work in the system. Using the model to simulate the execution of work orders or jobs launched into the production system in a particular sequence, we can show the outcome in terms of completion dates, resource utilization, changeover times, etc. The tool then becomes helpful in determining the best sequence of work given the constraints within the process and the performance objectives management wishes to satisfy.

One of the key advantages to this approach is the simulation model’s ability to reflect reality and to adhere to the hard production rules as well as the softer management preferences in executing the work. The results from the simulation will be feasible given that process times, product routings, process rules, and resource availability are correctly specified. Another significant advantage is the inclusion of the variability of the parameters in the model in order to produce realistic predictions. Naturally, any of these input parameters can be easily changed within the simulation to show the affect on performance levels.

Indeed, with increasingly powerful computers and nearly unlimited size of simulation models, coupled with access and seamless linkage to ERP databases, simulation is now being used to develop efficient and feasible production schedules. Advanced versions of these applications are being used for adaptive planning and scheduling, where the system automatically updates the schedule based on feedback of shop floor information and new orders.

In the following examples, we demonstrate the above concepts and practices through a number of simulation-based production planning and scheduling applications.

Case Study: Production Planning and Scheduling

The head of Operations at a large ground beef processing production plant wanted to improve the scheduling process. He knew that the operations were interrelated, and implementing new processes would be laborious. He needed to first understand the impacts of any change to the decision process on overall production before going ahead with implementing any changes.

Background

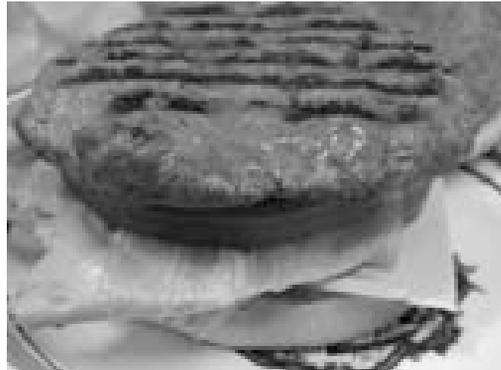
The basic flow pattern of beef is that it feeds from other production areas at the beef plant into the ground beef processing area and onto subsequent ground beef production. Since ground beef processing is reliant upon raw materials flowing from other areas of the plant, the company employs a reaction-based planning system. In this way, personnel watching the flow of materials were given the responsibility of meeting customer orders. This resulted in excessive product waste, as well as high overtime requirements for ground beef processing that was continually reacting to outside influences. Further inquiry revealed that one person had the decision-making capability for the entire process. He had developed the scheduling rules through experience and most of this knowledge was undocumented.

The operations within the area are governed by parameters such as shift patterns, material flows, beef types, and production rates on a minute-by-minute basis. A set of constraints were discovered that govern decision making, from using old beef first, to meeting customer order requirements, to minimizing waiting time for material flow, to minimizing different changeover types at all the different operations. A total of 45 influencing factors were identified!

It was clear that the scheduling function required the ability to see how different scheduling rules would influence the operation. The process was complex enough that it would be difficult to anticipate the results of any small change. Ideally, scheduling should be able to make informed adjustments to the operation to react to the changing operational climate.

Problem

As mentioned above, before the undertaking of this simulation project, the ground beef processing was scheduled by a lone individual in an ad-hoc manner, based on his perception of the urgency of various orders and the available beef on hand. This, of course, led to many production inefficiencies as incorrect decisions were made. For example, often pre-ground beef was not used due to the need to process other beef to satisfy a certain order. At other times, the exact opposite would occur. Namely, in order to prevent spoilage, the manager would elect not to meet certain deadlines. Often overtime would be required to meet these deadlines, greatly reducing the company's profit margins. Therefore, the problem facing the operations manager was to determine how to schedule ground beef production, removing these inefficiencies, while meeting customer demand.



Analysis

Initially, a high-level simulation model was developed to investigate the beef flows from other production areas at the plant into the ground beef processing area, and the subsequent ground beef production. Because of the number of factors influencing production in the area of concern, a detailed simulation model of the ground beef processing unit was developed to analyze the impacts of different decisions made within the unit. The process of developing the model required further investigation of plant processes in order to develop control logic that would function the same way as the plant's operations. The simulation allows the user to adjust any or all of these operating parameters and re-run the simulation for further analysis. This entire processing unit can be simulated over a daily production cycle within a few seconds.

By providing the production planner with the ability to influence decision factors with weighting preferences, the operations department can direct the decision according to the operational climate at the time. This

scheduling capability was then applied to transform the simulation into a powerful production planning and scheduling system.

By linking the simulation system to the current order management system as well as the material flow database, current orders and expected material flows were imported into the simulation. With this up-to-date information the simulation could deploy scheduling decisions through the use of a weighted algorithm to make informed scheduling decisions throughout the processing unit. By executing these decisions through the simulation, not only could a detailed schedule of events at each key process be generated, but performance reports were able to provide feedback to the user about how well the plan performed. This provided the necessary information to analyze the impact of the individual decision factors and their importance on influencing the scheduling decisions.

Recommendations

The detailed production planning system that has been developed is now deployed on a daily basis across more than 16 plants within the organization. Each plant has its unique set of decision rules and preferences that are used daily to provide the detailed operational schedules that are executed on the plant floor. As a result, the detailed decision rules that once were held with specific floor personnel have been captured and they are evolving with time, as off-line analysis provides the end-user with the capability to improve the process. Thus, the ground beef-processing area's schedule can now be determined far in advance using the simulation. Through informed proactive scheduling routines, a reduction in waste, improved customer due date conformance, and reduction in overtime requirements, millions of dollars a year are saved across these plants.

Discussion

1. The simulation study identified 45 factors influencing the manager's scheduling decision. Can you think of four quantitative factors? Can you think of four qualitative factors?
2. How does one simulate qualitative decision making rules?

Case Study: Bill of Materials

Simulation-based planning and scheduling applications are fast becoming a popular method for ensuring production schedules actually work on the shop floor. By using simulation, it is possible to make real-time decisions on many conflicting issues such as minimizing inventory, reducing change-over times, satisfying batch constraints, accommodating machine downtimes, and meeting order due dates. In order to effectively manage all these hard and soft production rules it is essential to have a dynamic set of sort and selection routines with relational database capabilities, and a multi-criteria search facility. These are required to manage all the data contained within the order books, product tables, bills of materials, process sheets, and inventory data files. Simulation based planning and scheduling provides these necessary capabilities. The following is a simple example of how these facilities can be utilized.

Background

When writing code for planning and scheduling lots, many loops are required for looking up times for jobs. Although SIMUL8 can execute code very quickly, like all software packages, large loops are quite time-consuming. With an extended set of simulation code routines, it is possible to extract required information from spreadsheets with even thousands of rows in the quick and efficient manner necessary for planning and scheduling applications.

The following example uses SIMUL8-Planner (www.simul8-planner.com), a SIMUL8 add-on developed by Visual8, to facilitate a dynamic search and extraction of information using indexed tables - a special form of spreadsheets that automatically sorts rows according to a specified column. Using the ranging and table indexing features the user can quickly sort and search through a spreadsheet to select the required information.

This is demonstrated using the following simple SIMUL8-Planner example problem:

Problem

A basic assembly operation produces nine different products. Each product is assembled according to a simple bill of materials of parts that are produced under a "just-in-time" policy.

The objective is to complete the orders in the sequence found in the Order Book. In most cases, assembly takes longer than production of the required parts, so it is possible to construct a simple dynamic scheduling rule. Each time parts are received in Assembly, work is scheduled for the production of the parts needed for the next order. To do this, SIMUL8-Planner's ranging function is used to quickly extract the information from the Bill-of-Materials spreadsheet (indexed on Product) to find which parts and quantity are required to make the next product.

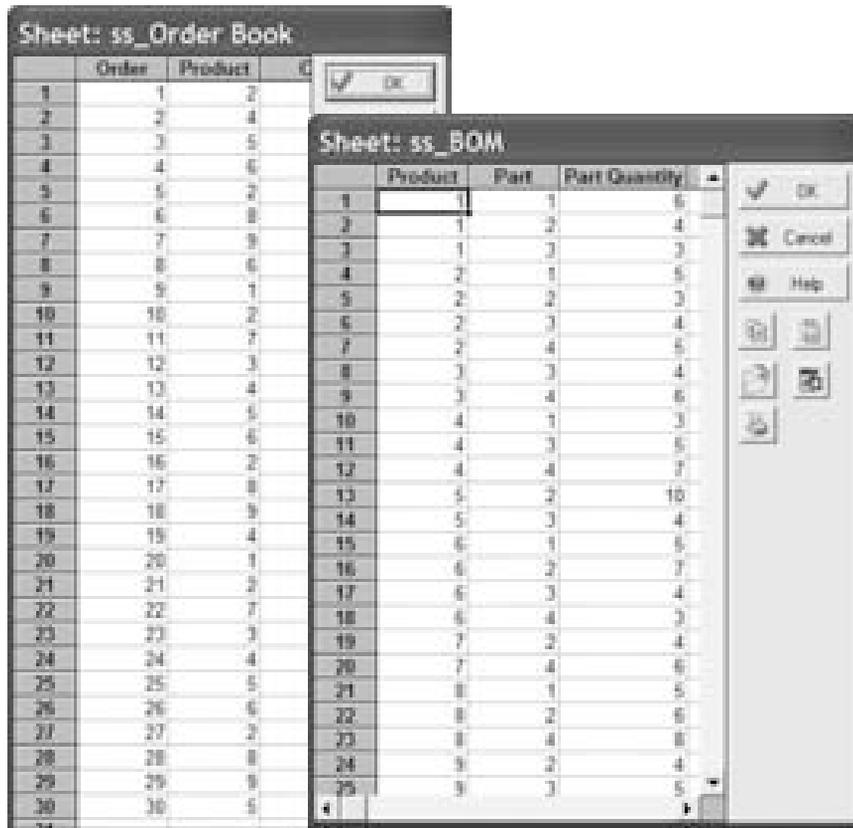


Figure 7-1: BOM - Input Spreadsheets

Analysis

The code below shows how the SIMUL8-Planner routines are used to quickly target the parts and quantity required. They are then added to the parts storage area.



Figure 7-2: BOM - Creating a New Order

Get First Row in Range finds the first row in the indexed table or spreadsheet called `ss_BOM` across the range set by the input variable `int_product` that is used for the minimum and maximum range parameters. Therefore, if `int_product` were set to 3, the row reference returned in the variable "int_row" would be 8 for the example shown alongside.

Get Next Row in Range, which appears in the bottom line in the diagram above, finds the next row in the range `int_product` to `int_product`, which for product 3 would be row 9. This is repeated until there are no further rows in the range defined, i.e. `int_row` will be returned as 0.

The use of "ranging" in this way provides fast access to specific rows in a spreadsheet satisfying certain criteria such as a product number or range of numbers, a time window, a minimum to maximum job duration, or a particular order range. In more advanced applications, a composite index can be used made up of several factors such as order due date and delivery

zone. This would be useful, for example, in a warehouse picking and shipping situation, for example.

Returning to the above example, the scheduled production is executed by SIMUL8-Planner to produce the Gantt chart shown below. Bars are color-coded by product so that the parts required to produce the products can be tracked as they are produced and assembled.

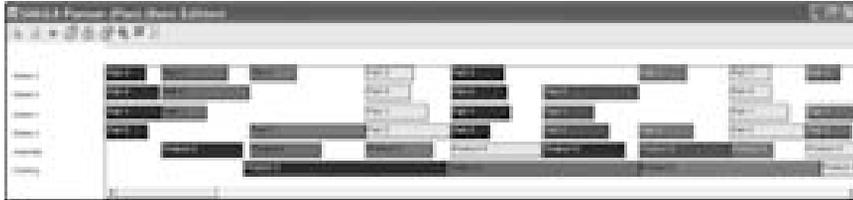


Figure 7-3: BOM – Gantt

The standard method of searching through a spreadsheet using looping commands is fairly effective for small sets of data, but this is not the case when a spreadsheet contains thousands of orders downloaded from an ERP system referencing a large products table requiring multiple combinations of sub-assemblies, parts and materials. This is when SIMUL8-Planner's ranging routines and indexed tables provide a powerful data handling combination within SIMUL8. Not only is coding greatly simplified, but also the use of indexed tables provides a fast and efficient method for working with large sets of information.

Discussion

1. Can you think of other areas where SIMUL8-Planner's unique functionality would be useful?
2. What feature in SIMUL8 (Professional Version 9+) can be used to determine if multiple loops are causing unnecessary delays in processing time?

Case Study: Ensuring Schedule Feasibility

Background

One of the main reasons for the trend toward simulation-based Planning and Scheduling systems has been the capability of the system to actually test the schedule at a shop-floor level prior to implementation. This ensures the plan is actually feasible at the detailed operational level. Most high-level ERP systems or algorithmic scheduling tools cannot provide the level of detail that a simulation of operations can. As a result, whether using simulation as the base for Production Planning and Scheduling, or using it to test the feasibility of a production schedule, simulation can play an important role in daily planning.

Problem

Daily production plans are generated at an Assembly Line Plant by its ERP system, which are handed to the shop floor at the beginning of each shift. At the end of each shift, the shift supervisor advises the plant manager of the current situation and the plan is re-generated based on the current conditions. Typically, orders have been missed from the schedule and will now be moved onto the next shift. The Plant Manager is aware of this frequent occurrence and would like to investigate the causes of these missed orders.

By developing a simulation of his six assembly processes, the plant manager was able to view the production schedule prior to its implementation on the shop floor.

Analysis

A simulation was developed of the six processes, and associated processing times, travel times, changeovers and storage capacities, as can be seen in the table:

Product\Process	1	2	3	4	5	6
1	12.5	10.2	11.2	14.1	12.7	11.1
2	11.5	13.4	14.2	9.3	12.2	11.9

Product\Process	1	2	3	4	5	6
Change Time	10	240	15	20	15	15
Travel Time	.5	.3	.7	.3	.9	.1
Storage Capacities	-	1	2	1	1	1

Figure 7-4: System Parameters

As this is a slightly un-balanced line with limited work-in-progress capacities, it is important to schedule products down the line efficiently. The following is Monday’s production schedule for the 8-hour shift:

Product	Quantity
1	320
2	420
1	180
2	340
1	170
2	100
1	270
2	150

Figure 7-5: Initial Production Schedule

To run this schedule through the simulation, it is necessary to complete a piece of logic to ensure that the correct product is being placed on the line. The following is an example of this code created within SIMUL8 and executed at the Work Entry Point of the mode:



Figure 7-6: SIMUL8 Example of Schedule Logic

Recommendations

With this particular schedule, the line will not be able to meet its requirements. See the Schedule menu, completion report. This is due to a combination of line changeovers and line imbalances causing assembly stations to become blocked or starved. A more efficient strategy is to create a schedule wherein similar products are processed continuously, with minimal changeovers to other product types. Creating groups of related product types avoids this level of starvation and blockages, and gets all orders completed on time.

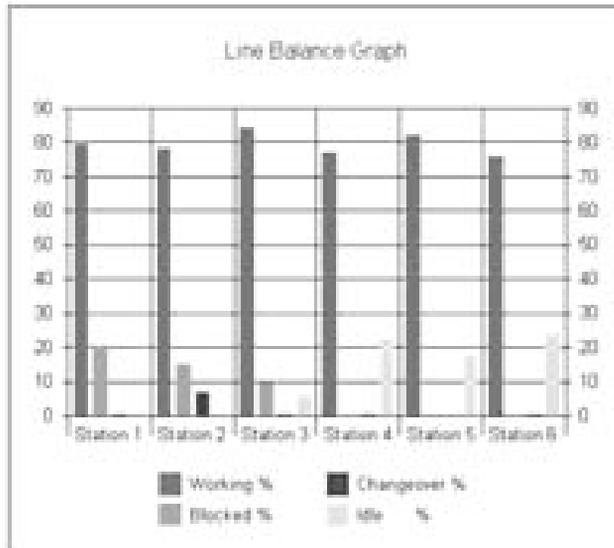


Figure 7-7: System Imbalance

By reviewing the performance report under the Schedule menu, it is possible to see the level of imbalance within the system. By implementing the following schedule, it is possible to meet the daily requirements:

Product	Quantity
1	400
2	760
1	440
2	250

Figure 7-8: Operational Production Schedule

This model is available for download at www.visual8.com/demonstrations.

Discussion

1. Where are the bottlenecks?
2. What causes bottlenecking in this process?
3. Why are they able to produce more parts with the second schedule?
4. Does the manner in which work is fed into the system affect the results? Discuss.
5. What model changes would make all schedules equal?
6. If the changeover time were reduced to zero, what would be the throughput of the original schedule? The second schedule?

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The third and final section of this textbook serves as a practical guide to readers for developing their own simulations. It covers almost all of the basic objects and elements necessary to build basic yet powerful simulation models. Some of the more advanced modeling techniques, which are often unique given the process being modeled and which are covered to a certain degree in the chapter on Visual Logic, are left for the reader to discover by working with SIMUL8 and trying the various functions.

If the reader can define and verbalize a process and the rules governing it, the system can be simulated using SIMUL8. There can be thousands of ways to configure a simulation of a given process. This section of the textbook will help readers to navigate through the various dialog boxes and

options in SIMUL8 to find the appropriate button that will make their models function properly.

The chapter immediately following this summary page provides a visual overview of the basic simulation objects – Work Entry, Storage Bin, Work Center, Work Exit, and Resource – and indicates specific pages that discuss a given topic. This chapter is an indispensable guide for SIMUL8 model developers and is correspondingly marked at the upper right sides of the pages.

Chapter 8: Quick Reference Guide

Work Item

Description

Work items are the 'moving' parts of a simulation model. They are used to simulate the 'flow' of items through the simulated process. They can represent assemblies, sub-assemblies, transport equipment, people, paper, or anything else being processed by the simulation.

Properties

- Labels (attributes)
- Work Item image
- Size
- Advanced - multiple Work Item Types

Common Uses

As mentioned above, Work Items are used to simulate the moving parts of a process. Some common examples of Work Items are as follows:

- Products - parts, assemblies, sub assemblies...
- People - patients, patrons...
- Information - work orders, documents...
- Equipment - vehicles, transportation...

Visual Reference Guide – Work Item

The screenshot shows the 'Work Item Type' dialog box. It has a title bar 'Work Item Type:'. Below the title bar is a text field containing 'Custom'. To the right of this field are three buttons: 'OK', 'Close', and 'Help'. Below the text field is a 'Labels' section with a list box containing 'Bl Age' and 'Bl Time', with 'Bl Time' selected. Below the list box are 'Add' and 'Remove' buttons. To the right of the list box is an 'Image' section with a small image of a person and a 'Select' button. Below the 'Image' section is a 'Size' field with a numeric value '1' and a 'feet' unit label. To the right of the 'Size' field is an 'Advanced' button. Arrows point from callout boxes to these various elements.

Name of this type of Work Item. Change it to something meaningful in the simulation model e.g.: *Customer, Engine, Product, Payment, Order, Patient, Claim, Parcel*, etc.

Select the image used to show a Work Item. See Graphics / Images on page 385.

This list shows the labels attached to this type of Work Item. See Work Item Labels on page 207.

Add/Remove the highlighted label from the above list.

Size: This is the length of the Work Item. (This information affects how much space it uses on a Conveyor. See Conveyors on page 287.)

Options for creating multiple Work Item types (Only recommended for simulation models with very large numbers of Work Items per Work Item type). See Work Items on page 187.

Work Entry Point

Description

Work Entry Points are objects that create or generate Work Items in the simulation model. They are typically the starting point of a process or sub-process where moving objects enter the simulation. Users can specify the rate at which Work Items arrive here. Work Entry Points are active objects as they *push* work into the model.

Properties

- Name
- Inter-arrival times – time between Work Items entering the system
- Results - results about the object
- Batching – number of Work Items arrive at each time interval
- Routing Out - disciplines by which the work leaves the object
- Label Actions - Work Item label values changed here
- Graphics - change the object's appearance

Common Uses

- Order arrival point
- Process start point, feeding process output
- Incoming telephone calls
- Door through which people/patients arrive

Visual Reference Guide – Work Entry Point

The name of this Work Entry point - change it to something meaningful in the model. The title display can be changed in the simulation window by clicking Title in the Graphics button dialog.

This defines the Work Item Type that this Work Entry point brings in to the model.

Enter the inter-arrival time of Work Items here: usually the mean, or average, value of the random numbers to supply - but not always - see the label above the box.

Click the arrow in this field to select the type of statistical distribution used to supply these values as the model runs. See Distributions on page 213.

Normally the first arrival will be at the time sampled from the distribution. If checked an additional arrival will occur immediately when the model starts running (at time zero).

Check this when work enters the simulation only when required (i.e. when a Work Center it feeds is ready for it)

Switches on/off the warning messages if SIMUL8 thinks the user has made a mistake and this Work Entry point is blocked.

The Memo button lets the user add detailed documentation about each simulation.

Access the performance measures that have been collected as the model ran. See Results on page 299.

Batching tells this Work Entry point to deliver Work Items in groups. See Batching on page 272.

Describes how the Work Entry point distributes Work Items to the next stage in the process. See Routing Out Page 267.

Sets up what this Work Entry point is to do to labels on Work Items as they leave the Work Entry point. See Label Actions on page 209.

Change the image used to show a Work Entry Point and the Current Image. See Graphics / Images on page 385.

Use this button for activity-based costing analysis. See Finance on page 321.

The screenshot shows the 'Work Entry Point Properties' dialog box with the following fields and buttons:

- Title: **Work Entry Point**
- Input Work Item Type: **Man Work Item Type**
- Inter-arrival times (minutes): **Average** (10)
- Distribution: **Exponential**
- Buttons: **New**, **Cancel**, **Help**, **Memo**, **Results**, **Batching**, **Routing Out**, **Label Actions**, **Graphics**
- Options: **First at start time**, **Unlimited arrivals**, **None**, **File**, **Ignore hints about blocked Work Items**
- Buttons: **Finance**, **Cancel**

Storage Bin

Description

A Storage Bin is an object in which Work Items can 'queue' up. They act as buffers/queues in between steps in a process or as storage areas for inventory or work-in-process.

Properties

- Name
- Capacity - limits the number of Work Items that can 'fit' in Storage Bin
- Shelf Life – number of time units before Work Items 'expire'
- Min Wait Time – minimum time Work Items must stay in Storage Bin
- Results - results about the object
- Start-Up – initial contents of the Storage Bin on model start
- Contents – displays the Storage Bin's current contents
- Graphics - change the Storage Bin's appearance

Common Uses

- Feeding Queues, buffers in between processes, Inventory...
- Storage/Holding Areas
- Waiting/Drying areas
- Kanban System
- IVR Waiting Lines

Visual Reference Guide – Storage Bin

The screenshot shows the 'Storage Bin Properties' dialog box with the following callout boxes:

- Top Left:** Number of time units before items in this queue become "out of date." Out of date items can be removed by Work Centers that have "Expired only" as their Routing In discipline. See Selection Method on page 257. Double-click this field to use a label on the item rather than a fixed value.
- Top Right:** The name of the Storage Bin (queue).
- Right (top):** A check here indicates that there is no limit on the number of Work Items that can be in this Storage Bin.
- Right (middle):** The minimum time a Work Item must stay in the Storage Bin. See page 190.
- Right (bottom):** Access the performance measures that have been collected as the model ran. See Results on page 299.
- Bottom Right:** Lets user specify what is in this Storage Bin (queue) at the start of the model run - Saves having to wait a long time for the model to reach normal operating conditions.
- Bottom Center:** Use this button for activity-based costing analysis. See Finance on page 321.
- Bottom (wide):** Use High Volume/BPR options. The quantity label will be used to account for capacity and the display of current contents. See Special Labels on page 210.
- Bottom Left:** Results information can be categorized by Labels on Work Items. If option is clicked, the user will be asked for a label name that will contain numbers to be used for categorization. See Segregating Results on Labels on page 307.
- Bottom Right (wide):** Change the image and/or type of icon (tank, queue, graph, etc.) that represents a Storage Bin. See Graphics / Images on page 385.

The dialog box itself contains the following elements:

- Title:** Storage Bin Properties
- Tabs:** Properties, Visual Logic
- Fields:** Queue for Work Center 1, Capacity, Shelf Life, Min. Wait Time (minutes)
- Buttons:** OK, Cancel, Help, Memo, Results, Start-Up, Contents, Graphics
- Options:**
 - Infinite
 - None
 - Prioritize
 - LIFO
 - High Volume
 - Segregate Results
 - Finance
 - Estate

Work Center

Description

Work Centers are where Work Items are processed. Usually, some time is taken to perform the task and sometimes this requires one or more resources.

Properties

- Name
- Timing - time to process Work Items set via a distribution
- Results - results about the object
- Resources - set Resource requirements to perform task
- Efficiency - specify breakdowns, repairs
- Routing In - how Work Items enter the Work Center
- Routing Out - disciplines by which the work leaves the object
- Label Actions - Work Item label values changed here
- Priority – how this Work Center competes against others for resources
- Replicate – a simple way to copy the Work Center
- Contents – displays the Work Center's current contents
- Graphics - change the Work Center's appearance and animation

Common Uses

- Process Tasks
- Machines
- Work Item manipulation – Labels, batch size, routing....

Visual Reference Guide – Work Center

The image shows a screenshot of the 'Work Center Properties' dialog box. The dialog has a title bar 'Work Center Properties' and a subtitle 'Work Center 1'. It contains several input fields and buttons. Callout boxes with arrows point to specific elements, providing detailed explanations for each. The callouts include: 'Timing dictates timing intervals – i.e. Standard, Jobs Matrix, or Cycle Matrix. Click button for details. See Alternative Routing/Timing Methods on page 275.' (pointing to the 'Timing' field), 'The name of the Work Center. Change this to something meaningful like CNC Machine, Help Desk, or Operating Room, etc.' (pointing to the 'Work Center' field), 'Access the performance measures that have been collected as the model ran. See Results on page 299.' (pointing to the 'Results' button), 'Enter the first parameter of the distribution here; usually the mean, or average, value of the random numbers to supply - but not always - see the label above the box.' (pointing to the 'Average' field), 'Click the arrow in this field to select the type of statistical distribution used to supply these values as the model runs. See Definition on page 213.' (pointing to the 'Distribution' dropdown), 'High Volume converts the timing information by multiplying the Timing for the Work Center by the value in the Work Item's Quantity Label. See Special Labels on page 210.' (pointing to the 'High Volume' checkbox), 'Use this button to input costs for activity-based costing analysis. See page 321.' (pointing to the 'Finance' button), 'Replicate is a simple way to copy a Work Center. See Copying Objects on page 204.' (pointing to the 'Replicate' button), 'Change the images that represent this Work Center and its various states. See Graphics / Images on page 385.' (pointing to the 'Graphics' button), 'Accounts for scheduled down-time at Work Center. See Calendars on page 200.' (pointing to the 'Calendar' button), 'When highlighted, view Work Items, and their properties, that are currently in this Work Center.' (pointing to the 'Work Items' button), 'Describes where and how the Work Center receives its work. See Routing In on page 257.' (pointing to the 'Routing In' button), 'Describes how the Work Center distributes Work Items to the next stage in the process. See Routing Out on page 267.' (pointing to the 'Routing Out' button), 'Dictates what Work Center is to do to labels of Work Items as they depart. See Label Actions on page 209.' (pointing to the 'Label Actions' button), 'Determines how this Work Center competes against others for resources. See Priority on page 245.' (pointing to the 'Priority' button), 'Accounts for unscheduled down-time at the Work Center. See Efficiency on page 251.' (pointing to the 'Efficiency' button), and 'Set floating Resources (labor, jigs, tools, etc.) required to do work at this Work Center. See Resources on page 231.' (pointing to the 'Resources' button).

Work Exit Point

Description

Work Exit Points provide a means for Work Items to leave the simulation model. SIMUL8 records overall and summary Work Item process statistics at these points.

Properties

- Name
- Results - results about the object
- Graphics - change the object's appearance
- Halt Model at Limit – stops model when number specified is reached

Common Uses

- End of process
- Gathering end of run results
- Stopping model when a certain number of Work Items complete

Visual Reference Guide – Work Exit Point

The image shows a screenshot of a software dialog box titled "Work Complete Proper...". The dialog box contains several options and buttons. Callout boxes with arrows point to specific elements, providing detailed instructions for each.

Callout 1 (Top): Name of the Work Exit Point - change it to something meaningful like *Products Complete* or *Patients Recovered*.

Callout 2 (Left): Use this button to specify revenues for activity-based costing analysis. See **Monetary units can**

Callout 3 (Left): The number of Work Items arriving at this Work Complete Point before model automatically stops. This facility enables the user have the model stop when a certain number of Work Items have been processed. If this is checked, model may not reach the end of its normal Results Collection Period. See Results Collection Period on page 165.

Callout 4 (Right): Access the performance measures that have been collected as the simulation ran. See Results on page 299.

Callout 5 (Bottom Right): Change the image that represents a Work Exit Point. See Graphics / Images on page 385

Callout 6 (Bottom): Results based on Quantity label. See Special Labels on page 210.

Callout 7 (Bottom Left): Results information can be categorized by information in the Work Items. If clicked, the user will be asked for a label name that will contain numbers to be used for categorization. See Segregating Results on Labels on page 307.

Resource

Description

Resources are items in the model that Work Centers can be set to require before Work Items can be processed. Thus, they represent either staff or special tools. Work Centers that have a Resource requirement cannot begin work until both a Work Item and the specified Resource are available. Resources can also be 'shared' between multiple Work Centers, favoring Work Centers with the highest Priority setting.

Properties

- Name
- Number Available – specify the number of this Resource type available
- Shift Dependent – have the Resource availability follow shift patterns
- Pool Resource – 'Pool' one or more Resource types
- Results - results about the object
- Travel – travel time for Resource movements between objects
- Graphics - change the object's appearance and visual behavior

Common Uses

- Process Operator
- Workers or staff required
- Parts required by operation, such as a tool or key

Visual Reference Guide – Resource

The image shows a 'Resource Properties' dialog box with the following fields and buttons: 'Resource 1', 'Number of this type of resource available' (set to 10), 'Shift Dependent' (checked), 'Pool Resource' (checked), 'Auto adjust replicate levels' (checked), 'Finance', 'Erate', 'OK', 'Cancel', 'Help', 'Menu', 'Results', 'Travel', 'Graphics', 'Find', and 'Availability'. A small person icon is visible in the bottom right of the dialog.

Callout boxes provide the following explanations:

- Name of the Resource – e.g. Press Operators, Power, Fork Trucks, etc.** (points to 'Resource 1')
- Shows the list of shifts and the number of this Resource available during each shift.** (points to the 'Shifts' button)
- Shows the availability of Resource at all times. This number can be changed during a run, but resources that are currently at Work Centers will stay there until their work is finished. Grayed out when Shift Dependent is checked. See Creating and Attaching a Resource on page 231.** (points to the 'Number of this type of resource available' field)
- Specify the Members of a Resource Pool (i.e. Add/remove Resources to/from pool.)** (points to the 'Members' button)
- When checked the number of resources available can be different in each shift. See Shifts on page 241.** (points to the 'Shift Dependent' checkbox)
- A Resource Pool is a list of SIMUL8 resources that are available to take the place of other resources. When checked, Work Centers that require this Resource can be given any Resource from the list of members. See Pooled Resources on page 234.** (points to the 'Pool Resource' checkbox)
- Access the performance measures that have been collected as the simulation ran. See Results on page 299.** (points to the 'Results' button)
- Specify Resource travel times manually, automatically, or in a matrix. See Travelling Resources on page 236.** (points to the 'Travel' button)
- Use this button to specify revenues for activity-based costing analysis. See page 321.** (points to the 'Finance' button)
- Automatically adjusts any Work Center that requires this Resource to the maximum number of resources available where replicate is allowed. See Replicate on page 195.** (points to the 'Auto adjust replicate levels' checkbox)
- Change the image that represents a Resource. See Graphics / Images on page 385.** (points to the person icon)

Chapter 9: Starting Up

The Start-Up Screen

The start-up screen, as shown below, is displayed each time SIMUL8 is opened. Choices of opening a recent model, creating a new simulation, or using a sample simulation as a starting point are available.



Figure 9-1: Start-Up Screen

To create a new blank simulation, click on Simulation under Create New. A number of file types, including Visio, XML, BPEL, SDX and Witness files, can also be imported under Create New. Additionally, choosing to open one of the sample simulations listed under Create from Samples can serve

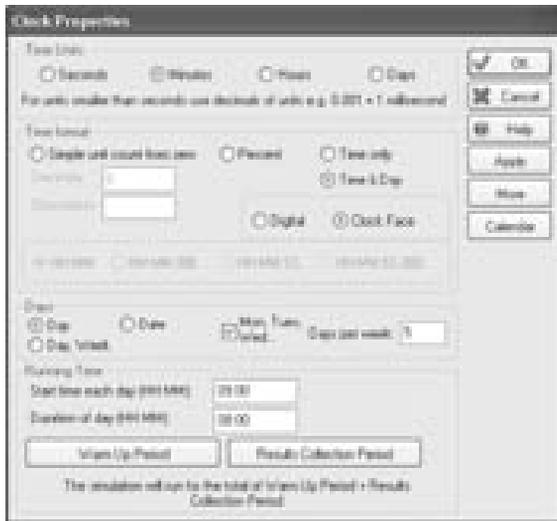


Figure 9-3: All Clock Properties

Time Units

The simulation can be set to run in seconds, minutes, hours, or days. This will apply to the model running time as well as parameters entered throughout the model.

Time Format

The clock displayed on the main screen can be shown in a number of different formats.

1. Simple unit count from zero – displays the count of time units as specified
2. Time Only – displays the time
3. Time & Day – Displays the time and day of the week (see Days for further options)
4. Digital – Displays the time in digital format (select from HH:MM, HH:MM.000, HH:MM:SS, HH:MM:SS.000)
5. Clock Face – Displays the time in clock face format

Days

If Time & Day has been selected from the Time format options, the following options will be available.

1. Day – Displays the day of the week
2. Day, Week – Displays the day of the week and the week number starting with “Week 1.”
3. Mon, Tue, Wed... - If checked, will display abbreviated weekday name, otherwise will display numbers 1-7. The first day of the week is considered as Monday.
4. Days per week – Sets the number of days per week that the simulation will run.

Running Time

This is used to determine the period for which the simulation model will run. The start time for each day the simulation will be running should be entered in HH:MM format. The number of hours and minutes that the simulation will run each day can then be entered in HH:MM format. The Warm Up Period and Results Collection Period can be specified.

Warm Up Period

This is the amount of time allowed for the simulation to reach a steady state. The simulation will begin to collect results after the warm up period has been completed. Note that the simulation clock will start counting during the Warm Up Period.

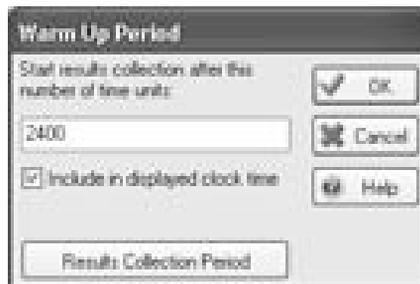


Figure 9-4: Warm Up Period Dialog Box

Results Collection Period

This is the amount of simulation run time following completion of the Warm Up Period. The total amount of time that the simulation will run for is, therefore, Warm Up Period + Results Collection Period. The option 'Include in displayed clock time' dictates whether the clock should reset at the end of the Warm Up Period or if the clock runs continuously into the Results Collection Period.



Figure 9-5: Results Collection Period dialog box

Simulation Speed

The simulation running speed can be altered using the Speed scrollbar. This can be docked or moved around the main simulation window. The arrows can be used or the square can be dragged to speed up or slow down the simulation animation. This operates in much the same way as other scroll bars such as MS Word™ or Excel™.

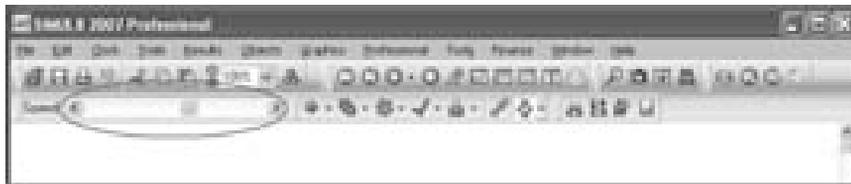


Figure 9-6: Changing simulation speed

Simulation Preferences

Simulation Preferences determine the general properties of the simulation model being developed. There are a number of properties that can be set by selecting File > Preferences.



Figure 9-7: Undo Preferences

The Undo preferences allow the user to speed up SIMUL8's interactive capabilities. However, by removing the Enable Undo, previous actions will not be saved, removing the ability to return to previous states within the model and remove mistakes.



Figure 9-8: Distance Preferences

These options allow the user to:

1. Change between meters and feet as the unit of distance measurement throughout the model. This also alters the text provided in user inputs and reports.
2. Travel Times can be automatically calculated based on an AutoCAD layout. Typically, this function is not used. It is advised that at the beginning of a model building exercise this feature is switched off and Set as the Default option.
3. Resources that are shared between Work Centers can have travel times associated with the movement between these objects or not. When Resources are attached to Work Items as they travel through a sequence of Work Centers, more computer memory is required. Therefore, it should only be selected when necessary.

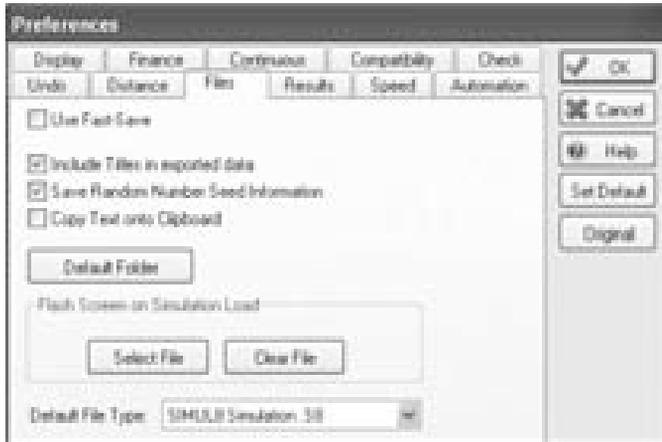


Figure 9-9: Files Preferences

These options allow the user to:

1. Only save the basic model – this will remove all results collected within the model, including results from multiple runs stored within internal spreadsheets.
2. Include Titles in exported data - When exporting data to other spreadsheets, it is advisable to include the titles as well as the data. If sending information to already formatted and titled spreadsheets, this option can be switched off to save time.

3. By saving the Random Number Stream, the simulation will always run with the current number stream allowing the user to compare eliminate the effects of different random number streams while developing the model.
4. Provides a list of simulation objects in text format for exporting to another package, as opposed to copying the actual simulation objects for exporting to another simulation model.
5. Flash screen is typically used for templates created from SIMUL8. If the template is a resalable product, then the product logo can be flashed in front of the user as the model is opened. By clicking on Select File, the standard Windows™ browser will be opened. Preferred formats for files are JPEG or BMP.
6. As simulation models can be saved as XML as well as standard S8 (SIMUL8) format, the option is provided to save as preferred.

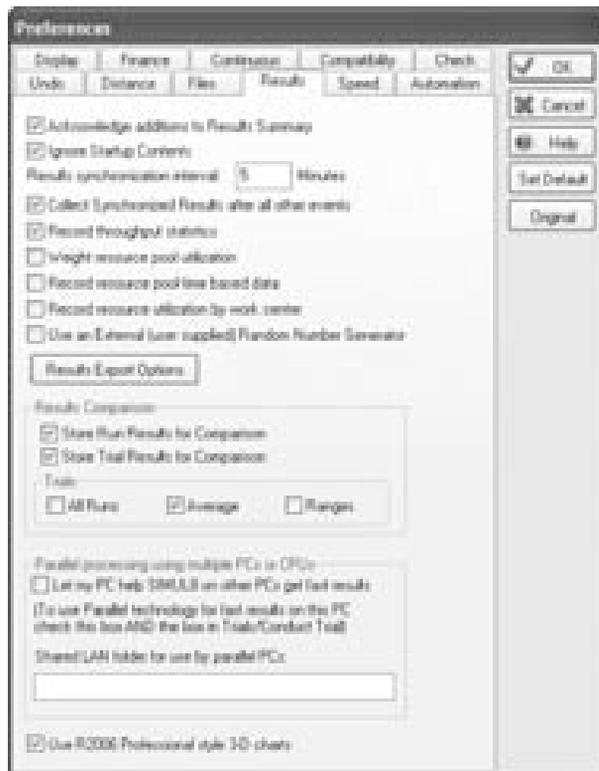


Figure 9-10: Results Preferences

These options provide the user with control of the results being saved within the simulation model:

1. Allow users to add new items to the Results Summary
2. Ignore the startup contents of queues in final Results Summary statistics.
3. Change the Results Synchronization Period, this changes the numbers of updates provided on the on-screen charts as accessed within the individual Results sections of simulation objects.
4. Set results synchronization to take place after all other events have taken place in a given Results Synchronization Period.
5. Govern resource statistics collection.
6. Use a random number generator external to SIMUL8.
7. By switching off the option to Store Run / Trial Results for Comparison, it is possible to speed up the execution of simulation runs. This is especially useful if when exporting results to Excel™, or other packages and saving them there.
8. Options for results stored from trial are set to default only as the average figures; this minimizes the amount of data that needs to be stored.
9. Allow multiple PCs to collect simulation data for faster results collection and analysis.



Figure 9-11: Results Export Options

All automatic exporting functions are kept under File > Preferences > Results > Result Export Options. This provides the ability to export any results held within the Results Summary of the model currently open. All

these results will be exported line by line after each run or trial depending upon which option is chosen at the right hand side of this dialog box.

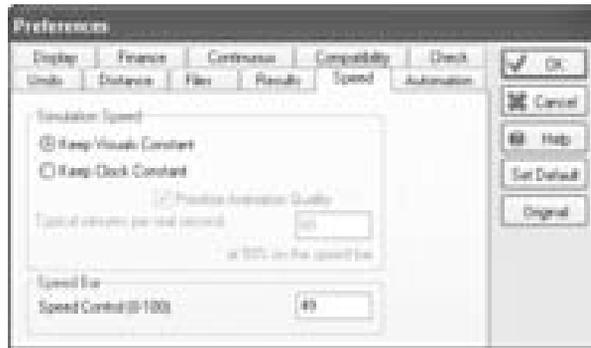


Figure 9-12: Speed Preferences

By selecting the Keep Visuals Constant option, the simulation will run with animations determined by the speed bar. The Keep Clock Constant will alter the graphical requirement in order to keep the clock as constant as possible. This is more consistent with real-life, but requires extra computer memory while running the model.

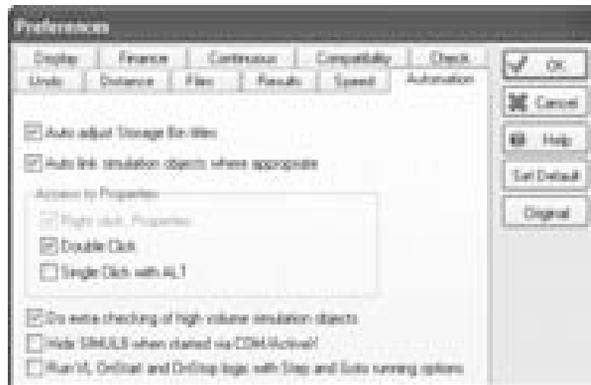


Figure 9-13: Automation Preferences

SIMUL8 has the ability to help the user develop models with smart logic that adjust the names of Storage Bins to the corresponding Work Center that it feeds. For example, if a queue leads to a Work Center named Milling, its preceding Storage Bin will automatically be named Queue for Milling. Of course, this is far more intuitive than multiple Storage Bin names of "Storage Bin 1" or "Storage Bin 2," etc.

Smart logic will also help the user by automatically linking simulation objects as they are created. When there are multiple routing options and complex systems, it is sometimes more useful to switch this option off, especially if the Jobs Matrix is going to be utilized.

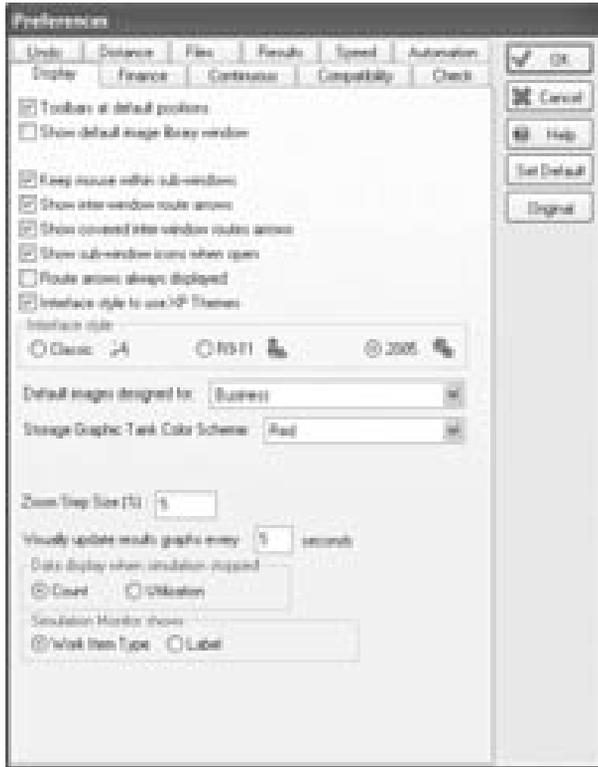


Figure 9-14: Display Preferences

The display preferences provide the following options:

1. Default settings for the toolbars consisting of the File + Edit, Speed, Run and Build tools placed along the top of the screen with the Graphics and Style tools available along the bottom of the screen.
2. The default library window provides the user with options for graphics, as simulation objects are created on the screen. This is especially useful when a model is being created as a sales tool.

3. An assistant is available for questions as the model is being created, very much like the paper clip from Microsoft Office. Generally most simulation users prefer to use the Help provided from the menu bar so this option defaults to the switched off mode.
4. The next four options all pertain to the use of arrows connecting objects within and between sub windows. By keeping the mouse inside a sub window, it restricts the connectivity provided by the routing arrows. The next three options are graphical representations between objects, showing dotted lines joining objects within sub-windows to objects below in other sub windows – sometimes these arrows can be misleading as they appear to connect to nothing, hence there is an option to switch the functionality off.
5. In SIMUL8 Release 12, a new graphical interface was created for all the tool bars and the simulation objects. The old interfaces are still supported for those who favor the previous style.



Figure 9-15: Release 1-9 Interface



Figure 9-16: Release 9+ Interface



Figure 9-17: Release 12+ Interface

6. The route arrows throughout a simulation window are by default displayed while the model is developed and are hidden while the model is running. Most models with multiple routings can become visually clumsy with the routing arrows switched on; hence, it defaults to the off position.
7. Using SIMUL8 Release 12 graphics, default object images can be selected to suit a business, call center, health care, or manufacturing simulation model.

8. Adjust the appearance of queues using the *Storage Graphic Tank Color Scheme* drop down options.
9. When using a scroll mouse and/or the buttons to the side of the zoom capability, the zoom features will step through the percentages. To change the zoom capabilities, enter a different step value here.
10. In the results sections of simulation objects, there are graphs that can be displayed during the simulation run. These will update every 'x' seconds of clock time – not simulation clock time. Change this option to update faster.



Figure 9-18: Finance Preferences

The Finance Preferences allow the use of different currencies. Use the letter “e” to represent a Euro. The € will appear in all of the corresponding Finance displays.

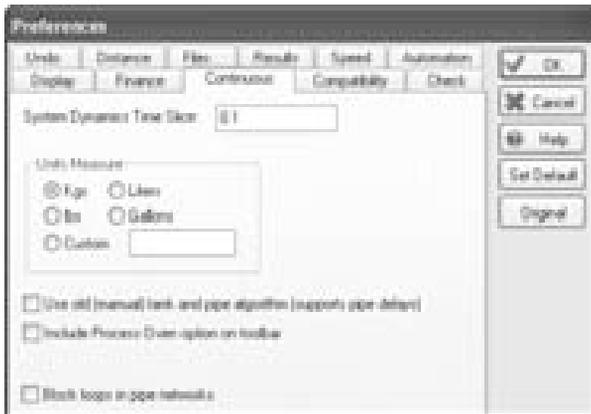


Figure 9-19: Continuous Preferences

These options allow the user to determine the continuous process default values for units. When creating continuous process simulations, few trigger

points exist for Visual Logic. A System Dynamics Slice determines the frequency of Visual Logic calls, and therefore the model accuracy. To increase model accuracy, decrease the time slice variable.

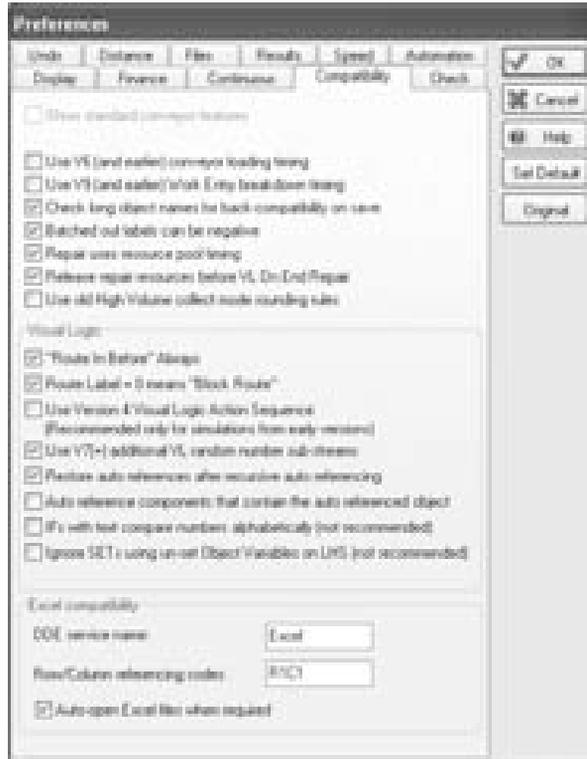


Figure 9-20: Compatibility Preferences

The Compatibility Preferences allows the user to decide which features are shown and used. It also allows users who are accustomed to certain features and logic from prior versions to continue using these older options.

File/Edit Tools



Figure 9-23: File + Edit

This toolbar allows the following capabilities:

1. Open – Allows browsing to open another simulation model. This will close the current simulation model and prompt to save the current model if it has not already been saved.



Figure 9-24: Open Simulation Browsing

2. Save – If the simulation model has been previously saved, the changes will be saved to replace the previous model. Otherwise, the *Save As* dialog box will provide the ability to browse for a location and name for the model.

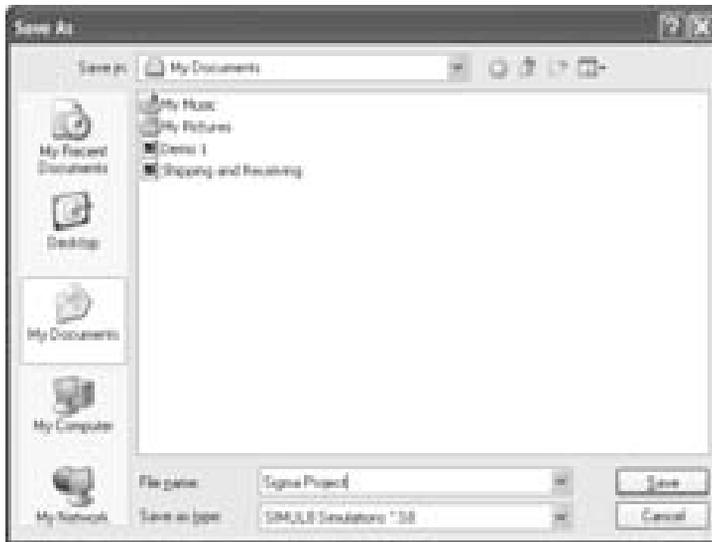


Figure 9-25: Save As Dialog

3. Print – The current screen can be sent to the printer. The option to print to file is also available. The file will be saved under Examples/Others within the SIMUL8 directory
4. Undo – The last action or change to the simulation model will be reversed. This is available as long as the Undo capability is enabled and will set the simulation clock to 0 unless specified otherwise (see the Simulation Preferences section on page 165). The previous 20 actions are stored and can be reversed. A particular action can be selected by using the Edit menu options. If an earlier action is selected, all changes made to the model after this action will also be reversed. The option to Redo is also provided here to reverse the changes of the last Undo.

- Use Ctrl+Z to undo ●

- Use Shift+Ctrl+Z to redo ●

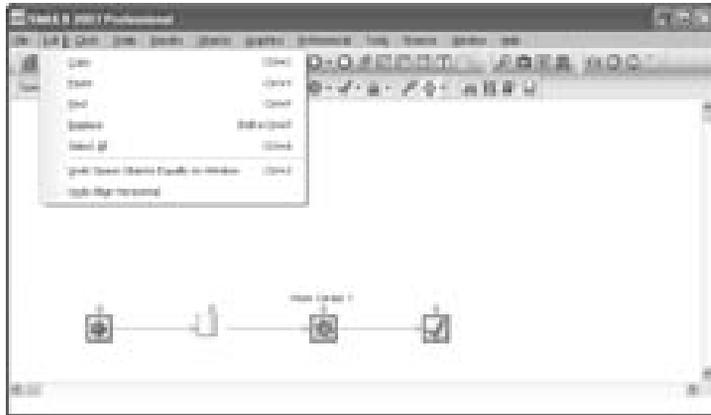


Figure 9-26: Edit Menu

- Use the mouse wheel inside the active window to change the size of window contents ●

5. Zoom – The size of the active window content can be altered. The + and - buttons incrementally increase and decrease its size. Entering a number inside the edit box can also set the size of the window content.
6. VR Simulation– Click on this button to convert your 2-D simulation to a 3-D one! Click again to revert back to a 2-D view.

Simulation Speed



Figure 9-27: Speed Bar

This toolbar is used to control the animation speed during the simulation run. (See the section on Simulation Speed on page 165.) Setting it to the far right shuts off animation completely and runs the simulation to the end as quickly as possible.

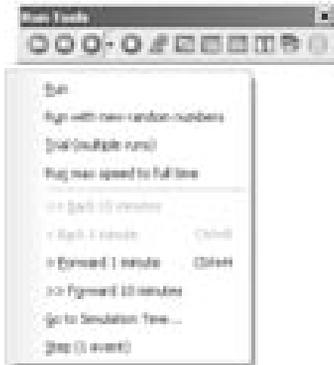
Run Tools



Figure 9-28: Run Tools

This toolbar provides control for running the simulation model and viewing results:

1. Reset Clock to Start – Sets the simulation clock back to 0.
2. Step – Moves the simulation to the next timed event.
3. Run – Runs the simulation model at the current speed. A number of drop-down options are also provided.



◆ Ctrl+B to move the simulation back 1 minute ◆

◆ Ctrl+H to move the simulation forward 1 minute ◆

Figure 9-29: Running Options

- Run with new random numbers – Resets the simulation and runs it at the current speed with a different set of random numbers.
- Trial (multiple runs) – Conducts a trial.
- Run max speed to full time – Runs the simulation until the end of the results collection period at the fastest possible speed.
- <<Back 10 minutes, <Back 1 minute, >Forward 1 minute, >>Forward 10 minutes – Moves the simulation instantly back or forward by the given number of minutes.



Figure 9-30: Go to time Dialog

- Go to Simulation Time... - Moves the simulation instantly to the time specified in the input box provided.

- Step (1 event) - Moves the simulation on to the next event.
4. Run a Trial and Display Results– Automatically runs a trial using the current random number stream and displays the Results Summary at the end.
 5. Make Time Graph of selected objects – Displays a chart showing the content of the selected objects over the course of the results collection period.
 6. Show Data Sheet – Displays the spreadsheet information store currently set as the main sheet.
 7. Results Summary – Displays results summary sheet. (See the section on Results Summary on page 299.)
 8. Financial Summary – Displays the Income Statement for the last simulation run, including revenue, cost and profit information.



Figure 9-31: Simulation Assistant

9. Simulation Assistant – SIMUL8 continuously monitors the simulation model. If SIMUL8 recognizes the opportunity to provide any relevant advice to help with modeling, the Simulation Assistant button will light up on the toolbar. Clicking the button will display the Simulation Assistant. Advice is summarized and, in some cases, the options to view further detail or background information are available. In addition, the option is provided to

prevent the Simulation Assistant from giving the same or any advice again.

Build Tools



Figure 9-32: Build Tools

This toolbar contains the basic simulation objects to construct a simulation. These will be discussed in more detail in Chapter 2 Creating and Navigating in SIMUL8. The two right-most buttons are options to switch on or off the route arrow drawing mode and the viewing route and Resource arrows.

Options:

1. Create Work Entry Point
2. Create Storage Bin
3. Create Work Center
4. Create Work Exit Point
5. Create Resource
6. Route Drawing Mode
7. Show/Hide Route Arrows

Build Tools 2



Figure 9-33: Build Tools 2

This toolbar contains the Conveyor object and any other objects included in installed SIMUL8 Plug-ins (i.e., load/unload point, vehicles, etc).

Graphics Palette



Figure 9-34: Graphics Palette

The Graphics Palette provides the capability to customize models with on-screen static graphics and data. The arrow button, which selects or moves graphic objects, is also used to exit any of the graphic editing buttons.

To add a graphic to the window, click the button to select the graphic. The graphic is placed on the main screen by clicking to position the first handle, then dragging and releasing to position the second handle. Click on a graphic to see the handles appear. The graphic can then be moved or resized. To select more than one graphic at a time, hold down the Ctrl key. Graphics can also be deleted with the delete key.

The following graphics can be added to the main window.

1. Box – Box outline
2. Solid Box – Box outline and fill
3. Rounded Box – Box outline with rounded corners
4. Rounded Solid Box - Box outline and fill with rounded corners
5. Circle – Circle or oval outline
6. Solid Circle - Circle or oval outline and fill
7. Line – Straight line

Other items, which can be added to the main window, can also be moved, resized, and deleted in the same way as the previous graphics.



Figure 9-35: Visual Data

8. Visual Data – This interesting and useful feature displays a text or numerical Information Store on screen that updates as the Information Store changes over the course of the simulation. To add Visual Data to the screen click on the button, click on the

■ To lock images on the screen and prevent accidental editing, close the Graphics Palette. ■

● A number variable must be created in the Information Store before it can be displayed on the screen ●

screen and select the required variable from the drop-down list provided.

9. Write Text – Position a text box as with other graphics and then type text into the box.
10. Load Graphics from Disc – Click on the button, click on the screen and browse the background images. Images should be saved in .bmp or .jpeg format. Images can be moved but must be resized with a graphics package.
11. Floor, Wall, and Static Object – Click on one of these buttons and place the object onto the main window. These objects will supplement your simulation image when you click on the “VR Simulation” button in the File/Edit toolbar.
12. The Snap to Grid button provides assistance in position and aligning graphics.
13. Rotate – This button rotates the selected image 90 ° clockwise.
14. Flip – Creates a mirror image of the selected image, across the horizontal axis.
15. Mirror – Creates a mirror image of the selected image, across the vertical axis.
16. Edit – Brings up the SIMUL8 Image Editor Dialog box for direct image editing.

Style Palette



Figure 9-36: Style Palette

The Style Palette provides the capability of formatting graphics, data, and text as outlined in the previous section.

1. Color Palette - The color palette is provided for use with graphics from the previous section.
2. Line Color Box - To alter the color of the graphic outline, click on the Line Color box (left box in Figure 9-36) and select a color from the palette.

3. Fill Color Box - To alter the color of the graphic fill, click on the Fill Color box (right box in Figure 9-36) and select from the color palette.



Figure 9-37: Text Font and Color

4. Font Size and Color – This option is provided for editing Visual Data and Text. Font type, style, size, effects, and color can be selected.
5. Include Arrowheads on Lines – This is used only in conjunction with the line graphic and when checked adds an arrowhead to the selected line.
6. Line Thickness – This option can be used to increase or decrease line thickness for any of the graphics from the previous section.

Using the toolbars provided allows the ability to build, save, and run models quickly. In addition, models can be customized to represent particular operations by utilizing the capability of the Graphics and Style Palettes.

Keeping Updated

SIMUL8 is a constantly evolving product. As manufacturing, production, and work flow systems change, a list of additions and alterations within

Some of the Help options provide access to different areas within the Help Files. Examples Libraries are provided to show users how certain features can be used within the modeling environment. Show me How Movies provide the user with systematic guides to building basic models. ASK.simul8.com provides access to the on-line Knowledge base and the user café. The About option will provide information on the Version Number, and if the version # is double-clicked it will provide the Build Number. If the Build Number shown is less than the current Build Number available on the web the user should download the latest release. After downloading a new release, the user should examine Latest Changes to see what new features, functions, and commands are now available.

If the Help file does not provide the desired answer, call support on 1-800-878-3373.

Chapter 10: SIMUL8 Basics

Introduction to Objects

SIMUL8 simulations are built using the basic objects provided in the Build Tools and Build Tools 2 toolbars. This section introduces these objects and their basic properties.

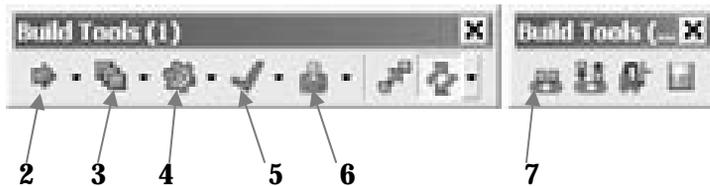


Figure 10-1: Basic Objects 1

1. Work Items

The most fundamental SIMUL8 objects are called Work Items. These move through the model and represent the entities to be processed, such as widgets in a factory, phone calls in a call center, or patients in a hospital.

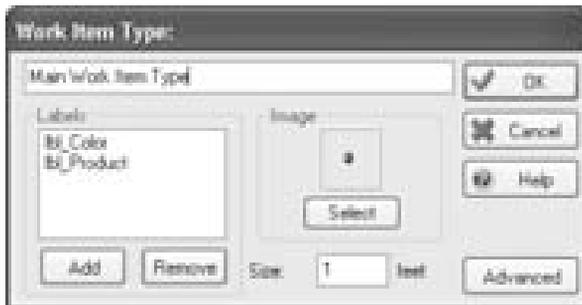


Figure 10-2: Work Item Properties

1. The name of this Work Item type. This can be changed to something relevant to the simulation.
2. Labels – Shows the labels relevant to this Work Item type. They are added automatically when a label is created but can be added or removed.
3. Image – An image can be selected to represent the Work Item type. See Graphics / Images on page 385.
4. Size – A size is specified for use with Conveyors. Double-clicking on feet opens the Preferences dialog for changes the default length unit for the simulation.
5. Advanced – This allows Work Item types to be added, deleted, or browsed.

Multiple Work Item Types

■ Since all properties of a Work Item can be manipulated using labels (i.e. graphics and size), multiple Work Item types are rarely used. ■

There are two methods for distinguishing between items traveling through a SIMUL8 simulation. The most common and popular method is to use labels. However, it is possible to have multiple Work Item types. As opposed to distinguishing between different types of product, these would distinguish between a product and a vehicle, for example. Each Work Item type will have the same properties as introduced above. Multiple Work Item types slow down a simulation and are not recommended for large models.

2. Work Entry Points

A Work Entry Point is where Work Items enter the simulation model. Here they can be specified to arrive at a certain rate and have set label values. Examples of Work Entry Points are a dock where inventory arrives at a warehouse, a telephone that introduces customers' inquiries into a call center, or a door through which patients enter a clinic.



Figure 10-3: Work Entry Point Properties

1. The name of this Work Entry Point – This can be changed to something meaningful for the model. It can be displayed in the simulation window. Click Title in the Graphics button dialog.
2. Input Work Item Type - Defines the "Work Item Type" that this Work Entry Point brings in to the model.
3. Inter-arrival Times - Enter here the inter-arrival time of Work Items. Parameters required will change depending on the distribution selected.
4. Distribution - This dropdown provides a number of statistical distributions used to supply these values as the model runs. Users can also create their own, as explained in Chapter 12: Distributions.
5. First at Start Time – Normally, the first arrival will be at the time sampled from the distribution. If this box is checked, an additional arrival will occur as soon as the model starts running.
6. Unlimited Arrivals - If this box is checked, work enters the simulation exactly when required (i.e. when a Work Center it feeds is ready for it)

7. None – Turns off the work entry point from bringing work items into the model.
8. File – The user can determine the exact simulation time at which work enters the model by checking this box and selecting a .csv file to use. In addition, the user can set a work item label to be a value also defined in the file. The .csv file must be formatted in the following way:

Simulation Name		
< name >	Inter-arrival Time	<label name >
	0.5	1
	0.6	2

The label name must be exactly the same as the label name within SIMUL8. The .csv file must be closed before running the simulation model.

9. Finance – Adds a capital cost and/or a cost per unit for each work item that enters the simulation.
10. Erase – Deletes the Work Entry Point.
11. Ignore hints about lost Work Items - Switches on/off the warning messages if SIMUL8 thinks the user has made a mistake that causes blocking of this Work Entry Point.
12. Memo - The Memo button lets the user add detailed documentation about each simulation object. When text is entered in the Memo area, the information will appear as pop-up text on mouse-over, so users can quickly understand what the Work Entry Point represents.
13. Results - The Results button accesses the performance measures that have been collected as the model ran.
14. Batching - The Batching button tells this Work Entry Point to deliver Work Items in groups of the size specified.

15. Routing Out - The Routing Out button describes how the Work Entry Point distributes Work Items to the next stage in the process.
16. Label Actions - Label Actions determines what changes to make to the Work Item's labels as they leave the Work Entry Point.
17. Graphics - The Graphics button changes the properties of the Work Entry Point's image and title.
18. Current Image – Shows the present screen display for the Work Entry Point.

3. Storage Bins

A Storage Bin is where Work Items can queue or be stored between process steps. Examples would be an in-basket, waiting room, inventory holding, or telephone call on-hold.



Figure 10-4: Storage Bin Properties

1. The name of this Storage Bin – this can be changed to something meaningful for the model. It can be displayed in the simulation window. Click Title in the Graphics button dialog.
2. Capacity - A check here indicates that there is no limit on the number of Work Items that can be in this Storage Bin.

◆Minimum wait time only functions when using labels as part of the reference if Work Items flow into the Storage Bin. If they are added using Visual Logic, no wait time will be applied. ◆

3. Shelf Life - Number of time units before items in this queue become "out of date." Out of date items can be removed by Work Centers that have "expired only" for their "routing in." Double-click this field to use a label on the item rather than a fixed value.
4. Min Wait Time – The minimum time a Work Item must stay in a Storage Bin. This can be set to follow a distribution, label or variable by clicking on the '...' button. Extremely useful for simulating drying or cooling Work Items.
5. Prioritize - When Work Items enter a prioritized Storage Bin, they are sorted into order of the values in a label. The highest values are placed nearer the front of the queue. When the box is checked, a list of available labels will be displayed.
6. LIFO - Use Last-In-First-Out rule to sequence Work Items through this Storage Bin. If this is checked, the item at the front of the queue is always the one that arrived in the queue most recently. Not relevant if the bin is prioritized on a label.
7. High Volume – Use BPR / high volume options. The quantity label will be used to account for capacity and the display of current contents. Speeds up the simulation considerably.
8. Segregate Results – Results information can be categorized by labels of the Work Items. If this option is clicked, the user will be asked for a label name that will contain the categories by which to segregate.
9. Finance – Adds a capital cost and/or a cost per item per minute for each work item waiting in the storage bin.
10. Erase – Deletes the Storage Bin.
11. Memo - The Memo button lets the user add detailed documentation about each simulation object. When text is entered in the Memo area, the information will appear as pop-up text on mouse-over, so users can quickly understand what the Storage Bin represents.
12. Results – The Results button accesses the performance measures that have been collected during the model run.
13. Start-up – Lets the user specify the quantity and label values of the Storage Bin (queue) at the start of the model run. This saves the

need for Warm-up Time in certain situations as it quickly simulates normal operating conditions.

14. Contents – Provides detail on the Work Items currently in the Storage Bin. Quite useful for troubleshooting a simulation
15. Graphics - The Graphics button changes properties of the Storage Bin's image and title.
16. Current Image - Shows the present screen display for the Storage Bin.

4. Work Centers

A Work Center is where Work Items are processed. Typical characteristics of a Work Center include work inflow, process time, and work outflow. Some common examples are a desk, machine, or office.



Figure 10-5: Work Center Properties

1. The name of this Work Center – This can be changed to something meaningful for the model.

2. Timing – By default, timing is determined by the statistical distribution chosen directly below. Click the button to use the Jobs Matrix or Cycle Matrix (Page 271) instead.
3. Processing Time - Enter the time to process Work Items next. Parameters required will change depending on the distribution selected.
4. Distribution - This dropdown provides a number of statistical distributions used to supply these values as the model runs. Again, users can create their own, too.
5. High Volume - Indicates that each Work Item entering the Work Center is actually a batch of Work Items, the quantity of which is defined by the Work Item's Quantity label. The High Volume check box converts the timing information by multiplying the processing time for the Work Center by the value in the Work Item's Quantity Label.
6. Finance – Adds a capital cost and/or a cost per minute for each work item processed at the work center.
7. Erase – Deletes the Work Center.
8. Memo – The Memo button lets the user add detailed documentation about each simulation. When text is entered in the Memo area, the information will appear as bubble text on mouse-over, so that end-users can quickly understand what is represented by the Work Center.
9. Results – The Results button accesses the performance measures that have been collected as the model ran.
10. Resources – Set the floating resources (e.g. labor, jigs, tools, etc.) required to do work at this Work Center.
11. Efficiency – Sets up the breakdown parameters for this Work Center.
12. Routing In – Describes where the Work Center gets Work Items and how they are collected.
13. Routing Out - Describe how the Work Center distributes its finished work to the next stage in the process.
14. Label Actions - Label Actions determines what changes to make to the Work Item's labels as they leave the Work Entry Point.

15. Priority - Lets the user determine how this Work Center competes against others for Resources or Work Items.
16. Replicate - Replicate is a simple way to copy the Work Center. Full Work Center facilities are not available if this option is chosen. (Instead, copy objects on the screen by dragging them or use the Duplication Wizard for full facilities.)
17. Contents – Provides detail on the Work Items currently in the Work Center.
18. Graphics - The Graphics button changes the image used to show a Work Center.
19. Shifts – Sets the times this Work Center operates and its behavior during a shift change. See page 241.
20. Current Image - Shows the present screen display for the Work Center.
21. On State Change – An access point for Visual Logic (to be discussed in more detail later) every time that the state of the work center changes.

■ Change the image of a Work Center depending on its state (working, blocked, etc.) through Work Center Properties → Graphics. ■

5. Work Exit Points

A Work Exit Point is where Work Items can leave the simulated workplace. This must occur in order for SIMUL8 to record overall Work Item process statistics.



Figure 10-6: Work Exit Properties

1. The name of this Work Exit Point – This can be changed to something meaningful for the model. It can be displayed in the simulation window - click Title in the Graphics button dialog.
2. Finance – Adds a capital cost and/or a revenue for each work item completed at that work exit point.
3. Erase – Deletes Work Exit Point.
4. Halt Model at Limit – Number of Work Items arriving at this Work Exit Point that automatically stops the simulation run. If this is checked, model may not reach the end of its normal run. This facility enables the user to have the model stop when a certain number of Work Items have been processed.
5. Segregate Results – Results information can be categorized by information in the Work Items. If this option is clicked, the user will be asked for a label name that will contain numbers to be used for categorization.
6. High Volume – Results will be based on the Quantity label.
7. File – The user can determine the exact simulation time at which work exits the model by checking this box and selecting a .csv file to use. In addition, all label values will be recorded. The .csv file must be closed before running the simulation model, and can be opened again when the simulation is finished running.
8. Memo – The Memo button lets the user add detailed documentation about each simulation. When text is entered in the Memo area, the information will appear as bubble text on mouse-over.
9. Results – The Results button accesses the performance measures that have been collected as the model ran.
10. Graphics - The Graphics button changes the image used to show a Work Exit Point.
11. Current Image - Shows the present screen display for the Work Exit Point.

6. Resources

A Resource is a special object that may be required by a Work Center in order to operate. Examples are doctors required for surgery, workers at a machine, a receptionist at a desk, or a tool necessary for a specific task.



Figure 10-7: Resource Properties

1. The name of this Resource – This can be changed to something meaningful for the model. It can be displayed in the simulation window - click Title in the Graphics button dialog.
2. Number of this type of Resource available – When shifts are not used, the number of this type of Resource available for the duration of the simulation.
3. Shift Dependent – When checked, the number of Resources available can be different in each shift.
4. Shifts - Shifts allow the user to control the availability of a particular Resource at different times of the day or week. See page 241.
5. Pool Resource – A Resource pool is a list of SIMUL8 Resources that are available for use at this Work Center. When checked, Work Centers that require this Pool Resource will be provided a Resource from the list of members.
6. Auto-adjust replicate levels – All Work Centers where this Resource is used will be adjusted to handle the maximum number of Resources available (where replicate is allowed).

7. Finance – Adds a cost per resource unit and/or a cost per resource unit per minute.
8. Erase – Deletes Resource.
9. Memo – The Memo button lets the user add detailed documentation about each simulation. When text is entered in the Memo area, the information will appear as pop-up text on mouse-over. This can be used to easily provide an end-user with more insight into the function of the resource.
10. Results – The Results button accesses the performance measures that have been collected as the model ran.
11. Travel – Allows travel times to be set for Resources moving between different Work Centers where they are required.
12. Graphics - The Graphics button changes the image used to show this Resource.
13. Current Image - Shows the present screen display for the Resource.
14. Find – Shows the present location of the Resource.
15. Availability – Sets the percentage availability of the Resource, and the Resource's average absence time. Options are also available for detailed availability setup.

7. Conveyors

A Conveyor is used to move Work Items around the simulation. It has a certain amount of space for Work Items and moves them along its length from one end to the other. The number of Work Items that can be held is dependent on the length of the Conveyor and the size of the Work Items.



Figure 10-8: Conveyor Properties

■ Double-click on the units beside the Length or Speed input box to change units ■

1. The name of this Conveyor – this can be changed to something meaningful for the model.
2. Length – The length of the Conveyor (combined with its speed) affects how long it takes Work Items to travel from one end to the other. The Length is also used with the "size" of Work Items to consider how many can fit on to a full Conveyor.
3. Speed – How fast the Conveyor is moving relative to the time and size units. This affects how long it takes a Work Item to travel from one end of the Conveyor to the other.
4. Accumulating – Accumulating Conveyors are powered roller type Conveyors where all Work Items keep moving until they have all accumulated behind the item at the front of the Conveyor. Otherwise, all Work Items stop when an item reaches the front until it leaves Conveyor.

5. Allow Gaps – If unchecked, the Conveyor will stop if no work is available to feed it until work arrives.
6. Erase – Deletes Conveyor.
7. Memo – The Memo button lets the user add detailed documentation about each simulation. When text is entered in the Memo area, the information will appear as bubble text on mouse-over.
8. Results – The Results button accesses the performance measures that have been collected as the model ran.
9. Efficiency – Sets up the breakdown parameters for this Work Center.
10. Routing In – Describes where the Conveyor gets Work Items and how they are collected.
11. Routing Out – Describe how the Conveyor distributes its finished work to the next stage in the process.
12. Label Actions - Sets up what this Work Center is to do to labels of Work Items as they leave the Conveyor.
13. Contents – Provides detail on the Work Items currently in the Conveyor.
14. Graphics - The Graphics button changes the image used to show this Conveyor.
15. Current Image- Shows the present screen display for the Conveyor.

The basic objects outlined in this section provide the building blocks to create an endless range of simulation models emulating a variety of different systems. The following section will discuss an important feature that relates to many of the objects presented here.

Calendars

This section is included here as it is a useful function for determining the availability of many of the simulation objects previously discussed in this chapter. The calendar is also used for setting the schedule for the entire plant or business being simulated. The calendar is accessible through the Clock command menu.



Figure 10-9: Calendars

Click on the drop down menu for the simulation start date to view an actual calendar. Select a different month using the right and left arrows.

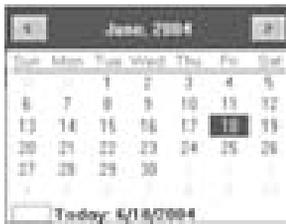


Figure 10-10: Calendar Simulation Start Date selector

Use the initial dialog box to create any number of calendars for the simulation and to edit any previously created calendars.

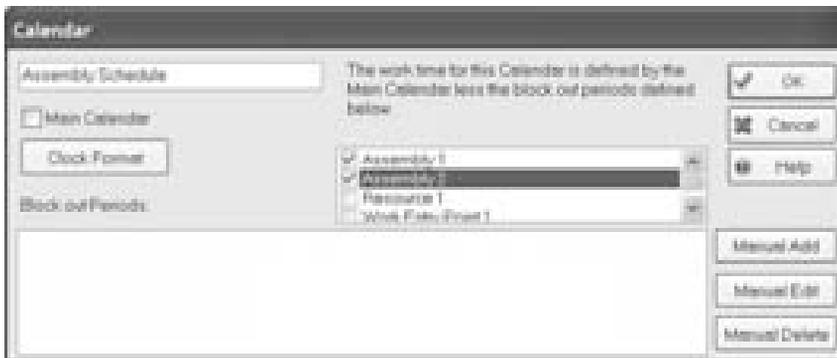


Figure 10-11: Calendar Block out Periods

After clicking on new, set the properties of the schedule. Check Main Calendar to apply this schedule to the entire plant. If the schedule applies to specific objects and not to the entire plant, uncheck Main Calendar and instead check one or more of the objects in the list to the right.



Figure 10-12: Calendar Unavailable Time Block

The actual dates are set using manual add and inserting the dates as desired.

Now that the basic simulation objects have been presented, the next section will describe how to build a basic simulation model using the objects described.

Building a Model

With SIMUL8, it is possible to quickly build a working simulation model and begin using it to analyze operations. This section details how to build a basic simulation flow by placing objects on the simulation screen and linking to create a flow.

Adding Objects to the Main Screen

Objects can be quickly added to the main screen by clicking on the required object on the Build Tools 1 or Build Tools 2 toolbar. Clicking on a location on the main window then adds that object to the screen. As objects are added SIMUL8 may automatically create links.

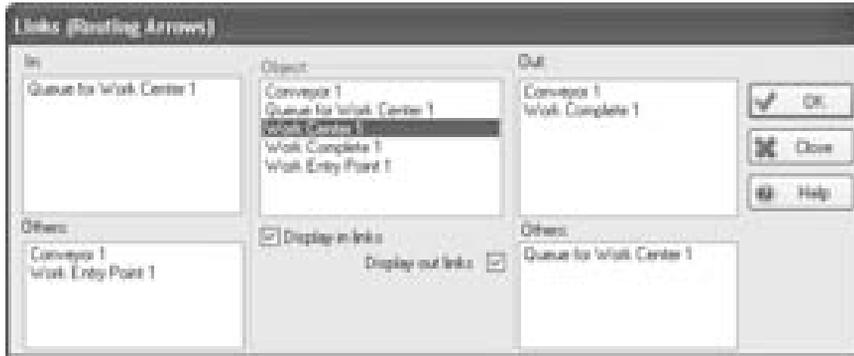
Moving Objects

Objects can be moved around the simulation window by selecting an object or group of objects, dragging, and dropping it on a new location.

Linking and Unlinking Objects

As mentioned in the previous section, objects are often automatically linked by SIMUL8. To view links between objects, click the Show/Hide Arrows

button on the Build Tools 1 toolbar. Links can also be viewed via the Objects command menu and selecting Links. This is particularly useful for larger models or those with graphics or titles hidden.



■ To quickly link and unlink Objects, hold down the Shift key ■

Figure 10-13: Links

1. To switch on or off the Route Drawing Mode, select the button on the Build Tools 1 toolbar. This changes the cursor to a black arrow that can be used to link or unlink objects. When clicking and holding the mouse button on an object, a black arrow and “?” will appear. Dragging across the screen to another object will display a larger black arrow when a legitimate link has been made. Releasing the mouse button then makes or breaks the link.
2. For quick editing of links, the same click, drag, and release method can be used when not in Route Drawing Mode. This is achieved by holding down the Shift key.
3. Clicking on a routing arrow to select, and then pressing delete can also be used to quickly erase links.

Alignment and Spacing

Objects can be selected by clicking and dragging to enclose them. The objects selected will appear with a dotted line around them.

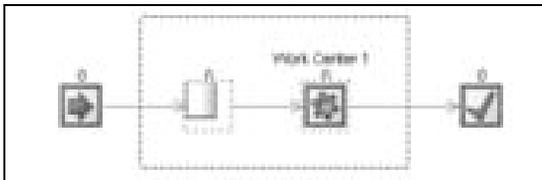


Figure 10-14: Selecting Objects

To align objects, right click within the box and select Align from the menu. To create equal spacing between each object, right click on the selected objects and select Space Equally from the menu.



Figure 10-15: Right Click Object Menu

Copying Objects

There are a number of ways to copy objects and place them on the screen.

1. Select an object or group of objects. Right click on the selected objects and select Copy from the menu. Right click and select Paste from the menu. The new objects will be placed directly on top of the original objects. They can now be dragged to a new location, if desired.
2. As above but use Ctrl + C to copy and Ctrl + P to paste.
3. Select an object or group of objects. Hold down the Ctrl key and drag objects to the required position on the screen.

■ Hold down Ctrl while clicking and dragging to quickly copy objects ■

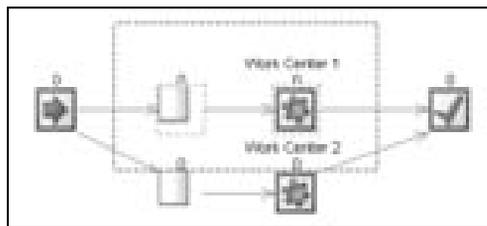


Figure 10-16: Copying Objects

4. Select an object or group of objects. Right click on the selected objects and select Duplication Wizard from the menu. Enter the number of copies required. Enter the number of pixels to increment the position of the objects with each copy along the X-axis (horizontal) and the Y-axis (vertical). Newly created objects can be placed within a new group. The group will be automatically named.

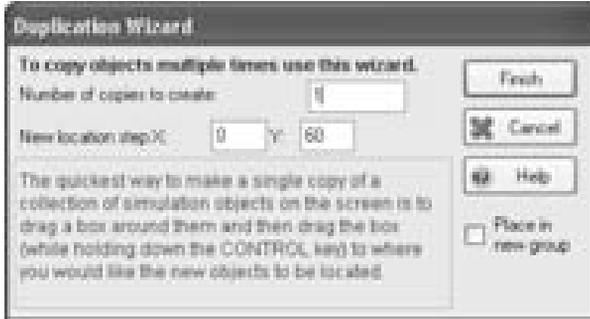


Figure 10-17: Duplication Wizard

Sub Windows

Sub-windows can be created for a hierarchical model or simply to tidy-up large or complicated models by compartmentalizing areas. Objects are selected by dragging a box around them. The right-click menu option, *Create a Sub-Window*, can then be selected. Sub-windows can be created inside other sub-windows.

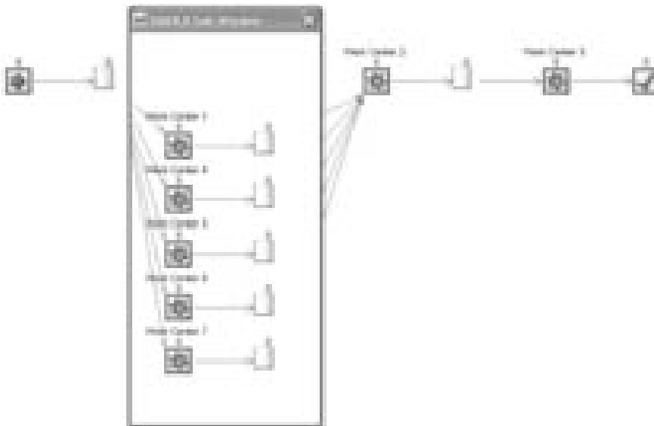


Figure 10-18: Sub Window

The Sub Window properties can be viewed by right clicking anywhere inside the window and selecting Window Properties from the menu or by clicking on the S8 logo at the top left of the window and selecting Window Properties. Properties can also be accessed for a closed Sub Window by right clicking on the Sub Window and selecting Sub Window Properties from the menu.



Figure 10-19: Sub Window Properties

1. The name of this Sub Window. This can be changed to something relevant to the simulation.
2. Background – Select a background color for the Sub Window. This helps keep the simulation tidy.
3. Graphics
 - Title with image – Displays the name of the Sub Window on the main screen.
 - Invisible – Hides the Sub Window.
4. Image - An image can be selected to represent the Sub Window.

Using the model building techniques outlined it is possible to create many types of models from large to small and simple to complex. The following chapters detail how the features in SIMUL8 can be used to further develop and customize simulation models.

Chapter 11: Work Item Labels

Definition

In SIMUL8 Work Entry Points create Work Items, which then travel through the simulation and are processed by Work Centers before leaving the simulation through a Work Exit Point. Work items can have individual pieces of information physically attached to them. This can be information such as color, size, and product type, or can be special labels, such as image and quantity. SIMUL8 refers to this information as Labels. Labels can be used to simply carry information about the Work Item, trigger changeovers at Work Centers, product routings from Work Centers, different process timings at Work Centers, and many other activities.

Creating Labels

Labels are created by selecting Objects > Labels. A list of the available labels will appear with a few options:



Figure 11-1: Available Labels and Options

◆ Preface all labels with “lbl_” when assigning names to labels (i.e. use a naming convention) ◆

By clicking either New or Properties, the following dialog will appear. Labels can be either Text or numerically based. Text Labels are not as useful as numerical values and take up more memory. Therefore, it is recommended to avoid text labels.



Figure 11-2: Label Properties

Once a Label has been created, it will be automatically attached to the Work Item the first time it is set. Labels are set to numerical values to represent different production information. For example, if a car assembly plant produces 5 different colors, each car is painted on completion and a changeover time is associated with the cleaning of the painting operation for a color change a label is required to note which color each assembly requires. This requires ONE Label, such as `lbl_color`. Using 'Label Actions' found in Work Entry or Work Center dialogs, this Label should be set to a 1, 2, 3, 4, or 5, as shown below.

Color Name	lbl_color value
Black	1
White	2
Red	3
Navy	4
Green	5

Figure 11-3: Example Table of Labeling Representation

Some users will attempt to create five different Labels, one called `lbl_Black`, `lbl_White`, etc. There is no need for this inefficient use of labeling. For example, changeovers can be triggered by a change in the value of a label. Therefore, there should be one label representing the information, such as case color. As this value will then differ for various colors, it can easily be

checked to determine if a changeover will occur. This can not be done efficiently, if there is a different label for each color.

Label Actions

All labels can be set using label actions or Visual Logic. If a label has not been set to any value, it will default to empty or zero. Label Actions can be found in the following places:

- Work Entry Points
- Work Centers
- Conveyors
- Storage Bin - Initial Conditions under Start-Up



Figure 11-4: Label Actions Button

By selecting the Label Actions options in any of these dialogs, the following screen will appear:

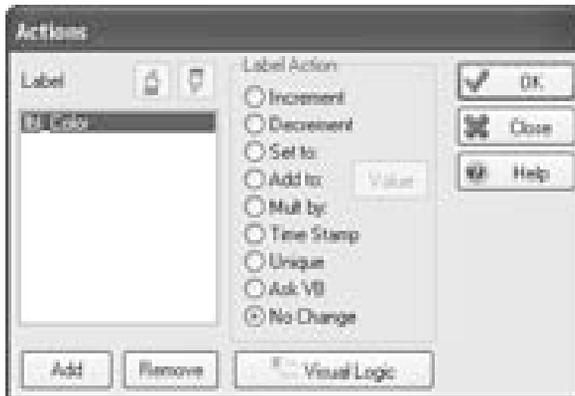


Figure 11-5: Label Actions Options

Click on Add to bring the label into the list box. Once it is available in the list box, it is possible to change the properties of the label. Different actions can be taken on different labels. Most of the options for Label Actions apply to Numerical labels, these are:

1. Increment – this action will add the value one to the current value of the label. This is useful for tracing how many times a Work Items has been through a certain location or type thereof.

2. Decrement – This action will remove the value one from the current value. This is useful for counting tasks remaining.
3. Set to - This is the most often used option. This will set the label to a numerical value according to the distribution set. One of the most popular actions is to use a probability distribution where the label is set to a numerical value according to a percentage probability. If this is used at a Work Entry Point, the distribution will be sampled every time a Work Item arrives in the system, labeling each item with its own corresponding value.
4. Add to and multiply by - Both of these functions perform mathematical calculations on the value already contained within the label.
5. Time Stamp - This stamps the simulation clock time onto the Work Item. It is particularly useful if the completion time is recorded at a later date. Use this stamp on work entry, if time in the system is to be calculated individually on completion of all work.
6. Unique - This stamps a unique numerical identifier onto each Work Item.
7. Ask VB: - this sends a signal to VB or VBA, which calls a macro to decide what the label should be. This option is not recommended as calling an external program will significantly slow down the simulation run time. Visual Logic should be used instead.

Once the label has been stamped with an initial number, this value will remain on the individual Work Item until it either leaves the system or the value is altered through subsequent label actions or Visual Logic code.

Special Labels

There are a number of labels within SIMUL8 that are designed for a special purpose. When these labels are created, a message will appear to check whether the label should be that the label should be used for its assigned purpose.

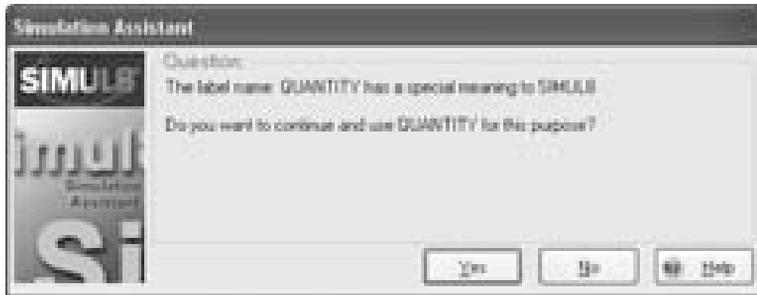


Figure 11-6: Special Labels - Simulation Assistant

If the user checks 'Yes,' the following labels and definitions will apply:

- Quantity
- Image:
- Priority
- Due
- Work Type
- Job
- Length

Quantity label is designed for operations producing large numbers of product, for example bottling plants, semi-conductor productions. The Work Item will actually represent a batch of items corresponding to the number on the Quantity label. Storage Bins and Work Centers have 'High Volume' check boxes. Checking these boxes will ensure that each individual piece is processed and not the Work Item.

Image: is designed to alter the image of the Work Item. This feature is quite tricky, but very helpful. The label should be a combination of 'Image:' and the name of the images. For example if the images are called Type1, Type2, Type3, etc, then the label should be called 'Image:Type'. To alter the image of the Work Item by using this Special Label, it should be set to 1, 2, or 3 respectively. By setting the label value, the image of the Work Item will automatically change to the images called Type1, Type2, and Type3. This is case and space sensitive.

Priority and **Due** labels are used in accordance with Interruptible Work Centers, an option under Routing In. In order to interrupt work at a Work Center, there must be a Work Item waiting with a Priority label of a value higher than the one currently being processed. In order for the Work Center to remember the remaining processing time left on the interrupted

Work Item, the Due label must be present. SIMUL8 will stamp the Due label automatically with the time remaining on the Work Item.

Work Type and **Job** are two label types that are created automatically by SIMUL8 if the Jobs Matrix is in use. The Jobs Matrix will use the work type and job number to determine where the next processing is to take place. The user need not alter them.

Length is used in conjunction with Conveyors to determine what length of the Conveyor each Work Item will take up, determining overall capacity on the Conveyors. This is only required if there are different lengths according to different product types.

Chapter 12: Distributions

Definition

Statistical distributions are the heart of simulation. In SIMUL8, they are essentially 'number generators' used anywhere timing and number values, fixed or variable, are required.

Random numbers are what distributions use to 'return' or 'sample' values. Each distribution in a simulation model uses a separate stream of random numbers; this allows the user to make a change in one area of a model without affecting other areas. These streams are a product of a starting random number 'seed' that does not change unless the user specifies the model to do so. This means that a model will produce the same results repeatedly, until some aspect of it is changed. SIMUL8 has 30,000 sets of random numbers available for use!

Distributions, using the aforementioned random number streams, return values within a range specified by the shape of a probability graph. The classic example is a 'Bell Curve' or Normal Distribution (Figure 12-1). The bell shape of its graph shows that the highest concentration, or probability, is at the middle or average. The width parameter of this particular distribution is given by its Standard Deviation.

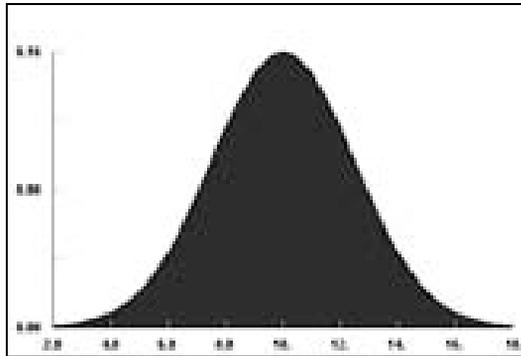


Figure 12-1: Normal Distribution Bell Curve

In this example, the average is 10 and the standard deviation is 2.5. This distribution would return most of its values between 8 to 12 with the majority around 10, or the average. Occasionally it will return a number from its far extremes, between 2 to 8 or 12 to 18. One way to think of distributions are like a set of 'loaded' dice – thrown repeatedly, they will show certain numbers more often than others.

This element of variability in the values that a distribution 'dynamically' generates, used in a process model, is what gives simulation an enormous advantage over 'static' spreadsheet calculations.

Choosing a Distribution

SIMUL8 has many, many choices for setting distributions, which can be confusing to some users. So before looking into the distributions options, consider the importance of the distribution. If the model in development is a high-level capacity planning model, the answer is probably not much. If this is the case, choose something simple like an average distribution and then when the model is complete, test the assumption made.

If there is data available on the process and a distribution can be fitted, it is recommended that a package such as Stat::Fit™ for SIMUL8 be used to identify the distribution.

Typical Distribution Choices and Justification

When objects are created within SIMUL8, there is always a default value and distribution selected within the object. These distributions change depending on what object is selected and what the distribution represents. The following is a list of the different places a distribution is used and the default type assigned, along with a reason behind the choice.

1. Work Entry Inter-arrival Rates – Exponential – The Exponential is the popular choice for arrival rates due to its random nature. It is bound by a lower value. The bulk of the arrivals occur earlier than the average time but there is some chance of an arrival occurring far later than the average. This is typical of arrivals as most arrivals will arrive on time, but occasionally situations cause the arrival to err on the late side.

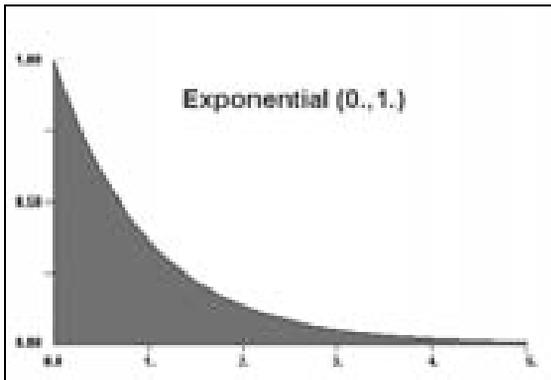


Figure 12-2: Exponential Distribution for Inter-arrival Rates

2. Work Center Process Time – Average – The average distribution is a commonly used distribution that is similar to the Normal distribution, which assumes a bell curve. This creates some variability around an average value. The standard deviation is automatically set to 25% of the mean.

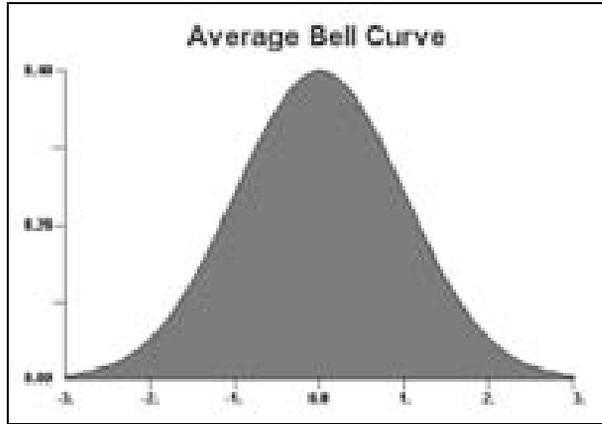


Figure 12-3: Average Distribution Bell Curve for Process

3. Mean Time to Breakdown – Exponential
4. Mean Time to Repair – Erlang

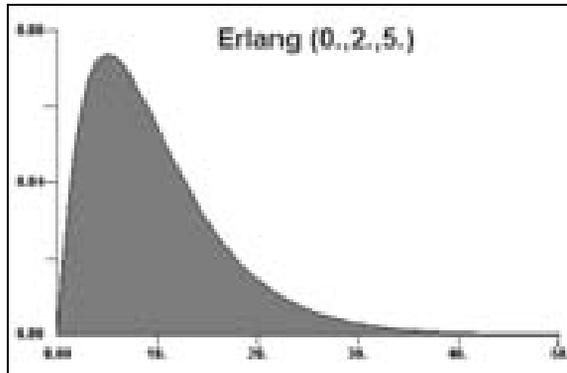


Figure 12-4: Erlang Distribution Example for Repair

Standard Distribution Types

As mentioned previously, distributions are defined by the shape of their graphs. SIMUL8 employs a number of different types of standard distributions. The most commonly used types are:

Average:

An Average distribution, unique to SIMUL8, is a Normal distribution, with a Standard Deviation that is 25% of the Average. Average distributions are useful in simulations where little data is available to justify the use of a particular statistical distribution; therefore, it is used quite commonly for process times. This is the default distribution used in SIMUL8 Work Centers.

Parameters: 1 - Average. (St Dev is 25% of Average)

Fixed:

A Fixed distribution is not really a distribution but is a 'fixed' or static value that does not change. It is commonly used for machine process times or to 'set' fixed values.

Parameters: 1 - Fixed Value

Normal:

The classic 'Bell Curve' shape distribution. Returned values are centered on the average with an even chance of falling on either side of the average, or mean. It is used to simulate durations where variability is low - 95% of sampled values are within the mean plus or minus 2 Standard Deviations.

Parameters: 1 - Average, 2 - Standard Deviation

Triangular:

A Triangular distribution has a graph that looks like a triangle. It has three points, an upper and lower bound, and mode. It can be 'skewed' so that it returns values closer to one of its bounds.

Parameters: 1 - Lower, 2 - Mode, 3 - Upper

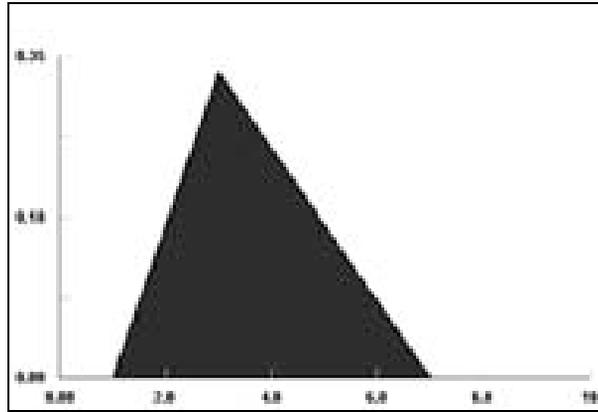


Figure 12-5: Triangular Distribution

Rounded Uniform:

A Rounded Uniform distribution uniformly returns only 'whole' or integer numbers between 2 points. There is an even chance that the value will be any integer between its upper and lower bound. No samples will occur outside this range.

Parameters: 1 – Lower Bound, 2 – Upper Bound

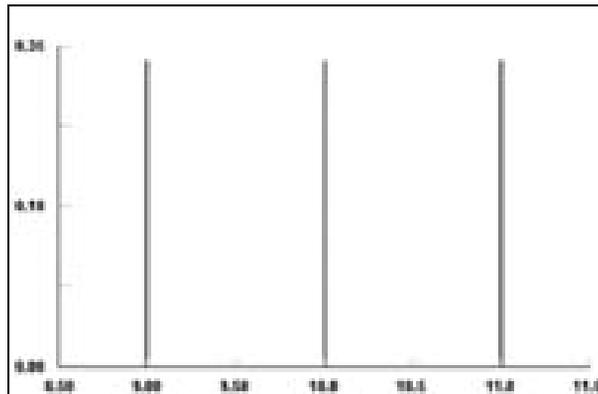


Figure 12-6: Rounded Uniform Distribution

Uniform:

A Uniform distribution is the same as a Rounded Uniform distribution except it returns 'real' or decimal values.

Parameters: 1 – Lower Bound, 2 – Upper Bound

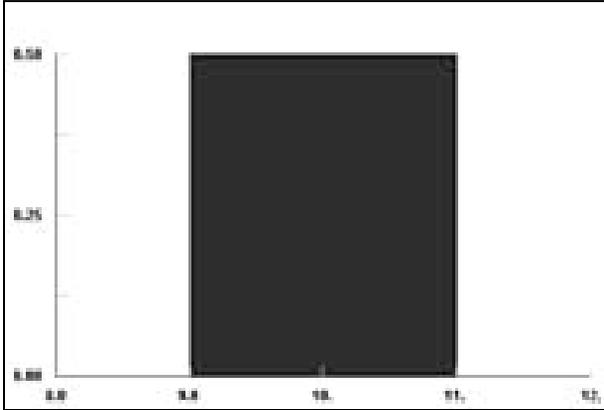


Figure 12-7: Uniform Distribution

Exponential:

Exponential distributions, also known as Negative Exponential, are used mainly for simulating arrival times where one arrival is independent of the next. Since this distribution has its 'peak' at zero, the majority of samples will be less than the average with a few returned values that will be quite large. This equates to a pattern where arrivals occur in 'bunches'. For example, an arrival rate of 30 items per hour exponentially has items arriving not 1 every 2 minutes, but bunched together in clusters followed by long gaps averaging 30 per hour over time.

A good place to use an Exponential distribution would be for customers arriving at a store or patients arriving at a hospital. This is the default distribution for SIMUL8 Work Entry Points.

Parameters: 1 – Average

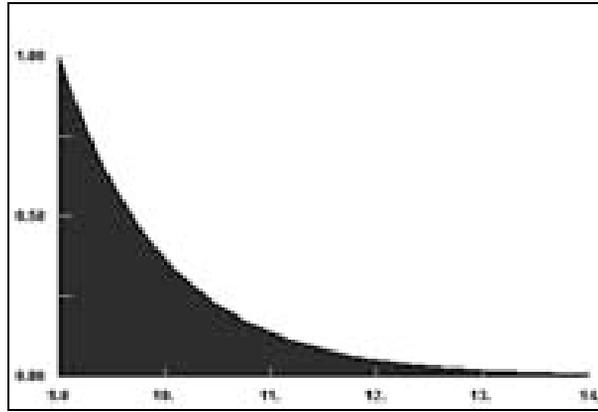


Figure 12-8: Exponential Distribution

Erlang:

An Erlang distribution is essentially comprised of two Exponential distributions back to back. It has two parameters, an average and K . At $K = 1$ it is the same shape as an Exponential distribution. At $K = 2$ it resembles an extremely left-skewed 'Bell Curve' cut off at 0. As K increases, it approaches a Normal distribution, but will never sample a value less than 0.

Parameters: 1 – Average, 2 – K

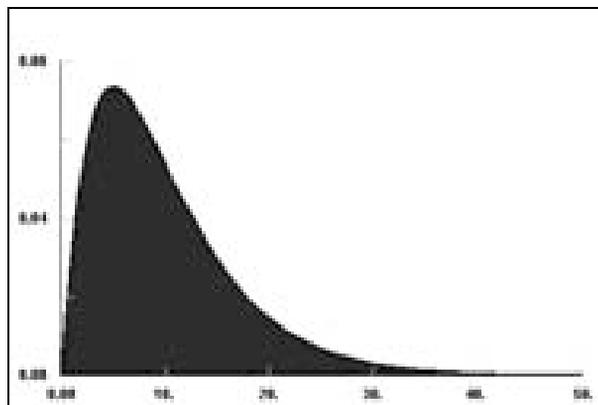


Figure 12-9: Erlang Distribution

Some less commonly used Standard Distributions are as follows:

- Log Normal**
- Weibull**
- Gamma**
- Beta**
- Pearson V**
- Pearson VI**
- Gauss**
- Binomial**
- Poisson**
- Negative Binomial**
- Bernoulli**
- Geometric**

Distribution 'Fitting' software such as Stat-Fit® can be an extremely useful way of determining what distribution to use for a given a set of data.

Standard Distributions in SIMUL8

As mentioned earlier SIMUL8 employs distributions wherever timing and number information is required. A distribution panel in an object's dialog box looks like figure 2. It will appear wherever a distribution is needed to set a value.



Figure 12-10: Selecting a Distribution

To change the distribution type and parameters, simply pick the standard distribution type from the drop down list and fill in the desired parameters.

Some of the areas that distributions are used in SIMUL8 are as follows. Understanding this list will provide the reader with a good understand of simulation.

Work Entry Point

- Work Item inter-arrival times
- Batch Size (*must be whole-number generating distribution)
- Label Actions – Set to, Add to, Mult by:

Storage Bin

- Minimum Wait time
- Start-Up Label Actions

Work Center

- Work Center process timing
- Efficiency (Detailed) – Time Between Breakdowns, Time to Repair
- Change-over time
- Batch Size (*must be whole-number generating distribution)
- Label Actions – Set to, Add to, Mult by:

User-Defined Distributions in SIMUL8

SIMUL8 also provides the means to create several different types of user-defined distributions. An easy way to create, erase, and manage user-defined distributions is found under Tools/Distributions on the main toolbar (or use the Ctrl-D shortcut). When selected, a list of all user-defined distributions contained in the model appears.

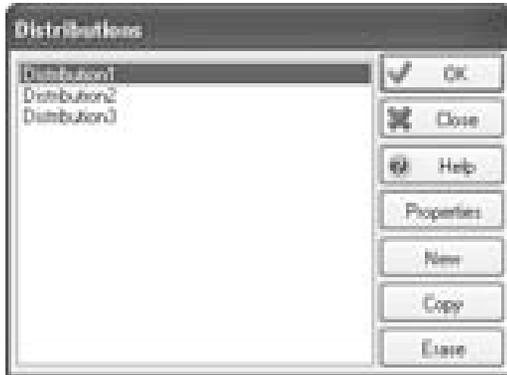


Figure 12-11: All Distributions

To create a new distribution, click the 'New' button and the following dialog will appear.

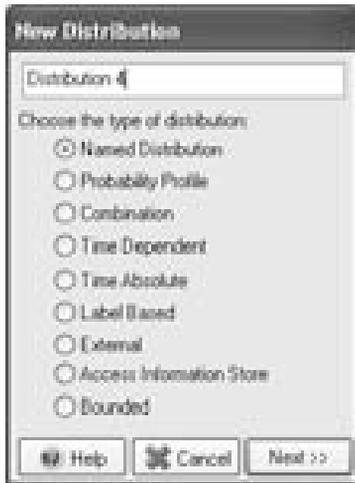


Figure 12-12: Creating User-Defined Distribution

Named Distribution

The Named Distribution permits the user to create a distribution, which can be altered using Visual Logic. The parameters of the Named Distribution are the same as when using the standard distributions, but also enable the use of Pre-Sample Logic.



Figure 12-13: Named Distribution Parameters

Pre-Sample Visual Logic is used to make a decision prior to the sampling of the process time of an event, typically to assign a process time based on a rule.

Probability Profile Distribution

The Probability Profile Distribution allows the user to create distributions, according to a probability of a certain return value.

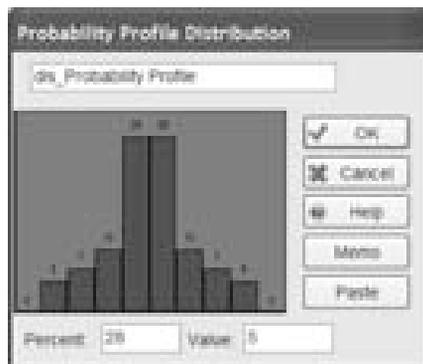


Figure 12-14: Probability Profile Distribution

The user can define unlimited numbers of profiles, with associated probabilities. The probability profile will be a discrete distribution. These distributions are often used to set work labels, so as to associate a discrete number with a product type, color, or any other attribute on the Work

Item. To read more about labels, please read Chapter 11: Work Item Labels.

Combination Distribution

The Combination Distribution provides the user with the capability to use several shapes to serve as a combined distribution. Named Distributions are added to the list, and the combined distributions provide the range for the random number sampled. See below where two named distributions provide the range for the Combination Distribution.



Figure 12-15: Combination Distribution with an Exponential and Normal Curve

Time Dependant Distribution

The Time Dependant Distribution permits the user to use different Named Distributions dependent upon the time of day. The user adds a time slot and defines the Names Distribution to be sampled from during that period, until the next defined time slot.

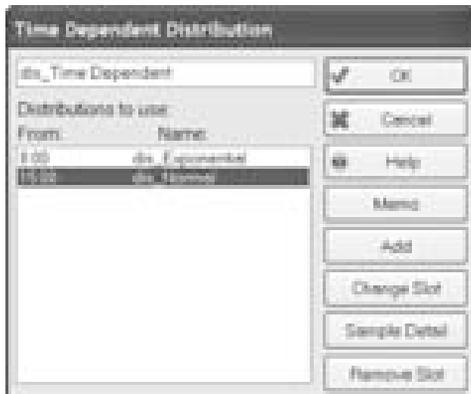


Figure 12-16: Time Dependant Distribution

By selecting the Change Slot option, the user creates a time slot, with an associated Named Distribution as can be seen below.



Figure 12-17: Creating a New Time Dependant Distribution Time Slot

This distribution is often used for altering arrival patterns over the course of a day. For example in a call center, inter-arrivals rates can change as often as hourly, and the impact of these changes on workload is significant. Another example might be truck arrivals during the day, which might be frequent in the morning, sporadic in the afternoon, and practically non-existent in the evenings and over-night. The time dependant distribution provides a quick facility to set-up this complex arrival pattern.

Time Absolute Distribution

The Time Absolute Distribution provides the user with the facility to define a time when an event will take place, with variation around that time. The user defines a time, and a Named Distribution will provide the variability around that time.

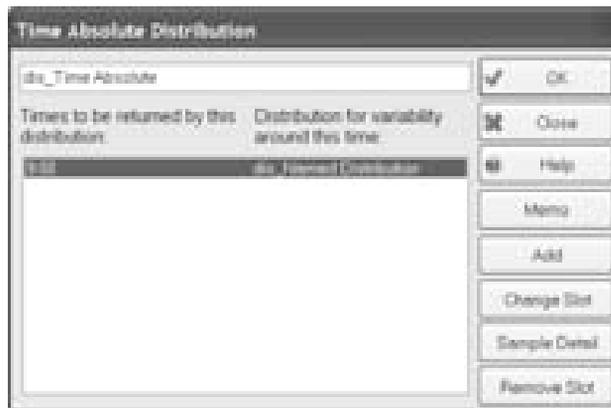


Figure 12-18: Time Absolute Distribution

To add or change the time slot, the user clicks on the appropriate option and makes the modification to the time slot or the Named Distribution which will be sampled from.



Figure 12-19: Changing the Time Slot for a Time Absolute Distribution

A good application for this distribution type is the scheduled arrival of an item, for example a mail drop, or truck arrival. The mail drop might be expected at 9:00 AM but will arrive between 8:30 AM and 9:30 AM, so the user could use a Normal Distribution to provide the schedule variance.

Label-Based Distribution

The label-based distribution simply states that the time associated with this event will be read from the label value on the current Work Item. The user simply states which label this value should be read from. The label value should be set previously.

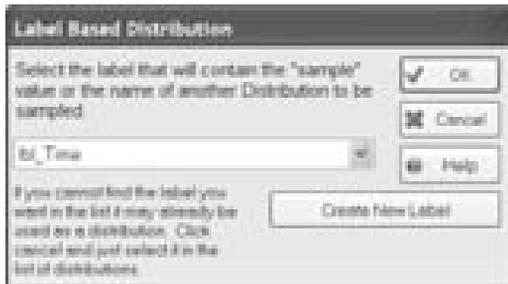


Figure 12-20: Label-Based Distribution

External Distribution

The External Distribution provides the utility to pick up the information required from an Excel™ spreadsheet or VB program. This utility has been available within the SIMUL8 from the days prior to the existence of the Information Store spreadsheet inside SIMUL8. During a simulation run, to maintain a good run speed, it is not advisable to communicate with an external package for distribution purposes. It is much more efficient to import the data from an external source on Reset Visual Logic and then to grab this data during the simulation run, as described in the next section.



Figure 12-21: Referencing an External Source for Distribution Values

Access Information Store

Reads distribution parameters from Information Stores (SIMUL8's internal spreadsheets). This option provides the easiest facility to do so. Simply state the location of information in the Information Stores; it is possible to use complex calculations, such as label-based row locations, too



Figure 12-22: Access Information Store Distribution

Double-clicking on the gray element in this option will access the Formula Editor for placing the location of the distribution time.



Figure 12-23: Enter the Spreadsheet Location for Access Information Store Distribution

As this option has no variation, often Pre-Sample logic and Named Distributions are used to read from spreadsheets and apply variability in the number sampled.

Bounded Distributions

If the user wishes to exert some control over a number sampled from a distribution, the bounded distribution provides the necessary features. The Bounded Distribution provides all the features of a Named Distribution with Standard distribution parameters, and pre-sample logic. However, the Bounded Distributions allows the user to constrain the random number sampling by applying lower and upper bounds.



Figure 12-24: Bounded Distribution Parameters

By entering a number in one of the bounds and checking the Resample option, the user bounds the distribution. This is especially useful with distributions such as the Exponential, which can move towards infinity.

Using Pre-Sample Logic

One of the most powerful uses of Distributions is the ability to alter the Distribution parameters based on a rule. Once a Named Distribution has been created, all of its parameters, including type, can be altered using Visual Logic. Below is a small example using Pre-Sample logic to alter the processing time at a Work Center based on a product label. A Work Center processing Product 1 will incur Normal 10, 2.5 minutes, while Product 2 will incur Exponential 12. The Named Distribution, dis_Processing Time, is altered using the following Pre-Sample Logic.

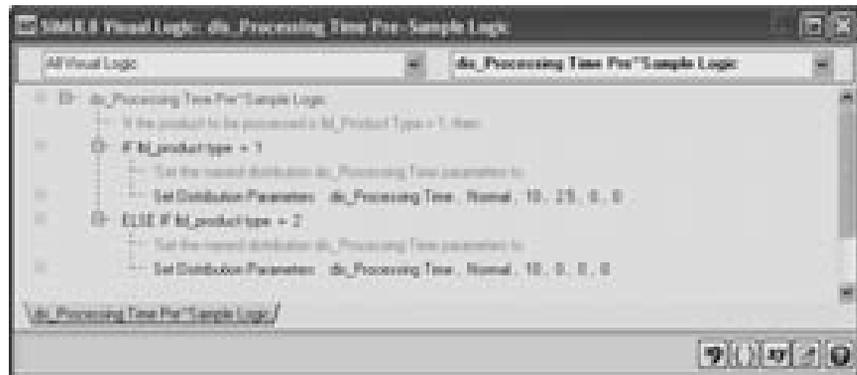


Figure 12-25: Using Pre-Sample Logic to alter a Processing Time

To learn more about Visual Logic, using If statements, the Formula Editor, and creating Commands, refer to Chapter 25: Visual Logic.

Chapter 13: Resources

Definition

Resources are one of the main SIMUL8 build objects, as introduced in the resource explanation on page 197. These objects are not used to create part of the workflow in the model; they are used to operate Work Centers. The most obvious examples of this are people: an operator required to operate machinery, doctors required for surgery, telephone operator at a call center desk, etc. Other examples could be tooling: machines dies, incubators at hospitals, etc. The reason for introducing Resources into the simulation model is that these Resources will restrict the workflow by their availability. If it can be assumed that a Resource would be permanently available to operate the Work Center, there is no need to introduce this dimension.

Creating and Attaching a Resource

Clicking, dragging, and dropping a Resource icon into the simulation window creates a resource.



Figure 13-1: Create a Resource

Once a Resource has been created, it needs to be attached to an individual, or multiple, Work Centers. There are two methods for attaching Resources to Work Centers; the first requires drawing an arrow between the Resource and the Work Center, while holding down the shift key. No arrow will be

drawn, as in normal workflow objects, but a message will appear, stating that the Resource requirements have been added to the Work Center.

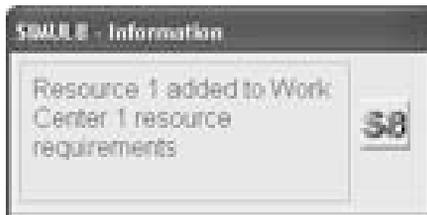


Figure 13-2: Adding a Resource

The second method for adding a Resource requirement to a Work Center is to double-click on the appropriate Work Center and access the Resources option.

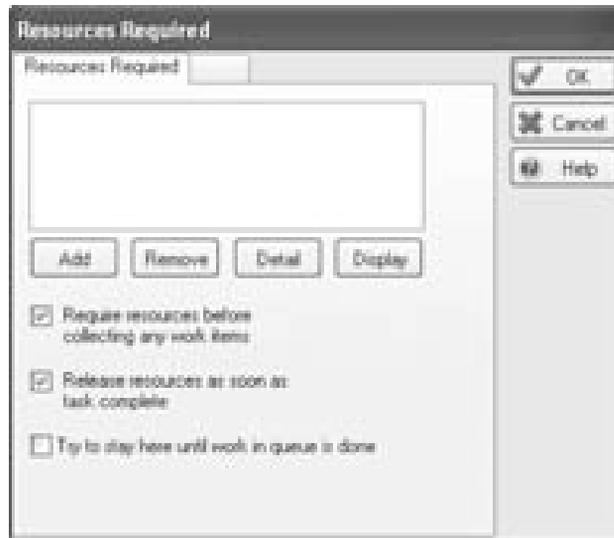


Figure 13-3: Resource Requirements

By clicking Add within this section, a list of all available Resources will be accessed. Select the appropriate Resource(s) required to operate the Work Center. Shift Patterns for a Resource working at a Work Center can be set in the Resource properties dialog. See Shifts on page 241.

Detailed Resource Requirements

Once a Resource is selected at a Work Center, many options can be detailed for the use of that Resource. The first is the manner in which the Resource is picked up and released. These options can be seen in Figure 13-3: Resource Requirements. If a Resource is required before a Work Item can be picked up, the first option should be selected. As this is the most common request, this is the default option and covers everything from ensuring a call desk operator is available before a call is accepted from the queue to ensuring an operator is available before a piece of work can be loaded onto a machine.

If a Resource is required to remain with the Work Item even when the downstream operation is blocked, the second option should be unselected. This is most commonly deselected when the downstream operation is a Conveyor and the Resource is required to move the item onto the Conveyor.

If a Resource should remain at the Work Center until there is no more work to be done, select the third option. Once a Resource arrives at the Work Center, it will not leave until the queue feeding that Work Center is empty. This can be useful in situations where the number of Work Centers requiring a Resource is greater than the number of available Resources, as it will prevent Resources from rapidly moving from Work Center to Work Center trying to complete work.

In some instances, a Work Center can be operated by more than one of the same Resource. Clicking on the Detail button as seen in Figure 13-3: Resource Requirements will access these options.

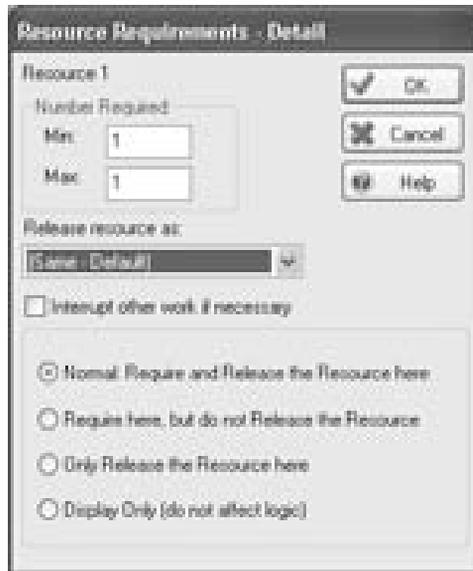


Figure 13-4: Resource Requirements Detail

By altering the Min. and Max number required, the Work Center will use as many Resources as available within that number range. The more Resources picked up by the Work Center, the faster the Work Center will operate. Twice as many resources will do the work in half the time; three times the resources, in a third of the time, and so on.

Options are also available for using the Resource sequentially. For example, if the simulation model is emulating an assembly line, or work cell, where the same Resource type operates all the Work Centers, it is possible to have the Resource currently selected follow the Work Item down the line, or around the work cell. If this is the case, the second option requiring the Resource at this Work Center (but do not release the Resource) should be selected. At the end of the line or cell, the third option should be selected to release the Resource back into the pool of available Resources.

Pooled Resources

If a Work Center can be operated by any one of a number of possible Resource types, a Resource Pool is required. A Resource Pool is a collection of available Resources, which is attached to a Work Center in the

same manner as a regular Resource. One member of the Resource Pool is drawn to the Work Center.

To create a new Resource, first select the Pool Resource option found under Resource Properties.



Figure 13-5: Resource Properties

Clicking on the Members button will open the Members dialog box.



Figure 13-6: Pooled Resource Member

In the example above, the Pooled Resource has both Resource 1 and Resource 2 available to complete the Work Center operation. Timing at the Work Center can be over-written by the Timing stated in the Members dialog. These are exceptionally useful when trainees are available to operate a Work Center, but at a slower speed, the timing can be entered as a delay

factor (original value x 100 %) or as the actual new timing at the Work Center, as in the figure below.



Figure 13-7: Pooled Resource Timed Delay by Resource Type

Resource Priority

Priority allows the user to specify the preference as to which Resource should be drawn to the Work Center. The list sequence defines that SIMUL8 will always attempt to use the Resource listed first; it will only use the second listed Resource if the first is not available. By switching to Circulate, SIMUL8 will assume that there is no preference as to which Resource is selected and will circulate evenly between the options.

Traveling Resources

When a Resource is available to work several different Work Centers, there can be travel time involved. This means that the Resource would not be available to operate the Work Center until the travel time has been completed. Double-clicking on the Resource, then Travel accesses travel times for Resources.



Figure 13-8: Resource Travel Times

All animation can be switched off if required, as this could potentially slow down the model execution. Travel times can also be updated automatically when Work Centers are moved, or an overall speed can be defined. Note if a speed is defined, care must be taken in the placement of objects within the simulation model

All Individual Journey Times can be specified by selecting the 'From' location, defined as a SIMUL8 simulation object, and the 'To' location, then entering the time (the units will change according to the defined simulation units). By selecting the Always check box, only the one-way travel times need to be specified. Click on 'Matrix of all journey times' to see the complete matrix; this will display all journey combinations.

Time From/To	Resource 1	Work Center 1	Work Center 2
Resource 1	0	0	
Work Center 1	0		2
Work Center 2	0	2	

Figure 13-9: Resource Travel Time Matrix

Not only can Journey Times be specified between Work Centers, but also from the Resource to the Work Center. This would be used if the Resource has a dispatch point where it/he/she returns to until it is required.

By accurately including all the detailed traveling requirements, shift availabilities, and detailed Resource task requirements it is possible to evaluate the total impact that Resources will have on the throughput of the system.

Resource Availability

Resource Availability models the time that a Resource is not available to perform work. It is similar in concept to Work Center Efficiency. There are two options for inputting Availability information: auto and detailed.

The auto option (see figure 13-12) requires that an availability percentage be entered to determine for how much time the Resource will be unavailable. An average absence time can also be input if desired. If this is left as “?”, an average absence time will automatically be generated by the simulation based on factors such as the length of the Results Collection Period. Average absence length is calculated according to an Erlang 2 distribution.



Figure 13-10: Auto Resource Availability Settings

Selecting the detailed option allows modeling of more sophisticated resource behavior. As with Work Center Efficiency, distributions can be input for both time between absences (either mean time between absences or mean cycles between absences) and time to return. Multiple absence types can be set up by creating a new absence type in the list on the right of the dialog (see Figure 13-13).

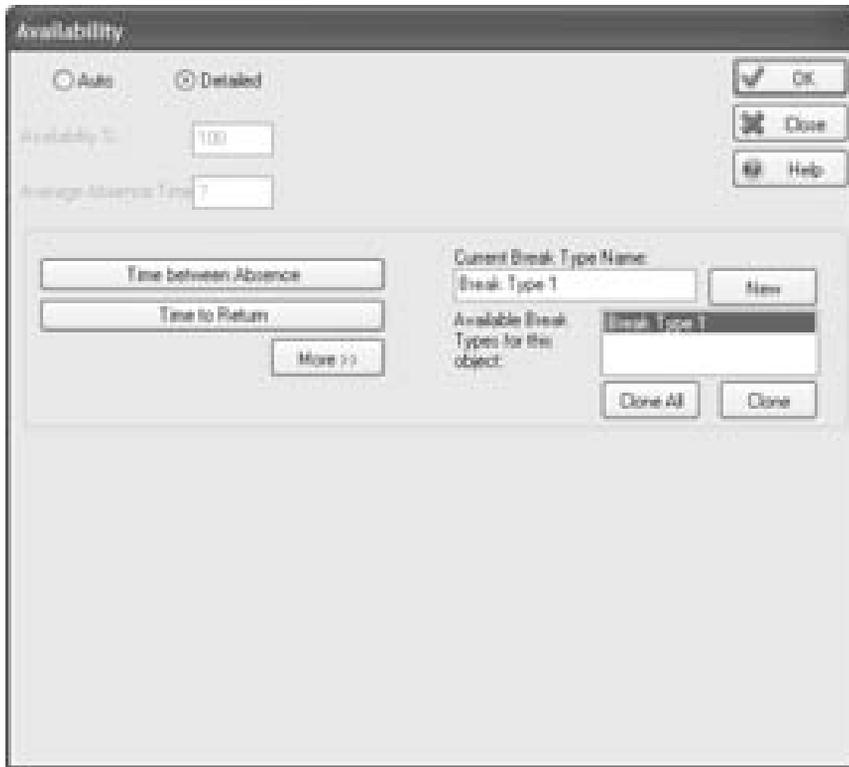


Figure 13-11: Detailed Resource Availability Settings

Detailed resource availability can be useful for modeling situations where resources must take specified breaks after a certain amount of working time, or when there are several types of breaks taken through the day (for example “long” and “short” breaks).

Chapter 14: Shifts

Definition

Shifts are used to schedule the availability of both Resources and Work Centers. During a simulation run, there may be times of greater availability of certain Resources or Work Centers. Instead of removing these entities, which is quite a complex process, simply set their availability by time of day and week by creating shifts.

Setting Availability - Shifts

Shifts can be created once a Resource or Work Center to which they apply has been created. For resources, check the Shift Dependent checkbox. For Work Centers, check the Shifts checkbox in the lower-right corner of the dialog box shown on page 156. Alternatively, proceed directly from the main menu under Clock > Shift Work Patterns.

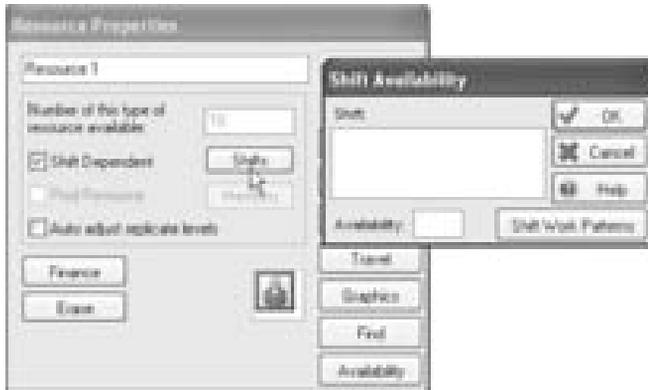


Figure 14-1: Resource Properties

This opens the shift availability dialog box, which contains a list of all the shifts that have been created for every type of Resource and Work Center. Click on the Shift Work Patterns button to add new shifts.

- Shift Patterns can be applied to both Resources and Work Centers ■

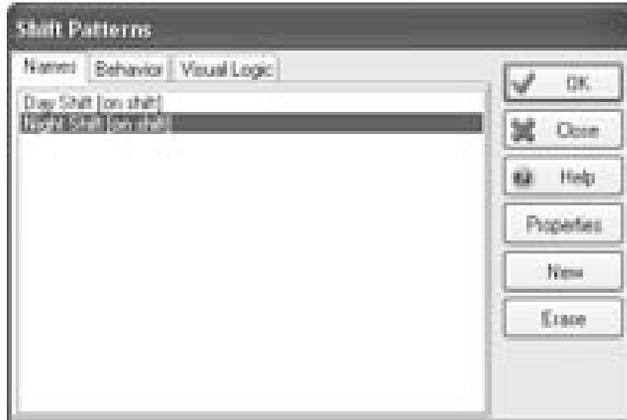


Figure 14-2: Shift Patterns

Shifts are defined by their start and end time, and by the days of the week to which they apply. Shifts that apply to specific dates must be input using the calendar feature discussed on page 200. Start and end times are entered in 24-hour clock time units, and daily patterns can be selected as appropriate from the Days options.

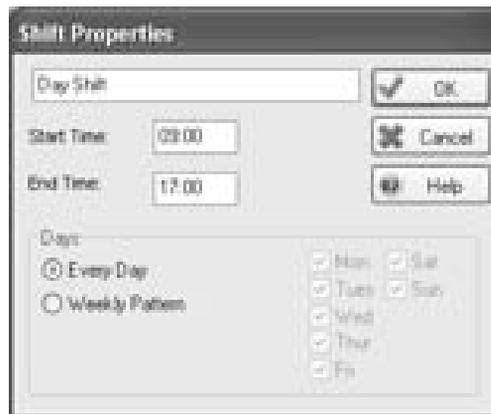


Figure 14-3: Shift Properties

SIMUL8 governs the shift change events, altering the number of the Resource type or Work Centers available according to the figures set in the

Shift Availability Dialog, accessed through the Shifts button as seen in Figure 14-4: Shift Availability below. After the shift has been created, shift availability can be set.



Figure 14-4: Shift Availability

For resources, there is no limit to the availability. Entering a figure in the 'Number of this type of resource available' box will provide that number of Resources for the entire simulation run time. However, for a given Work Center, there are only two options: available or not. Therefore, numbers greater than 1 should not be used.

Changing Between Shifts

When changing between different Shifts, there are different methods for handling these. The user is provided the choice between methods within the dialog displayed in Figure 14-5: Shift Patterns, on the 'Behavior' tab.

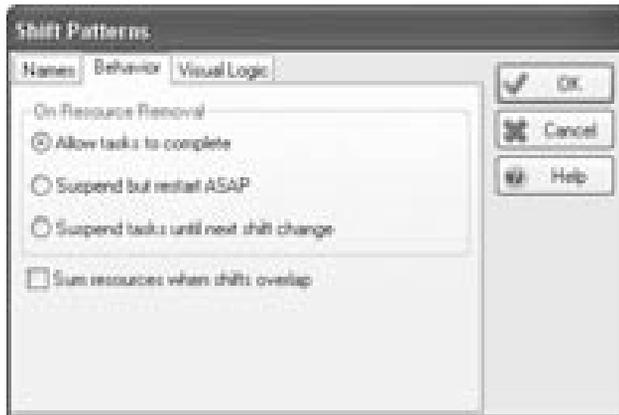


Figure 14-5: Shift Patterns - Behavior

When a shift changes, typically, a task will be in the process of being completed. The decision that has to be made is whether the task is completed or not. Typically, if the product being processed has a limited

shelf life or the cycle is short, the task will be completed before the Resource or Work Center is released from a shift. Sometimes this will result in a utilization of a Work Center or Resource of over 100%, but this is solely due to the extra work that is completed after a shift has ended.

However, if tasks can be suspended at the end of a shift, then two options are available and will be chosen depending upon the urgency of the job restart. If the first option is chosen, SIMUL8 will continue to look for a Resource or Work Center to commence the job every time one is available. The second option will allow the job to wait until another shift change occurs. By restarting ASAP, SIMUL8 will call many more events than waiting until the next timed shift change event. If model speed is a concern, the latter is the preferred option.

Visual Logic

Though we will deal with Visual Logic in another section, it is important to note that Shift Patterns provide a Visual Logic access point, both On Shift Start and On Shift End.

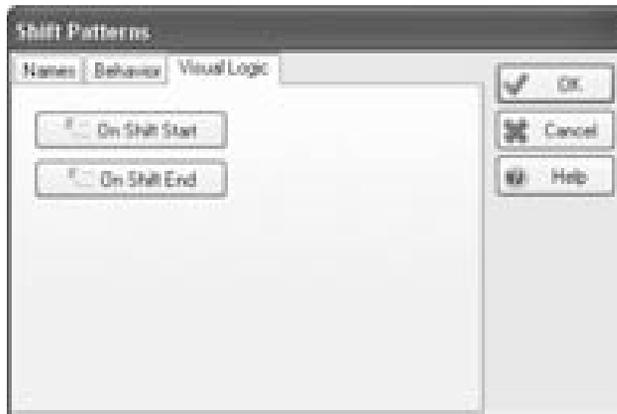


Figure 14-6: Shift Patterns – Visual Logic Access

Chapter 15: Priority

Definition

Priority in SIMUL8 has many different connotations. One simulation object may have priority over another for a number of different reasons. Priority could be used for determining the order in which Work Centers receive a shared Resource, the order in which Work Items are processed, or even which Work Center has control over the routing of Work Items.

Work Center / Resource Priority

If a Resource is attached to several Work Centers and one Work Center is more critical to the overall throughput than others (i.e. the system bottleneck), then it is important that this Work Center receives the Resource before any others do. In order to accomplish this each Work Center is given a priority value. Clicking on the Work Center Properties and then the Priority button will access the Priority dialog where the options of Fixed, Label and Combined by Multiply are given. These options are described in detail below.



Figure 15-1: Work Center Priority Options

1. Fixed value - The Work Center with the highest priority value will receive the Resource first. For example, Work Center 1 has a

priority value of 60 and Work Center 2 has a priority value of 50. If Work Centers 1 and 2 both require the same Resource, then Work Center 1 will obtain the Resource first, because it has the higher priority value. Note that all Work Centers will start with a default value of 50, giving no preference. The minimum value is zero, and maximum value is one hundred.

2. Label value –Resource priority can also be determined by a label. With this option, the Work Center that is waiting to process an item with the highest label value will receive the Resource first. For example, if the Queue for Work Center 1 has a Work Item with a `lbl_Importance` value of 5, but the Work Item in the Queue for Work Center 2 has a `lbl_Importance` value of 3, then Work Center 1 will receive the Resource first.

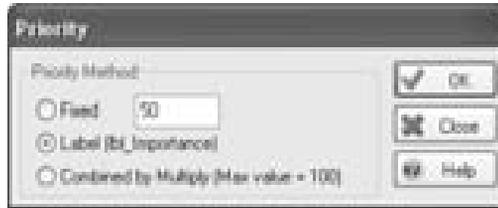


Figure 15-2: Priority by Label (`lbl_Importance`)

3. Combined by Multiply value – This option will take a combination of the Fixed value associated with the Work Center and the label value of the item about to enter. For example if Work Center 1 has a priority of 70, and a Work Type label value of 1 then its combined priority value is $70 \times 1 = 70$. Similarly, if Work Center 2 has a priority of 60 and a Work Type label of 2 then its combined value would be calculated as $60 \times 2 = 120$. However, the maximum priority value is 100, so the value given to Work Center 2 is actually 100. In this example, Work Center 2 will receive the Resource since it has the higher combined priority value.

Routing Out

Priority can also be give to the path Work Items take when exiting a Work Center. This type of priority is unrelated to resources. A list of the objects to which the Work Center may route work is given in the Work Center Routing Out dialog. When the Priority Routing Out discipline is chosen, this list represents the priority sequence, or the order in which routing out

objects are preferred. For example, in the figure below Queue 1 is given preference because it is the first object listed. As such, Work Items will always flow into Queue 1, unless it is blocked (i.e. at capacity). In the case that Queue 1 is blocked, preference will be given to the next object listed, and Work Items will flow into Queue 2.

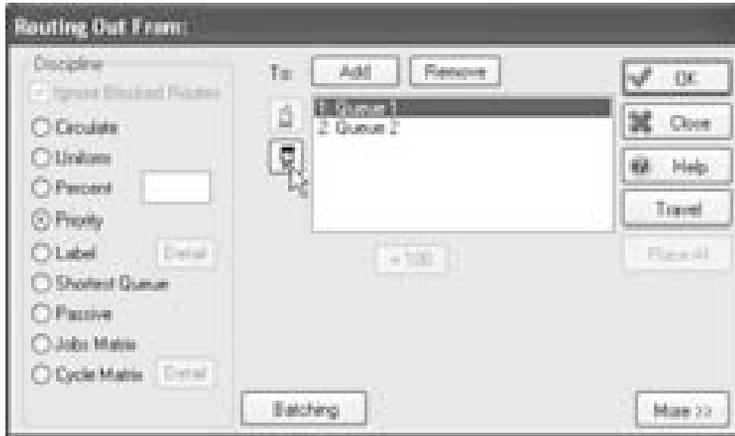


Figure 15-3: Prioritizing Work Center Routing Out

The priority sequence can be changed by using the up and down hand arrows to change the object order.

Routing In

A priority sequence can also be assigned to a Work Center's Routing In objects. Preference will be given to objects in the order they are listed. Consider the example shown in the figure below. In this example, Work Items enter Work Center 1 from one of two storage areas, with preference given to Storage Area 1. This means that Work Center 1 will accept Work Items from Storage Area 1 before accepting Work Items from Storage Area 2. Only when Storage Area 1 is empty will Work Center 1 accept items from Storage Area 2.

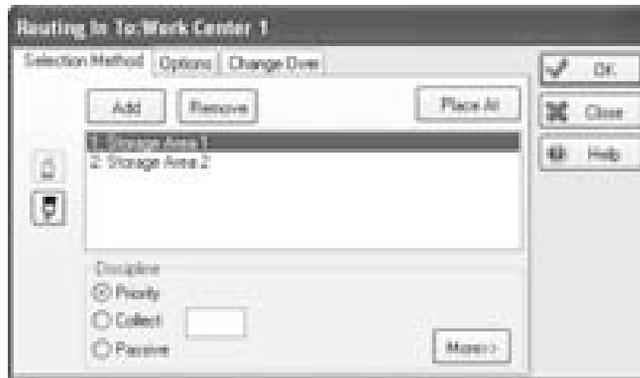


Figure 15-4: Routing In Properties - Priority Setting

The opposite of the Priority option is the Passive option, which gives the previous simulation object control over whether or not the Work Center should accept work. The previous simulation object cannot be passive, i.e. a Storage Bin, as it would be incapable of making decisions for the Work Center. Allowable feeding objects would include a Work Center routing out based on priority, or a Conveyor pushing Work Items in.

Label / Work Item Priority in Queues

SIMUL8 will allow work to be prioritized within a queue based on a label. In earlier versions of SIMUL8, this would have to be a label called Priority, however now any label can be used. By clicking on a Storage Bin / Queue's Properties and checking the box marked Prioritize, a list of potential labels will appear. To prioritize according to a label, select the appropriate label. SIMUL8 will now sort all Work Items in the queue according to the label value, from highest first to lowest. Alternatively, the user can choose to sort according to a reverse priority, where labels are sorted from highest to lowest.



Figure 15-5: Prioritize a Storage Bin

Note that the Storage Bin must be populated by another simulation object. If the Visual Logic command 'Add to Queue' has been used to populate the queue, the command will result in a non-sorted queue.

Interrupting a Work Center

The label called Priority has a special meaning in SIMUL8 and is used to determine the priority of items for interrupting a Work Center. A Work Center can actually be interrupted by another Work Center that is holding a Work Item with a higher priority label. The current Work Item will be pushed into a Storage Bin (specified at the Interruptible check box) until the prioritized work has been completed.



Figure 15-6: Interrupt a Work Center with a Priority Work Item

When the Priority label is created, a warning is displayed, advising the user that the Priority label has a special meaning in SIMUL8. If the user elects to continue, the Priority label will be activated for use in this context.

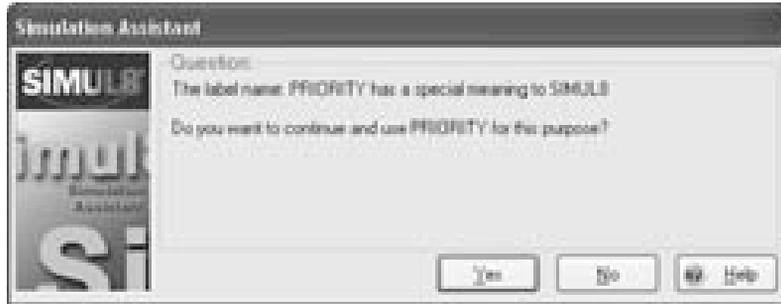


Figure 15-7: Accepting Priority Label's Special Meaning

Consider the example where Work Center 1 feeds Work Center 2. Work Center 2 is set to route interrupted items to Queue 2, an unrelated queue. Work Center 2 is processing a low-Priority Work Item when a Work Item with a higher Priority exits Work Center 1. Since the item waiting to enter Work Center 2 has a greater Priority value than the item currently in it, the low-Priority item will be interrupted. Work Center 2 will send the interrupted Work Item to Queue 2, and receive the priority item from Work Center 1 immediately.

When the high-Priority item is complete, the low-Priority work will continue from where it was interrupted. To accomplish this, a Work Item label called Due must be created. Like the Priority label, the Due label has a special meaning. It will store the remaining working time for the interrupted Work Item. A small piece of Visual Logic must be executed to do the following:

IF Due > 0 Then

Set Distribution Work Center Timing: Fixed, Due, 0, 0, 0

End if

Chapter 16: Efficiency

Definition

Efficiency options are provided in the Work Center and Conveyor objects to provide a method of simulating downtime. The efficiency option works by preventing objects from working during all available simulation time. The Efficiency feature can accommodate Mean Time To Failure (MTTF), Mean Cycles Between Failure (MCBF), Mean Time To Repair (MTTR), and other such statistics.

Automatic

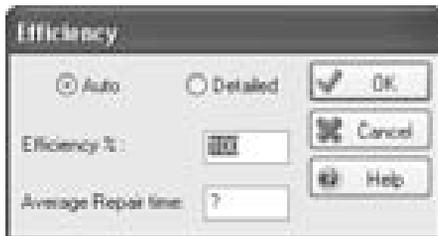


Figure 16-1: Auto Efficiency

To set auto efficiency, a percentage is entered to determine how much time the object will spend broken down. An average repair time can be entered. If this is left as “?”, the simulation will automatically repair the object at a rate that is consistent with its working speed. SIMUL8 calculates automatically MTBF figures and uses negative exponential distributions for MTBF and Erlang 2 distributions for repair time.

Detailed



Figure 16-2: Detailed Efficiency

Detailed efficiency allows more control over the timing and nature of breakdowns and repairs to Work Centers and Conveyors. It is possible to specify how often a breakdown will occur and how long it takes to repair the Work Center or Conveyor.

Time between Breakdowns

The time between each breakdown can be specified using any of the distributions available in SIMUL8 or using a specially created distribution. See the section on Distributions on page 213.

1. Time or Cycles – MTBF is selected to specify the amount of time between each breakdown that occurs. MCBF (Mean Cycles Between Failures) is selected to specify how many cycles occur between each breakdown. This means that a number of Work Items or batches will be processed before a breakdown occurs.

- Only count busy time – This option is used in conjunction with the MTBF option. If the box is checked, only working time will be counted when calculating the time between failures. If the box is not checked, elapsed time will be counted when calculating the time between failures.



Figure 16-3: Time between Breakdowns

Time to Repair

The time taken to repair when a breakdown occurs can also be specified using any of the distributions available in SIMUL8 or using a specially created distribution. See the section on Distributions on page 213.



Figure 16-4: Time to Repair

1. Resources – Resources may be required to repair the object. Resources can be added or removed as required. For each Resource, further detail can be specified. See Chapter 13: Resources.
2. The detail button sets the minimum and maximum number of Resources to be allocated for the repair. If more Resources are available, the repair can be completed more quickly. See Chapter 13: Resources.



Figure 16-5: Repair Resource Requirements

3. The display button allows the Resource to be displayed beside the Work Center when it is being used there. The Display at Work Center check box allows this option to be switched off or on. The position of the Resource in relation to the Work Center can be set automatically or by using the X and Y coordinates.

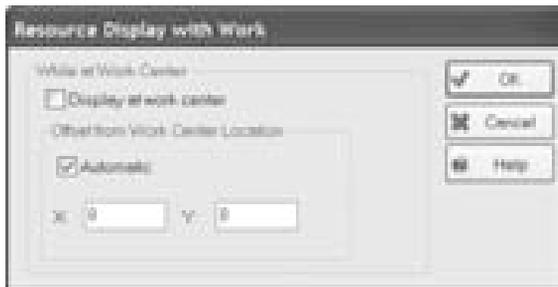


Figure 16-6: Repair Resource Display

When a breakdown occurs

When equipment breaks down, there are a number of options that can be selected to control how Work Items are processed.

1. Close feeding queues – Any Storage Bins that feed the object will stop receiving Work Items.
2. Stop work immediately – The Work Center will not complete processing the current Work Item before breaking down.
3. Extend breakdown by time to empty queue – This option is available if 'Stop work immediately' is not checked. It allows the processing of the Work Item to be completed before the object becomes unavailable.

Breakdown Types

Equipment may have more than one type of breakdown. For example if a machine has two working parts, each of which fails according to its own rules, this can be represented by adding a second breakdown type. One part might break down after a number of cycles and require only a short time to repair. The other part may break down after a certain amount of working time and take a long period of time to repair.

A breakdown type can be added by clicking the “New” button, and removed with the delete button on the keyboard. Specifications for each breakdown type can be entered separately by selecting from the “Available Breakdown Types for this object” list box. Current Breakdown Type Name displays the breakdown type that has been selected. This box can be used to change the name of the breakdown type.



Figure 16-7: Efficiency Breakdown Types

Visual Logic

Visual Logic is available for breakdowns. It can be used either when the breakdown occurs, on start of the repair, or when the repair has been completed.

Chapter 17:

Routing In

Definition

Routing In describes the method of selecting Work Items at a Work Center from the upstream objects.

When building a simulation model, it is crucial to accurately capture the processing rules for work in the system. The simulation must be capable of managing how items are selected at a Work Center. For example, certain items may be of higher priority, or a Work Center may be required to collect and assemble a certain number of different items.

There may also be information that must be known before selecting a piece of work. One example is the type of work the Work Center is able to process. Another example is whether or not there is somewhere to send the Work Items after processing.

Set-up or changeover times must also be considered when an item or number of items has been collected at a Work Center. Changeover times can be dependent on a number of different factors including the type of work, and how many items have been processed since the last changeover.

Selection Method

The selection method On Routing In to a Work Center allows the users to apply rules or decisions on how to feed that Work Center. Objects, which feed the Work Center, can be viewed in the Selection Method tab. Objects can be added to or removed from the list using the routing arrows on the main simulation screen or the Add and Remove buttons provided.



Figure 17-1: Selection Method

Priority

The priority option will ensure that the Work Center gives priority in descending order to objects in the list. This means the Work Center will attempt to collect from the first object listed. If no items are available, it will move on to the second object on the list and so on. The pointers to the left of the Selection Method tab allow priorities to be changed.

Collect

The collect option is used when the Work Center is required to take several specific Work Items from different objects on the list. This is useful when modeling a station that assembles a collection of parts. For each of the items on the list, a collect number can be specified. This number determines how many Work Items of each type are required in order for the items to be processed. There are further options provided to control the collection of the required Work Items.

1. Do not collect until all available – If checked, none of the Work Items required by the Work Center will be routed in until all of the required items are available. If unchecked, items will be routed into the Work Center as they become available, but will not be processed until all have been routed in. Note that this does not

■ When collecting and assembling multiple Work Items, final label values are set to the highest of the collected values unless otherwise specified. ■

affect the processing time. Processing only begins after all required Work Items have been collected.

2. Match – Only items that have the same value for the specified label will be collected.
3. Assemble – All of the Work Items collected will be combined together to form a single Work Item.

When multiple Work Items are assembled, the user must define how the time in system for the resulting assembled Work Item is calculated. This definition impacts the time-in-system results, which can be found in the results summary or the Work Exit Point results.

1. First Collected – The entry time to the system stamped on the first Work Item routed in is used.
2. First in List – The time stamped on the first source item on the list is used.
3. Youngest – The time stamped on the item that has been in the system the least amount of time is used.
4. Oldest - The time stamped on the item that has been in the system the longest amount of time is used.
5. Set to Now – The time is set to the current simulation time.

When the Assemble option is checked, the user also has the option of setting all labels of the assembled product according to three rules:

1. Highest – The Assembled product takes the highest label values from each of its parts.
2. Lowest – The Assembled product takes the lowest label values from each of its parts.
3. Selected – The Assembled product takes the label values of the part coming from the selected upstream operation.

■ The maximum collect number is 10,000 if using manual input ■

◆ The maximum collect number is 32,000 when set in Visual Logic ◆

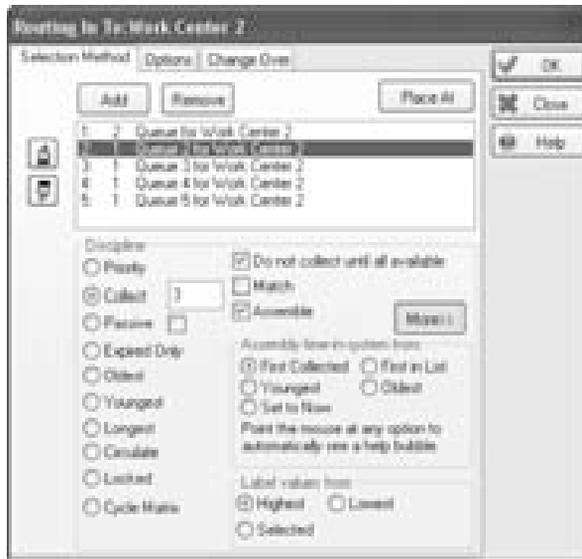


Figure 17-2: Routing In Collect Selection Method

Passive

The passive option is used to prevent the Work Center from pulling Work Items in. If this option is selected, the Work Center will not actively route in Work Items but will simply wait until items are pushed into it much like a Storage Bin. This is commonly used when one Work Center feeds another and the flow is to be determined by the upstream Work Center.

Expired Only

This option will allow the Work Center to route in only those items that have surpassed their shelf life as defined in an upstream storage bin. This is useful for reworking expired Work Items before returning them to the system, or sending them on to an “expired item” Work Exit Point.

Oldest

The Work Center will route in the Work Item that has spent the longest time in the system.

Youngest

The Work Center will route in the Work Item that has spent the shortest time in the system.

Longest

The Work Item will be routed in from the object on the list containing the largest number of Work Items (generally the storage bin with the longest queue).

Circulate

Items will be routed in from each of the objects on the list in turn. If the Ignore Starved option is checked, the Work Center will move on to the next object on the list when there are no Work Items available. If this option is not checked, the Work Center will wait to route in a Work Item before moving on to the next object on the list.

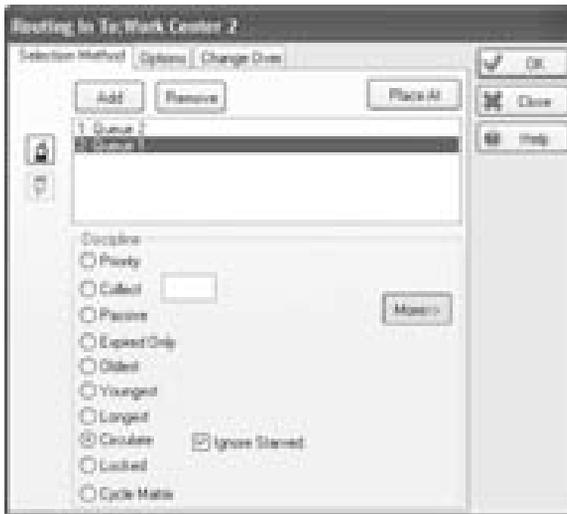


Figure 17-3: Routing In Circulate Selection Method

Locked

Only the highlighted object on the list will be used to route in Work Items when the locked option is selected. To prevent the Work Center from routing in from any of the objects on the list, select this option and

immediately click OK. To select a particular object for routing in, select the option and click on one of the objects on the list before clicking OK. This option is most commonly utilized through Visual Logic to switch off certain storage areas.

Cycle Matrix

This option routes in to the Work Center according to the cycle matrix. See the section on Cycle Matrix on page 279 for more information.

Options

Special options are provided to allow further control over the routing in of Work Items to the Work Center. These include the ability to stop working on the current item in favor of another, use labels to batch in a number or sequence of Work Items and prevent the Work Center from routing in Work Items until it has a clear exit to route them out.

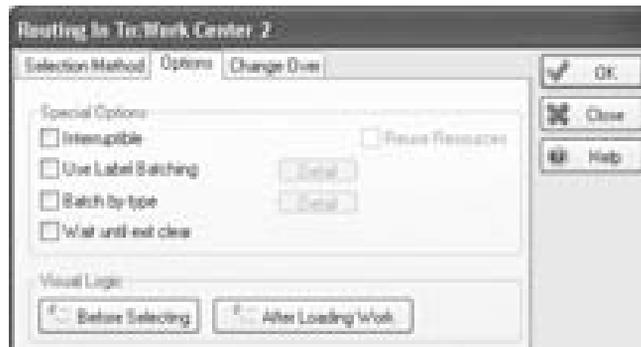


Figure 17-4: Routing In Options

Interruptible

This option means that if a Work Item with a higher priority is ready for processing, the Work Item currently being processed is sent to a Storage Bin to await completion. This is useful when certain work has precedence and is used in situations where scheduling is important.

Use Label Batching

The values of the selected label are added together on available Work Items. Items are routed in if the total value of their labels is between the minimum

and maximum levels. The Use button determines which label should be used.



Figure 17-5: Routing In Label Batching Options

Batch by Type

The Work Center will attempt to route in items with the same label value as the last Work Item it processed. When there are no more items with this label value available, it will move on to the next Work Item. This is commonly used to minimize the number of changeovers required. If the 'Use fixed value' option is checked, the Work Center will only route in Work Items that have a specific label value.



Figure 17-6: Routing In Batch by Type Options

Wait Until Exit Clear

The Work Center will not route in any Work Items until the exit route for the Work Item is able to accept it.

Changeovers

Work Centers have the ability to allow a changeover or set up time. This will be set either when the Work Item has been collected or after a certain amount of working time has elapsed. The timing for changeovers can be set using the distributions provided in SIMUL8 or using a pre-created distribution.

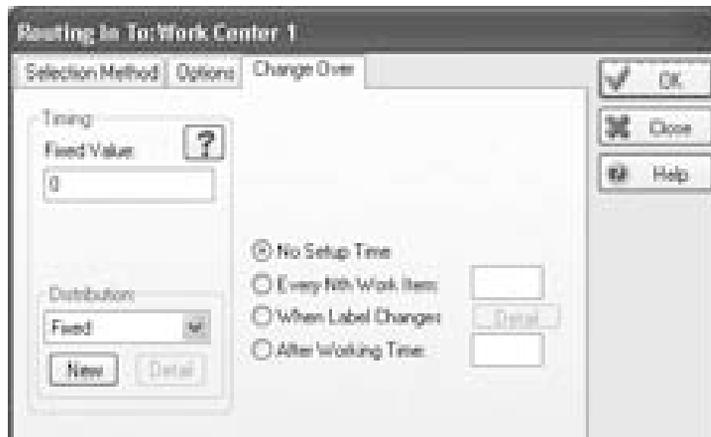


Figure 17-7: Routing In Changeover

No Setup Time

There will be no setup time applied.

Every Nth Work Item

The number entered will determine how many items are processed before the changeover time will be applied. For example, if 4 is entered, the Work Center will process 4 Work Items and then require a changeover or setup.

When Label Changes



Figure 17-8: Routing In Changeover When Label Changes

When the value of the selected label changes, the changeover time is required. This might be useful if we are processing different product types or items that require painting different colors.

After Working Time

The changeover will be required when the Work Center has completed the specified amount of working time.

Chapter 18: Routing Out

Definition

Routing Out describes the method through which Work Items are moved from a Work Center to the downstream objects when work is complete at the current Work Center.

Routing Discipline

The Routing Out disciplines are available at Work Entry Points, Work Centers, and Conveyors. This chapter discusses Routing Out methods for a Work Center. The same methodology, however, generally applies to Work Entry Points and Conveyors as well.

Ignore Blocked Routes

Several potential disciplines exist for routing out to multiple destinations. If the check box for 'Ignore Blocked Routes' is activated, routes to destinations that are blocked (i.e. Storage Bins at capacity or Work Centers not ready for more Work Items yet) are ignored. Instead, the Work Center will attempt to move Work Items to the next available destination given the current routing discipline.

- Leaving the 'Ignore Blocked' option unchecked could block the Work Center unnecessarily ■

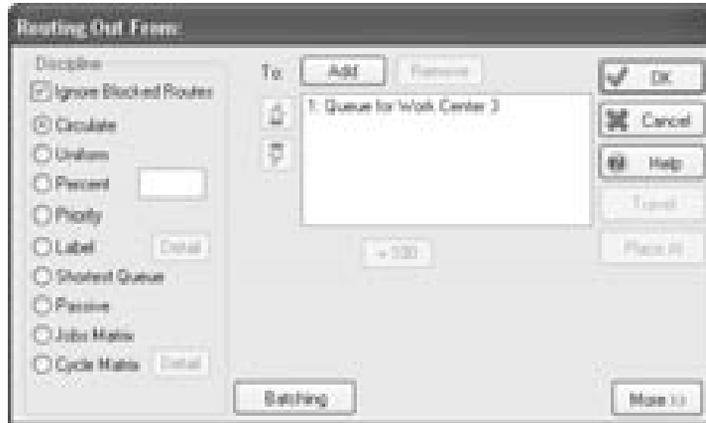


Figure 18-1: Routing Out Disciplines

Circulate

Circulate moves Work Items in an incremental fashion in the order shown in the list, much like dealing out a deck of cards. When the end of the list is reached, the Work Center will route Work Items to first item in the list if possible. The user can change the routing order by selecting a destination from the list and pressing the 'Move Up List' (finger pointing up) or 'Move Down List' (finger pointing down) button to rearrange the list.

Uniform

The Uniform discipline for routing randomly distributes the output from the Work Center among the choices with a uniform probability.

Percent

Using a percent for moving Work Items from a Work Center will distribute the work from the Work Center to the choices with probabilities equal to the values specified by the user.

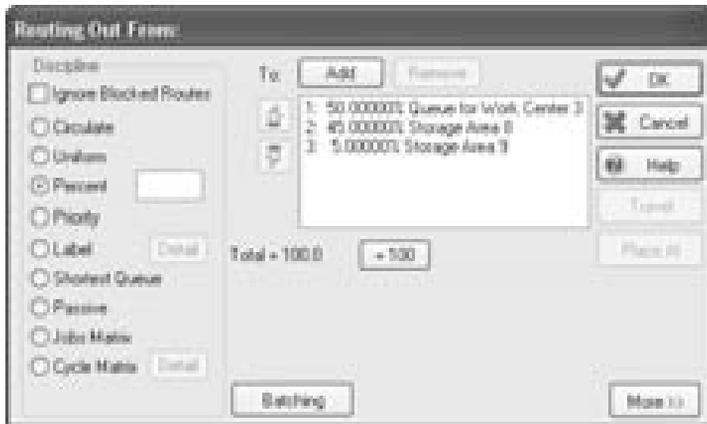


Figure 18-2: Routing Out - Percent Discipline

To specify the percent routed to each object, select the destination from the list and type the percent in the field beside the 'Percent' heading. If the exact percent is not known and instead a ratio has been estimated, type the ratio values for the desired destinations and then press the '=100' button to automatically calculate percentages.

Priority

The Priority option routes Work Items according to the order in the list. Output from the Work Center will always go to the first object in the list (i.e. highest priority) unless it is at capacity or otherwise blocked. If the first destination is unavailable, work will be routed to the next in the list and so on until an available destination is found. As before, the user can rearrange the priority list by selecting destinations from the list and moving them up or down using the up or down buttons.

Label

For complete control of where Work Items go, Label-based routing should be used. It allows the user to specify the exact destination of Work Items based on the numeric value of a label.

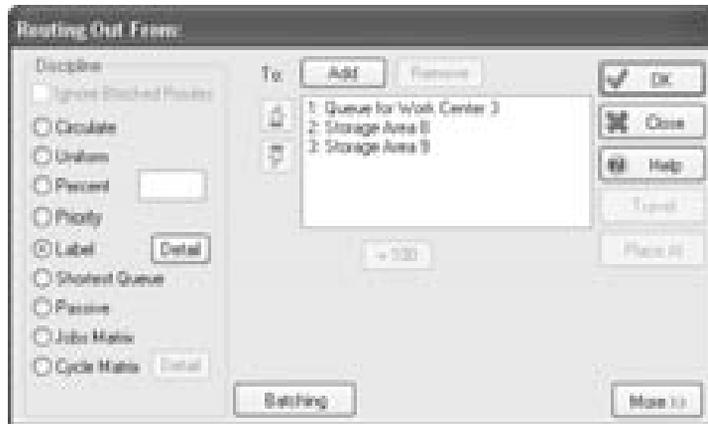


Figure 18-3: Routing Out – Label

In the above list of potential destinations, if the designated label on a Work Item has a value of 1 then the Work Item will be routed to “Queue for Work Center 3”, if the value is 2 then the destination is “Storage Area 8”, and if the value is 3 then the Work Item is sent to “Storage Area 9”. Note that in this case if the value on the label is anything greater than 3 the Work Item will be sent to Storage Area 9. If the label is set to 0, the Work Center then becomes blocked.

Press the ‘Detail’ button to specify which label determines the routing.



Figure 18-4: Routing Out –Label Details

Shortest Queue

When the Shortest Queue option is chosen, the current Work Item is routed to the object in the list that contains the fewest Work Items. No option is available for blocked routes since the Work Center automatically defaults to ignore them.

Passive

Passive routing is used when the user wants the Work Center to be treated as a passive object. More specifically, the current Work Center does not actively move Work Items out from it when work is complete. Instead, the object downstream must actively route in Work Items from the current Work Center.

Jobs Matrix

The Jobs Matrix is a method of setting routings in a multi-product, multi-stage process such as that found in a Job Shop. See Alternative Routing/Timing Methods on page 275 for more information.

Cycle Matrix

The Cycle Matrix is used when the emphasis is not on the flow of work, but rather the sequence of steps taken at a Work Center. See the section in Alternative Routing/Timing Methods on page 275.

◆ Note that Shortest Queue routes to the destination object with the least Work Items and NOT the smallest proportion of capacity ◆

Travel

To set the travel time from the current Work Center to a specific destination, select an object from the list and press the "Travel" button. The following dialog box will appear where the user can input the exact travel time in the current simulation time units.



Figure 18-5: Routing Out – Travel Time

Note that the travel time input is not available for Conveyors, since they are meant to take work items directly to their destination. Travel Time is only available from Work Centers to Storage Bins or Work Exit Points.

All travel times in the simulation can be set to zero through File > Preferences > Distance. See Simulation Preferences on page 165.

Batching

Batching is a method of splitting one Work Item into multiple duplicate Work Items, as if it were a batch of similar parts. The default is “Fixed 1”, meaning that for every Work Item that enters a Work Center or the simulation through a Work Entry point, one exits. (Note: when items are collected, they are assembled into one Work Item by default, and a single item is routed out.) Press the ‘Batching’ button to view the dialog below.



Figure 18-6: Routing Out – Batching

In general, a fixed distribution is used for batching out at a Work Center or Work Entry Point. However, a user can employ any distribution in the list including named distributions and probability profiles. The number of Work Items leaving the Work Center will always be a whole number and all label values will be identical to the original Work Item. If the check box ‘Use for High Volume Quantity’ is selected, the batching value will be applied to the Quantity label instead of the number of duplicate Work Items. Note that batching is not available at Conveyors.

- Create a user-defined distribution to use for the batch size ●

Routing Out Options

Note that these options are available only at Work Centers and not Work Entry Points or Conveyors. Press the 'More >>' button to access the Routing Out Options for the Work Center.

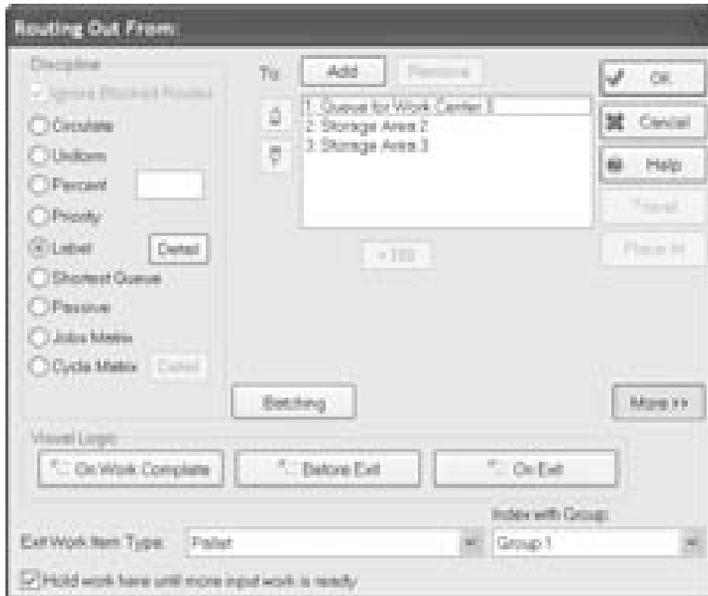


Figure 18-7: Routing Out – Work Center Options

Visual Logic

Visual Logic can be accessed through the 'On Work Complete,' 'Before Exit,' and 'On Exit' buttons (See chapter on Visual Logic on page 345).

Exit Work Item Type

When Work Items leave the Work Center, they can be converted to a different Work Item type. Note that multiple Work Item types must be available for this feature to function. The default, recommended approach is for the Work Item type to remain the same as when it entered.

Index with Group

This feature is used when Work Items only move when the last Work Item in a group of objects is ready to be moved. See section on Indexing with a Group on page 298 for more detail.

Hold Work

When the 'Hold work here until more input work is ready' option is checked, Work Items are not allowed to leave the Work Center unless a new Work Item can be routed in from an upstream object.

Chapter 19:

Alternative Routing/Timing Methods

Definition

Several options exist for routing out from a Work Center or Work Entry Point without using routing arrows. These methods allow the user much greater control over the flow of Work Items within a simulation model. The three main alternatives are using a Look Up table, a Jobs Matrix, or a Cycle Matrix.

■ Alternative Routing Methods can be used in a simulation alongside conventional flow routing ■

Jobs Matrix

The Jobs Matrix is useful for handling situations in which there are a large number of locations to which work can flow, including multiple repeat passes through the same Work Centers, or many ways of performing the same task on an item of work. The Jobs Matrix itself is a table of information that controls complex routings and timings when multiple product types exist.

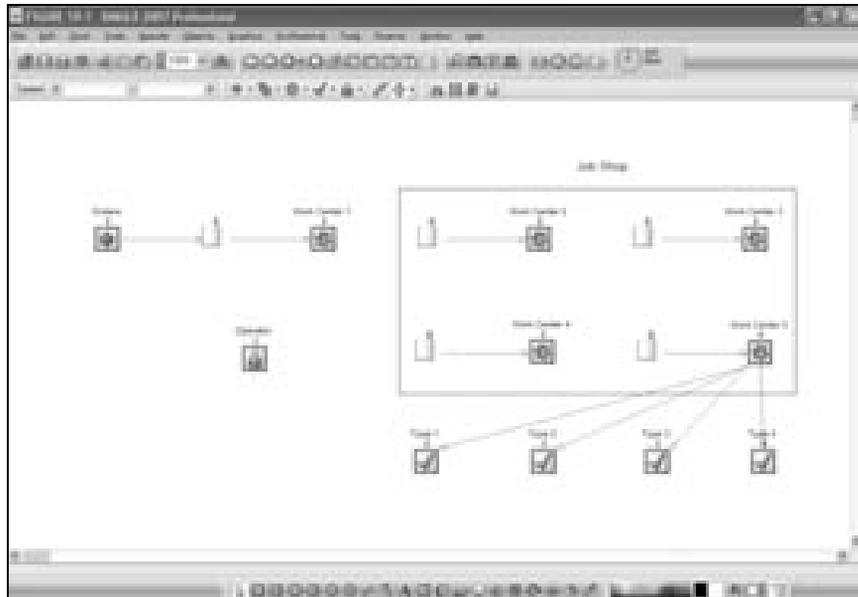


Figure 19-1: Example Simulation Screen Capture for Jobs Matrix

To access the Jobs Matrix, select Objects > Jobs Matrix.

Work Type	Job	Location	Timing	Change Over
1	2	Work Center 2	10	2
1	3	Work Center 3	Distribution1	0
1	4	Work Center 2	8	1.5
1	5	Work Center 5	6	0
2	2	Work Center 3	Distribution1	0
2	3	Work Center 5	7	2.2
3	2	Work Center 4	Distribution3	0
3	3	Work Center 5	8	0

Figure 19-2: Jobs Matrix

Each row in the table represents a job or a task at a certain stage for a specific work type. The columns in the matrix have specific meanings.

Work Type

Work Type is the name of a special label on the Work Item. Its content is used to distinguish between the different types of work or products. In this case the simulation contains three types of work numbered 1, 2, and 3.

Job

Again, Job is the name of a special label on the Work Item. Every time the Work Item is processed by a Work Center that uses the Jobs Matrix for timing information, this label is automatically incremented by one. In this case, Work Type 1 enters Work Center 2 on two different occasions but at different stages in the process (i.e. Job 2 and 4). Job can be interpreted as the task number for the Work Type.

Location

Location is the name of the Work Center that will do the work for the specified work type at the specified stage. Type the name of a Work Center or double-click the cell to choose from a list of Work Centers.

Timing

Timing is the amount of time the job will take to process. Enter a number here for a fixed value or double-click the cell to choose a named distribution. This time will only be used if the Work Center has been set to use the Jobs Matrix for Timing by clicking the Work Center's Properties > Timing > Use Jobs Matrix radio button.

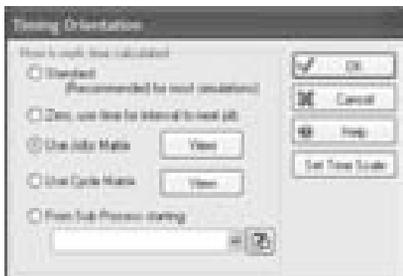


Figure 19-3: Jobs Matrix Timing

The properties dialog for the Work Center will appear as below when the Jobs Matrix timing is used in lieu of specifying a processing time.



Figure 19-4: Jobs Matrix Timing Selected

Changeover

If the Work Center is set to use a changeover time for routing in and the Jobs Matrix for timing, the time or distribution in the changeover cell of the Jobs Matrix will be used when changing over. Set the Jobs Matrix cell contents to -1 to instruct the Work Center to use its own changeover information.

Routing Out

All work centers using the Jobs Matrix, as well as the Work Center that first sends work items into the Job Shop, should have their route out disciplines set to "Jobs Matrix". This will ensure that jobs move through the model as detailed in the Jobs Matrix table. The only exception to this rule is for the Work Center that is performing the final Job in the Job Matrix. In this case the route out discipline will be set as required to move the product to the next object in the model (i.e., a Work Exit Point).

Cycle Matrix

The Cycle Matrix is used when the emphasis is placed on the sequence of steps taken at a Work Center instead of on the flow of work. It is particularly useful when a Work Center is used for doing a series of tasks but the user does not want to represent each task as a separate Work Center.

The Cycle Matrix defines the cycles of activity at each Work Center that uses the Cycle Matrix. Set a Work Center to use the Cycle Matrix using the Work Center's Timing Orientation dialog and in the Work Center's Properties > Routing Out > Cycle Matrix.



Figure 19-5: Cycle Matrix Timing

After setting the Timing Orientation to Cycle Matrix, the following dialog will be shown for the Work Center Properties.



Figure 19-6: Cycle Matrix Timing Selected

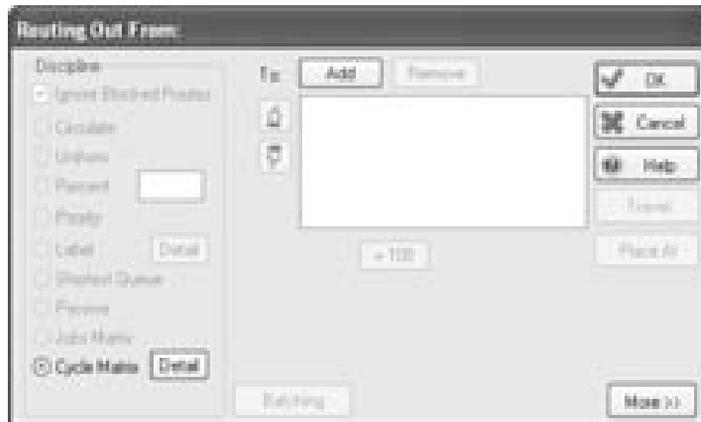


Figure 19-7: Cycle Matrix Routing Out

Access the Cycle Matrix through Work Center Properties > Routing Out > Detail, through the menu Objects > Cycle Matrix, or with the Ctrl-K shortcut. Each row represents a stage in the list of tasks that a Work

Description

The description can be any text that acts as a reminder about the task. It is not referenced by SIMUL8 when running the model so there are no formatting restrictions.

Task Type

Task Type describes the kind of task to be performed. Type the text name of the task or double-click to choose from a list of available types. The Task Type affects the meaning of some other Cycle Matrix columns.

Double-click a cell in this column to choose one of the following task types.



Figure 19-9: Cycle Matrix Task Types

The following Task Types are available:

UNLOAD FROM

This Command takes a Work Item into the Work Center from the simulation object listed in the “From/To” column. If the “Work Type” and/or “Job” columns are empty, any Work Item may be loaded from the specified objects (using priority rules defined externally to the Cycle Matrix). Otherwise the “Work Type” and/or “Job” columns are used to check the labels of the Work Items available in the specified object and only Work Items that match will be loaded. (Work Type must match the value in the Work Item’s label “Work Type” and Job must match the value in the Work Item’s label “Job”)

The Time column determines the time taken to perform the loading operation.

If the Work Item is not available for loading, the Work Center will wait in this stage until it is able to start the loading time. (See Waiting % result column below).

LOAD TO

Send the Work Item to the simulation object listed in the From/To column. If this route is blocked, time is recorded in the Waiting% result column as shown below.

WORK

Work for the amount of time in the Time column (the time may be a reference to a distribution or calculation).

If the WORKTYPE and/or JOB columns are non-zero, the labels of the Work Item will be tested. If they do not match, this task will be skipped. This lets the user specify several different tasks to select from depending on the nature of the work to be done.

WAIT BEGIN

Do nothing until the simulation object in the From/To column is in the State in the State column. The state can be defined with a generic state such as "EMPTY" or "LOADED" or may be a Task Number listed for the referenced Work Center elsewhere in the Cycle Matrix. A Work Center can reference itself for this type of task. For example WC1 might WAIT until WC1 is LOADED because some other Work Center in the Cycle Matrix has a task that will LOAD TO WC1.

Values in the State column must be positive.

WAITEND

Do nothing until the simulation object in the From/To column has completed the State in the State column. If the simulation object in the From/To column is not in the specified state when this row of the Cycle Matrix is entered, wait until the simulation object in the From/To column is in this state and then wait until it is complete.

"EMPTY" and "LOADED" (see WAIT BEGIN above) are not supported for this type of task.

Values in the State column must be positive.

GOTO

Instead of going to the next row in the Cycle Matrix, go to the task number in the State column. The number may be a variable or calculation. If the result of the calculation is -1, the Work Center will wait in this state. If the result of the calculation is 0, the Work Center will go to the next task in the list whatever its task number. Immediately before the calculation is evaluated, the Visual Logic in the Visual Logic column will be obeyed.

Work Type

This cell can be left blank or set to an integer value to specify the required value in the Work Item's "Work Type" label. (See LOAD TO above)

Job

This cell can also be left blank or a set to an integer value to specify the required value in the Work Item's "Job" label. (See LOAD TO above)

From/To

For tasks that communicate with other simulation objects, this column contains the name of the simulation object. Type the object name or double-click the cell to select from list of available objects.

Time

This cell is used to specify the time for the stage of the cycle. As always, the time units are specified in SIMUL8's *Clock Properties* menu. Alternatively, specify the name of a Named Distribution to be sampled to obtain the time, or the name of a Global Data Item variable that will contain the time, or a calculation to obtain the time.

State

Used to specify a stage to wait for, depending on the content of the "Task Type" column, see above. It must be text or a Task Number that some Work Center must be in.

For example if the Work Center should wait until "MyOtherWorkCenter" is in its cycle matrix row that contains "26" in column "TaskNumber" then enter 26 in the State column and WAIT in the TaskType column. Alternatively, if the Work Center should just wait until

“MyOtherWorkCenter” is empty then enter “EMPTY” in the TaskType column.

Permitted values for State are any positive integer value, “EMPTY” or “LOADED.”

(Note that “EMPTY” and “LOADED” are not supported for WAITEND Task Types)

Image

This specifies the image to be displayed while the Work Center is in this stage. Type the name of the SIMUL8 Image (from Graphics > Images list) or double-click the cell in the Cycle Matrix to select from the available list. Leave this column blank to have SIMUL8 use the images listed in the normal Work Center/ Graphics image animation dialog.

Stage

If the simulation has been run and the Work Center has referenced the Cycle Matrix to decide what to do next, this column will indicate with an arrow the currently active stage of the cycle at the Work Center. (This is a read-only cell).

Waiting%

This section holds some of the results data. The percentage of time the Work Center has spent in this stage but not actually performing the stage because the Work Center had to wait to start the stage. For example, for a LOAD stage the Work Center will record waiting time in the stage if the required Work Item is not available to load. This is a read-only cell.

Active%

This is another section that holds results data. The percentage of time the Work Center has been working in this stage. For some stage types, this will always be zero. For example, WAIT type stages, where as soon as the waiting reason is satisfied, the Work Center moves to the next stage in the cycle. This is also a read-only cell.

Cycles

This is another section that holds read-only, results data. This is the number of times the cycle has been started.

Chapter 20: Other Objects

Conveyors

Conveyor Properties

Many of the basic Conveyor constructs were introduced in the SIMUL8 Basics chapter. This section will discuss those concepts in greater detail. As stated previously, a Conveyor moves Work Items within the simulation model from one point to another. In simulation terms, a conveyor is a cross between a Work Center and a Storage Bin. This is because it takes a certain amount of time to move from beginning to end and there can be many items in the object at once, each at a different point in the process.

By specifying Conveyor length and speed and Work Item length, the Conveyor determines the number of Work Items it can hold and the length of time it will take to travel from one end to another.

Picking and Placing with Conveyors

As a Conveyor does not always move Work Items from one distinct place to another, there can be many pick up and place at points on the conveyor. More advanced features can be used in conjunction with Conveyors. By linking a Work Center to a Conveyor, both on routing in and on routing out, new features can be accessed to control the routing.

To feed a Conveyor at a specific place on the Conveyor, go to the Work Center Properties and Routing Out.

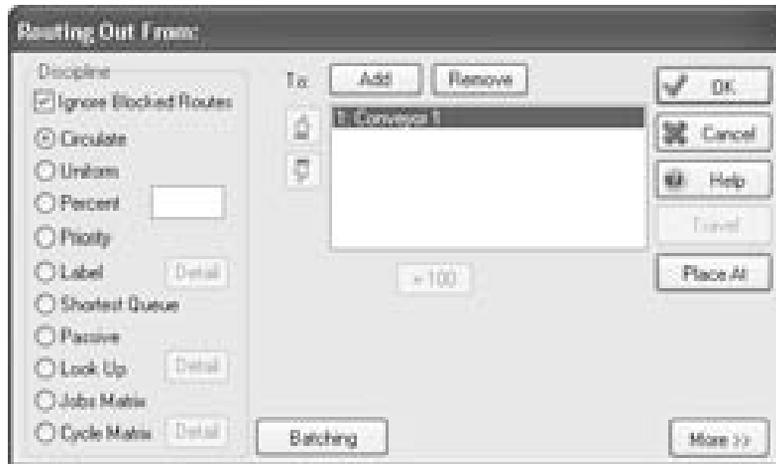


Figure 20-1: Routing Out to a Conveyor

By selecting the Conveyor in the list of routing out options, the 'Place At' button will become active. By clicking on this button, it is possible to state where the Work Center lies in relation to the end of the Conveyor. As always, the distance units are set under File > Preferences > Distance.



Figure 20-2: Conveyor Pick Up/Drop Details

Select the check box and then state the number of feet this Work Center is from the end of the Conveyor. Note that this refers to the end where items leave the Conveyor, not where they enter the Conveyor. The simulation model will now route Work Items out of this Work Center and on to the Conveyor three feet from the end, it will travel three feet on the Conveyor and then continue downstream.

Picking Work Items from a specific point on a Conveyor requires some adjustments to be made to the Work center on Routing In. By opening the Work Center Properties, and selecting the Routing In option, the following screen should be available.

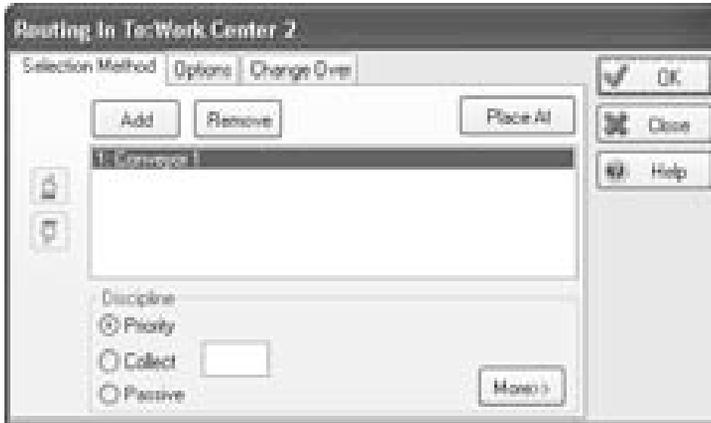


Figure 20-3: Routing In from a Conveyor

By selecting the Conveyor, the Place At button should become active. Select this option to access the dialog seen in Figure 20-2: Conveyor Pick Up/Drop Details. This allows the user to state where to pick Work Items from when feeding from a Conveyor.

This feature should be used in conjunction with the Pick Area as defined in the Conveyor Properties. The pick area defines the area around the placement of the Work Center from which the Work Item can be picked up. For example if the pick area is one foot, and the Work Center Pick Up point is specified as four foot from the end of the Conveyor then the Work Center can collect items from 3-5 foot from the end of the Conveyor.

If the Pick and Place functions described here are not available, check Help > About to see which Version of SIMUL8 is running. If it is less than Version 10 and these features are required, an upgrade is required.



Figure 20-4: Conveyor Pick Area

Tanks and Pipes

Although continuous flow or liquid management has been available in SIMUL8 Professional for some time, Tanks and Pipes are new features within SIMUL8 Standard. Tanks and Pipes are used specifically for modeling a continuous flow of work instead of distinct Work Items or batches.

Tank Properties

A Tank is used like a Storage Bin except that the work inside it is undifferentiated and is measured in terms of mass instead of individual Work Items. The user can specify the capacity of a tank as well as the start up level of contents. The units of measurement are specified under File > Preferences > Continuous.



Figure 20-5: Tank Properties

On the Visual Logic tab, the user has many options for times when Visual Logic can be triggered including: On Full, On Change From Full, On Pass Up (a specified mass), on Pass Down (a specified mass), On Change From Empty, and On Empty. See the section on Visual Logic on page 345.

Visual Logic is called at the following times:

- On Full – When capacity is reached.
- On Change From Full – When capacity was reached and then the contents go down to less than capacity.
- On Pass Up – As the contents go above the specified level.
- On Pass Down - As the contents go below the specified level.
- On Change From Empty - When work enters an empty tank.
- On Empty – When the tanks becomes empty.



Figure 20-6: Tank Properties – Visual Logic

Creating a Tank

Tanks can be found in the Build Tools2. Right click on the menu bar and select Build Tools2 or select Objects > Advanced > Tanks to activate/show the toolbar.



Figure 20-7: Tank Button – Build Tools2

Pipe Properties

Pipes allow the continuous movement or flow from one tank to another. Properties are as follows:

- Flow rate – the speed at which material is loaded into the pipe.
- Output % - the percentage of material that exits the pipe into the downstream tank.
- Delay – the length of time it takes the material to travel from one end of the pipe to the other.

Double-clicking the center of a pipe in the simulation window will open the pipe properties dialog, as will double-clicking a pipe listed in the Input Summary.



Figure 20-8: Pipe Properties

Creating a Pipe

Pipes are not located in the Objects menu or as a button in Build Tools2. Instead, Pipes are automatically created when two tanks are connected. When tanks are created on the screen, they will be automatically connected. To link or unlink the tanks, the same method is used as with any other objects and pipes are created or deleted as appropriate.

Chapter 21:

Groups

Definition

Groups in SIMUL8 are a collection of simulation objects that either have similar characteristics or work together in some manner. A good example of a group is a collection of three Work Centers that represent a machine's loading time, working time, and unload time. If the three Work Centers are grouped together and the capacity limit of the group is set to one, this effectively simulates one machine.

Creating a Group

To create a group, select the appropriate objects (Ctrl and select, or drag and draw a box) and then click right.

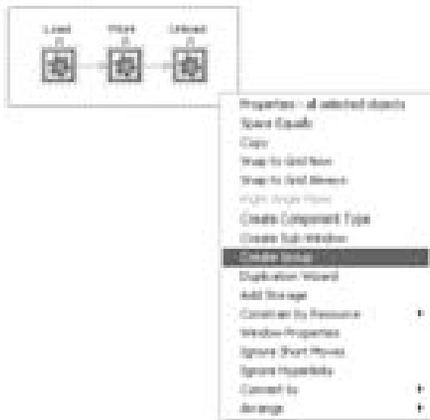


Figure 21-1: Create a Group

Group Properties

To see the Properties of the Group created or to create a new group, select Objects > Groups.



Figure 21-2: Group Properties

Once a group has been created, objects can be added, removed, erased, and duplicated from within the group.

Properties of the group include:

1. Limit the Work Items that can be held within all the objects at any one time. For example if the group represents the machine's load, work and unload Work Centers, then the group can only hold one Work Item at any one time, as above.
2. Provide Efficiency and Breakdown details for the group. Of course, this is limited to groups with Work Centers and not for groups with Storage Bins only.

There are two different types of results that can be extracted from the group. The most common type is the typical Work Center results summary provided instead for the entire group, as shown below.

Indexing with a Group

Indexing is a function that is utilized heavily within the manufacturing industry to represent multiple inline Work Centers that are tied together. In this way, work only moves from any given Work Center if all other Work Centers within that group have also completed their respective tasks. Work will then move from each Work Center simultaneously.

Once a group has been created, it is possible to index the line using all the objects within that group. This can be accessed through Work Center Properties>Routing Out.

◆ A group must be created and selected before any Work Centers can use indexing ◆

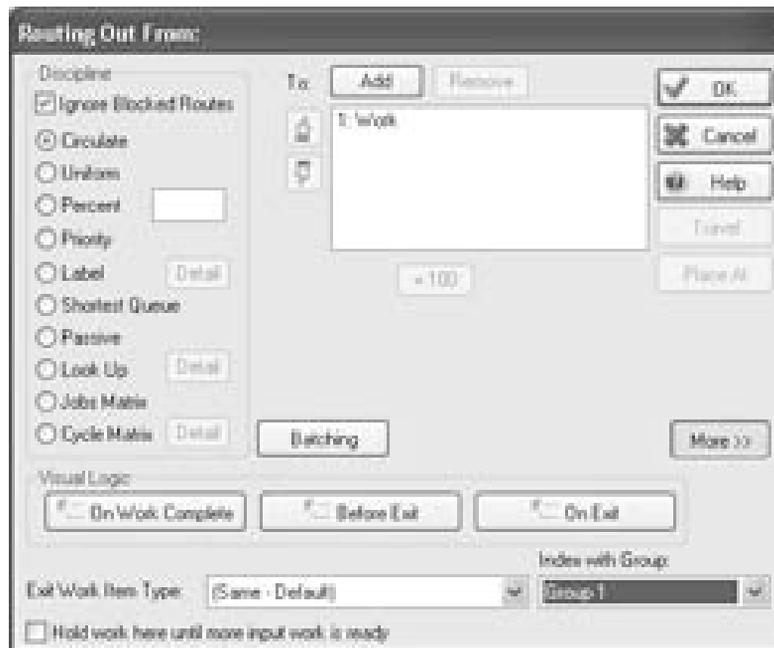


Figure 21-5: Indexing with a Group

Chapter 22:

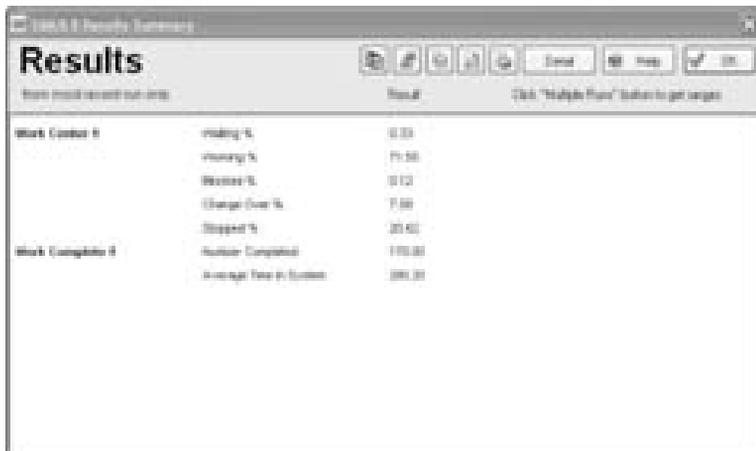
Results

Definition

SIMUL8 collects a number of results from any given simulation run. Results such as number of jobs completed, average time in system, etc, can be viewed at the end of a simulation run or a trial.

Results Summary

The Results Summary is a quick and convenient place to view results for a simulation run. Users must specify which results should be displayed. There are two ways to add results to the summary. Either click on the results button of any of the SIMUL8 objects and right-click the desired result, or click the Detail button in the Results Summary window.



The screenshot shows the 'SIMUL8 Results Summary' window. It has a title bar with the text 'SIMUL8 Results Summary'. Below the title bar is a section titled 'Results' with a toolbar containing icons for 'Clear', 'Copy', and 'Print'. Below the toolbar is a table with the following data:

Item	Result	Value
Work Center 1	Waiting %	0.00
	Inventory %	75.00
	Blocked %	0.00
	Change Over %	0.00
	Stopped %	0.00
Work Complete 1	Number Completed	100.00
	Average Time in System	100.00

Figure 22-1: Sample Results Summary

To view the current run's results, open the results summary using either the Results Summary button on the toolbar or select Results > Results Summary. The name of the simulation object is shown in the left most column followed by the specified result. The right most column contains the result value for the current run.

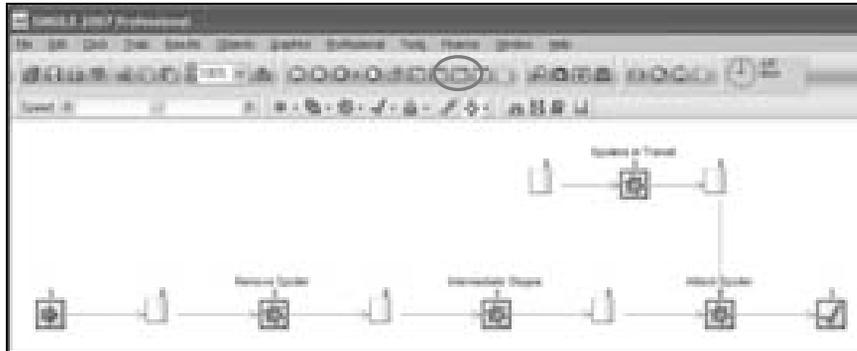


Figure 22-2: Accessing the Results Summary

The left-most button at the top of the Results Summary (shown in Figure 22-1) is used to compare results from various simulation runs. Click the button to view the comparison spreadsheet.

		Run 4:41:12 PM 11	Run 4:42:36 PM 11
Work Center 1	Waiting %	0.33134	0.31773
Work Center 1	Working %	71.54532	72.0562
Work Center 1	Blocked %	0.12323	0.36768
Work Center 1	Change Over %	7.58431	6.96142
Work Center 1	Stopped %	20.41528	19.99637
Work Complete 1	Number Completed	170	172
Work Complete 1	Average Time in Syst	290.20346	440.93633

Figure 22-3: Comparison Spreadsheet

By pressing the Compare button when viewing the Results Summary for a run, the program opens the spreadsheet that displays run results. The time and date will be displayed as the header for the run result. The results can be copied to the Clipboard using the left most button, deleted from the

sheet using the middle button, and options viewed using the right-most button.

The second button from the left on the Results Summary dialog can be used to conduct multiple runs, also called a trial. The third button copies the displayed data to the Clipboard so it can later be pasted into other applications, such as Excel™. The fourth button from the left is used to preview the results sheet before printing it.

Results		
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Change Cost 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00
Work Order 1	Waiting 11	11.00

Figure 22-4: Results Print Preview

On the Print Preview window, several options are available to change the zoom level, move between results sheets, set up print options, print, save, open, or close.

On the Results Summary sheet, the Print button is located next to the Preview button and sends the results to the default printer. The Detail button shows all objects in the current simulation.

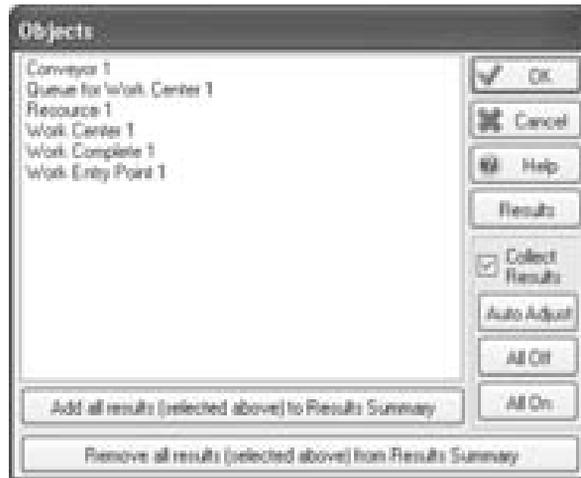


Figure 22-5: Simulation Objects Available for Results Collection

The user must select a simulation object and then make a choice: add all results for the object to the Results Summary, view the results for the object (Results button), choose whether or not to collect results, auto adjust, or turn all results collection on or off.

Object Results

All of the objects on the simulation screen in SIMUL8 have standard results available for collection and viewing at the end of a simulation run. They are accessible by double-clicking on a SIMUL8 Object and choosing Results.

Work Entry Point Results

The Work Entry Point Results dialog displays a few simple statistics, including the number of Work Items entered and number of Work Items lost in a case of blocking of the Work Entry Point.

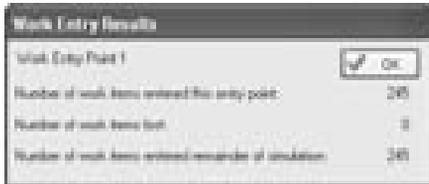


Figure 22-6: Work Entry Results

Storage Bin Results

Storage Bins have considerably more results to view. These include the number of Work Items in storage (current, minimum, average, maximum, and total entered), queuing time (minimum, average, maximum, standard deviation, and information about non-zero queuing time), and queuing time within limit.

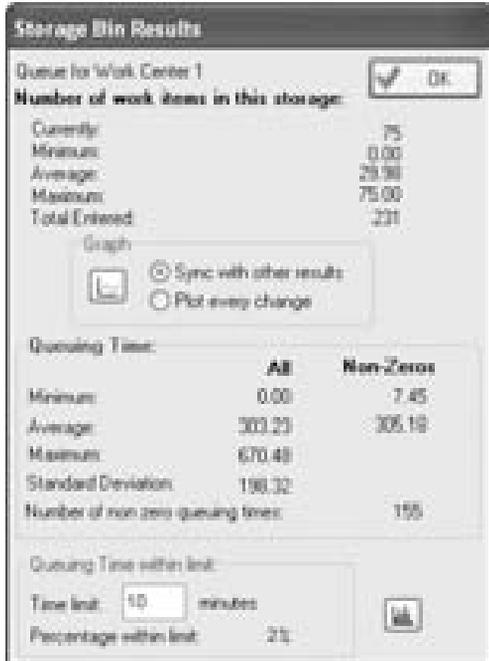


Figure 22-7: Storage Bin Results

The contents of a Storage Bin can be graphed and dynamically displayed by pressing the Graph button along with selecting either “Sync with other results” or “Plot every change.” Of course, “Plot every change” provides

greater accuracy, but it also requires more time. See Result Charts on page 316 for more detail.

For Queuing Time within limit, enter a value in the field for Time limit. A percentage for the number of all Work Items that have spent less than the time limit in the Storage Bin is displayed. Also, pressing the bar chart button displays a histogram of the distribution of Work Item queuing times at the Storage Bin.

Work Center Results

Work Centers, like Storage Bins, show results for number of Work Items (current, minimum, average, maximum, and total number of completed jobs) but also display percent time results for six Work Center states (awaiting work, working, blocked, stopped, changeover, and off shift).

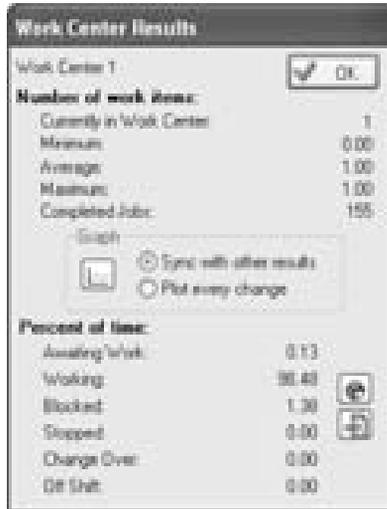


Figure 22-8: Work Center Results

Pressing the appropriate button will create charts or graphs of this data. A time graph of the contents of the Work Center is shown when the “Graph” button is pressed. A pie chart displaying the percentage of time spent in various states for the Work Center is displayed when the pie chart button is pressed. The button at the bottom of the dialog sends all of the Percentage of time results to the Results Summary.

Conveyor Results

The results displayed for Conveyors consist of the number of Work Items on the conveyor (current, maximum, average, and minimum number of items) along with a time graph of the contents, time on Conveyor (minimum, average, maximum, and standard deviation), and percentage of time the conveyor spent in different states (empty, moving, blocked, stopped).

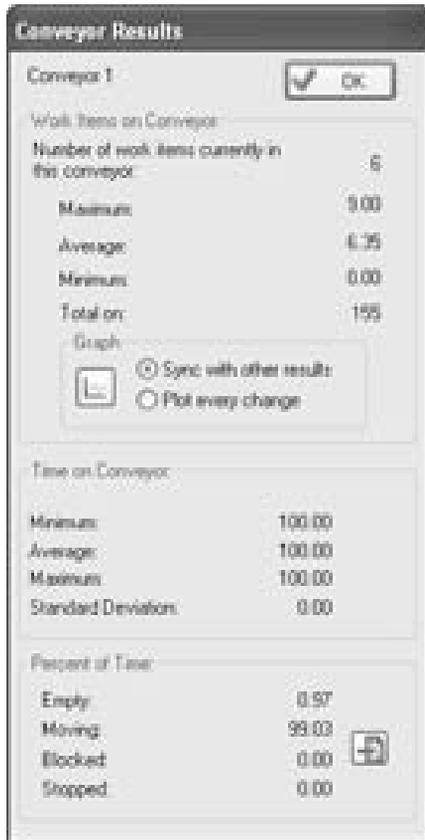


Figure 22-9: Conveyor Results

Work Exit Point Results

The Work Complete Results dialog box shows the number of Work Items completed, the time in system (minimum, average, maximum, and standard

deviation), and time in system within a user-defined limit. Changing the value in the time limit field will show the percentage of all Work Items that leave the system within that amount of time.



Figure 22-10: Work Complete Results

Resource Results

The Resource Results dialog shows utilization results for a particular Resource. Utilization % is the average percentage of time that each unit in the resource grouping spent working. For example, if there are 5 of a particular Resource type present and 4 of them spend the whole simulation working while the fifth did no work, Utilization will be 80%. Traveling % works in a similar fashion, reporting average percentage of time spent traveling. Clicking the Detail button will display the total time spent moving between each pair of locations in a tabular format. Note that both of these results are calculated as a % of available time.

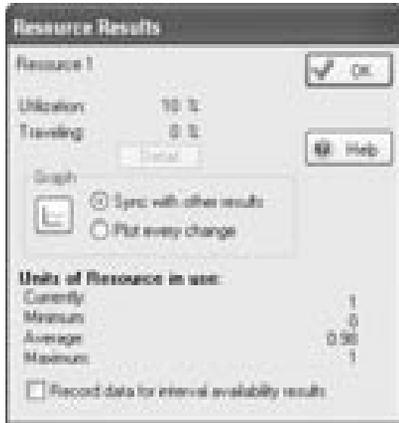


Figure 22-11: Resource Results

The bottom of the dialog displays the number of units of the Resource that were in use over the course of the simulation (current, minimum, average, and maximum). Pressing the Graph button displays a usage graph showing the number of resources in use over time.

Segregating Results on Labels

The results for Storage Bins and Work Exit Points can be broken down in finer detail by segregating the results based on a label. To enable results segregation, click the Segregate Results check box in the object's properties dialog.



Figure 22-12: Storage Bin Properties - Segregate Results



Figure 22-13: Work Complete Properties - Segregate Results

SIMUL8 will then prompt the user to choose a Label on which to segregate the results. Note that a simulation can have multiple Labels, but the user can only segregate results based on one of the Labels. For example, a product type Label will be more useful for segregation than a time stamp Label.



Figure 22-14: Select a Label for Segregation

The simulation must be reset and run again before any segregated results can be collected. The user will be asked to reset and run before attempting to view results again.



Figure 22-15: Advice - Segregate Results

Segregated results can be viewed after resetting and running the simulation again. The user can select which category of segregated results to view from the dropdown menu in the Results dialog. These results can be added to the Results Summary just like any other (see Customizing the Results Summary).

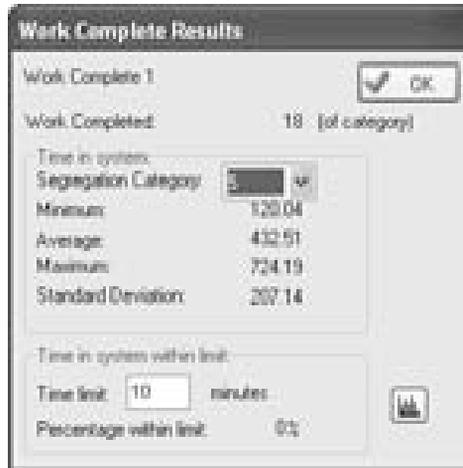


Figure 22-16: Work Complete Results - Segregated

The categories for segregation will only be displayed in the dropdown list if there were Work Items with that label value passing through the object (i.e. a segregation category for 542 will not be a choice unless a Work Item with a value of 542 on the segregation label entered Work Complete 1). The categorized and segregated results can be added to the Results Summary just like any other result.

Customizing the Results Summary

When opening a new simulation, the Results Summary will only display the average time in system for Work Items at a Work Exit Point. The user can customize the Results Summary to show result statistics for any of the values displayed in the various object results. To do this, open the results for the desired object and hover the mouse pointer over the desired result. When the mouse pointer is a black arrow with an “R” inside it, the user can click the right mouse button to add this specific result to the Results Summary.



Figure 22-17: Add to Results Summary Pointer

Another way to customize the Results Summary is to open it, as described in the Results Summary section above, and press the Detail button. Here, the user can choose various objects for which to collect results statistics. This way they can all be added from one central location instead of browsing through each object.

Trials and Confidence Intervals

The Results Summary can be opened at any time to view the results from the most recent simulation run. Each simulation run will yield the same results if neither the Random Stream Set Number nor any simulation parameters have been changed. When a simulation model has been validated and is ready for conducting experiments, a single simulation run is usually not sufficient since the user seeks to generate an expected range for results and not just a single data point. Therefore, the user should conduct a trial that consists of multiple simulation runs with a different random number seed for each run. To conduct a trial, select Trials > Conduct a Trial > Ok and Run the Trial.

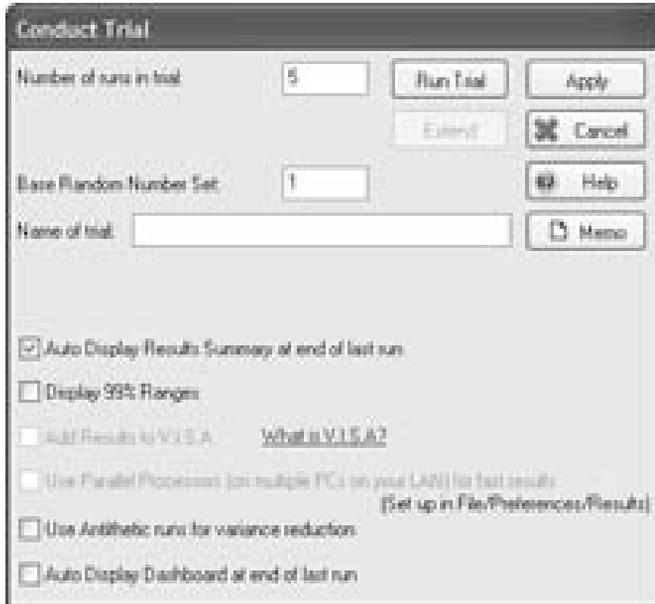


Figure 22-18: Conduct Trial

The user may specify the number of runs in a trial, the base random number set, a name for the particular trial, whether or not to have the Results Summary and Dashboard automatically appear at the completion of the trial, and the confidence interval to display.

■ Click the range titles to choose confidence intervals from 80 to 99.9 ■

		Low 95% Range	Average Result	High 95% Range
Block Counter #	Waiting %	0.00	0.72	1.42
	Working %	88.26	71.88	54.27
	Blocked %	0.00	0.19	0.30
	Change Over %	0.00	7.26	7.90
	Standby %	17.32	20.28	22.95
Block Complete #	Number Completed	184.26	171.88	159.27
	Average Time in System	224.17	200.54	187.92

Figure 22-19: Example Results Summary for a Trial

The Results Summary above shows a 95% confidence interval for each result given the specified number of runs in a trial. To change to a different confidence interval, simply click the heading title and choose the desired range.

Export Options

Several options exist for exporting simulation results from the Results Summary to other software applications. Choose Results > Results Export to see the typical export options as shown on the various tabs. Check the Include in Results export box to export to the specified path.

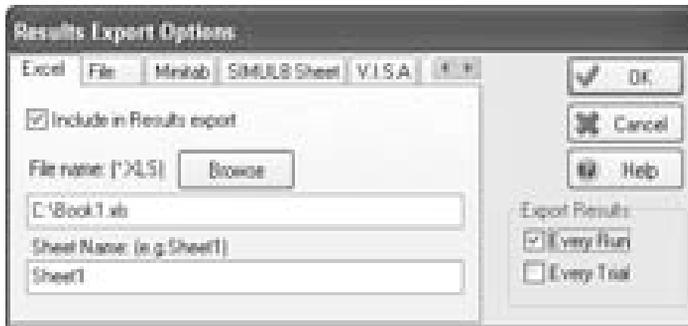


Figure 22-20: Results Export Options – MS Excel™

To export results to Excel™, select the Excel tab and specify the exact location, workbook name, and sheet name to write to. Before running the simulation or conducting a trial, ensure that the particular workbook is currently open. SIMUL8 can communicate with Excel™, but can not open an Excel file.

	Work Center 1 Waiting %	Work Center 1 Working %	Work Center 1 Blocked %	Work Center 1 Change over %	Work Center 1 Stopped %	Work Complete 1 Number Completed	Work Complete 1 Average Time in System
2	0.21286	72.48754	8.10442	1.87528	20.11989	100	423.9494
3	1.46212	73.81422	4.17888	1.87528	18.88288	100	281.70502
4	0.10364	74.9887	6.11427	1.87528	18.27421	173	341.96813
5	0.42888	71.21882	6.21888	1.87528	21.26822	163	474.0167
6	0.02888	71.37885	4.88788	1.87528	20.90021	100	403.47965

Figure 22-21: Results Export to MS Excel™

Column headings will automatically be copied over from the Results Summary to the top row of the Excel™ sheet. Subsequent runs or trials will

appear incrementally down the spreadsheet without overwriting prior results.

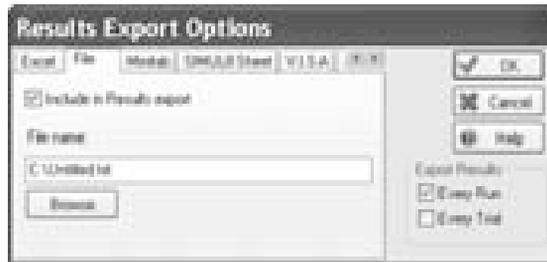


Figure 22-22: Results Export Options – File

Results from the Results Summary can also be exported to a tab delimited text file.



Figure 22-23: Results Export to a File

Note that no titles or headings are copied to the text file when exporting from SIMUL8.

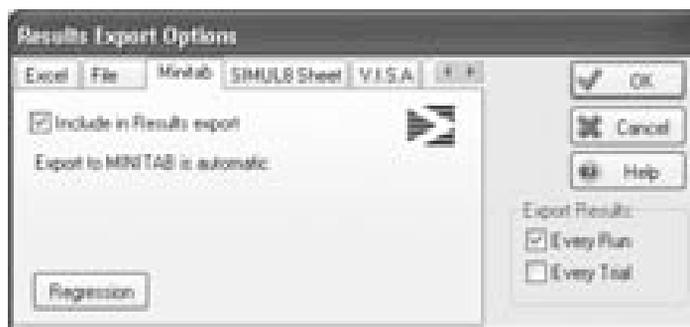


Figure 22-24: Results Export – Minitab

Results can also be exported to a Minitab™ worksheet for further data analysis.

	Work Center 1 - Average Time	Work Center 1 - Waiting Time	Work Center 1 - Work Center 1 - Waiting Time	Work Center 1 - Work Center 1 - Work Center 1 - Waiting Time	Change Item 1 - Work 1
R	10.789	11.140	40.000	0.000	0
R	10.800	11.000	40.000	0.000	0
R	10.789	10.420	40.000	0.000	0
R	10.738	1.200	40.000	0.000	0
R	10.742	10.500	40.000	0.000	0

Figure 22-25: Results Export to Minitab™

Note that the titles appear in the header row of the worksheet and that the first run's results appear in row 1. Statistical data analysis using Minitab™ can now be performed on these results.

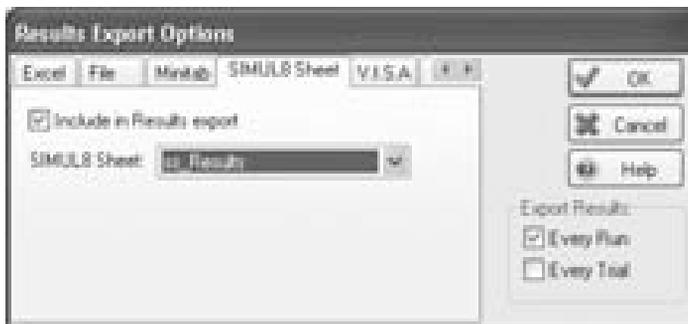


Figure 22-26: Results Export - SIMUL8 Sheet

The fourth option for exporting results is actually not an export but a copy of the data to a SIMUL8 spreadsheet. Before selecting this option and the

target spreadsheet in the drop down menu, the user must first create an Information Store spreadsheet.

Work Center 1	Work Center 2	Work Center 3	Work Center 4	Work Center 5	Work Center 6	Average Time in System
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	100

Figure 22-27: Results Export to SIMUL8 Sheet

The result of this export to a SIMUL8 Sheet is simply a copy of the values in the Results Summary, but unlike the Summary it will not be overwritten after a new run or trial, so it can be useful for comparing results.

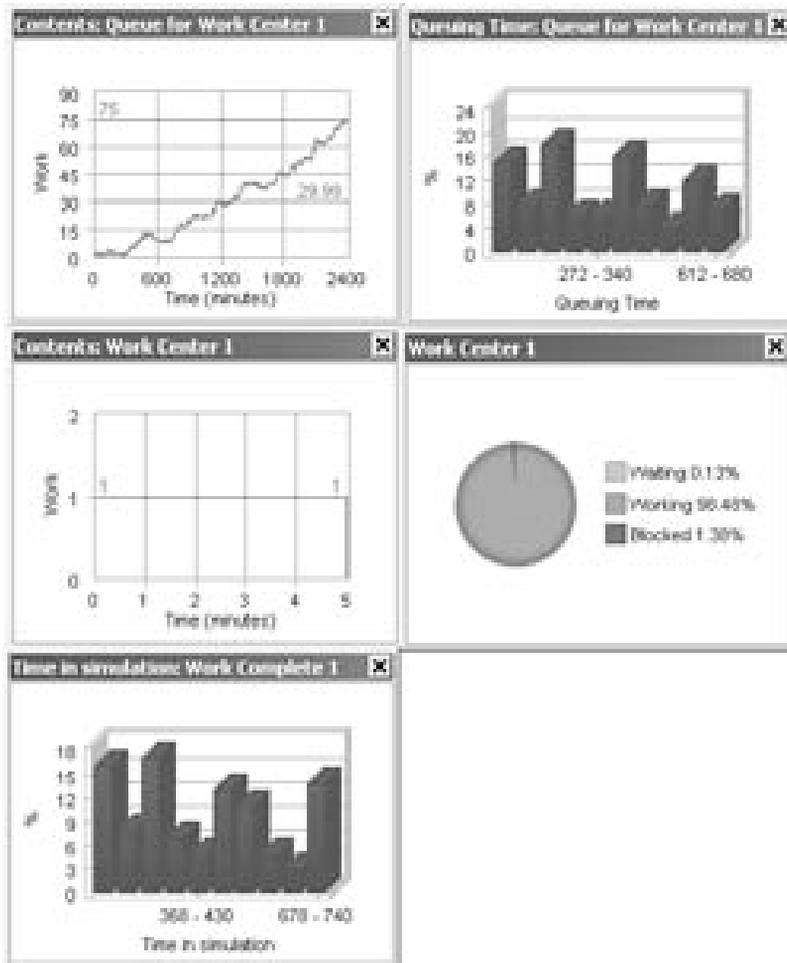


Figure 22-28: Results Export - V.I.S.A.

The final export option is to V.I.S.A. (Visual Interactive Sensitivity Analysis). Check the option and the results are automatically sent to V.I.S.A. as a new “alternative.”

Result Charts

The Results Summary shows results as numerical values of averages, total counts, minimums, and maximums. For a more visual presentation of the results, Result Charts can be displayed. These charts generally show the contents of queue(s) or Work Center(s), queuing time, Work Center's percentage of time spent in various states, and time in simulation.



- Click and drag the edges of a chart to re-size the plot ●

Figure 22-29: Sample Result charts

These charts can be displayed either through the results dialog box for a specific simulation object or by selecting one or more objects on the screen and pressing the chart button.

- Select multiple objects and create a plot of their contents in one chart ■

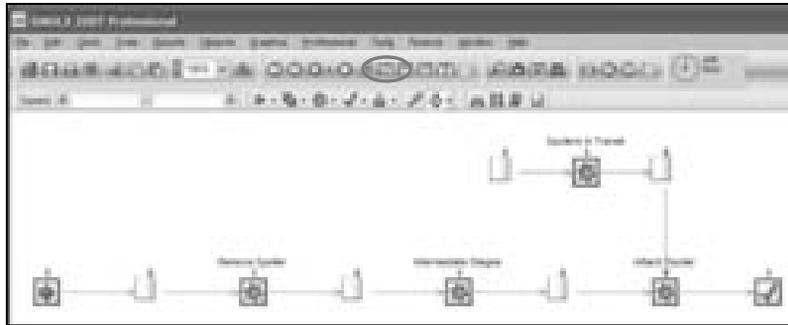


Figure 22-30: Chart Button

After pressing the button, the chart will appear at the bottom right hand of the screen. Clicking and dragging the chart with the left mouse button allows the user to place it wherever desired. Double-clicking the chart *docks* it at the bottom of the window. The user also has several options available for each chart.



Figure 22-31: Right-click Chart Options

The user can copy the data to the Clipboard so it can be pasted to Excel™, Minitab™, a text file, etc. The default title displayed for the graph can be changed using Set Title. The scale of the chart axes can be locked or rescaled at any time.

Note that the charts will now be displayed at all times, including model opening, unless otherwise closed by the user. These charts are quite advantageous as they are dynamically updated throughout the simulation run (graph synchronization frequency can be set through Simulation Preferences) and provide a time-based view of the results.

Charts can be customized through the chart properties dialog box. To access this dialog, open a chart as described above and then select Charts from the Results menu. Select the chart to be customized and click OK. This dialog sets different options including chart style (e.g. line, pie, bar), chart color options, chart data series, axis scales, grid lines, etc.

TimeView

Viewing results charts as shown above allows a visual depiction of a specific result data item. To compare several result types in one chart with a time scale, the TimeView feature is available. To obtain the following window, click on Results > TimeView. The dialog box will only display the first time a user opens TimeView. This can be configured with the simulation objects that appear on the chart.



Figure 22-322: TimeView Chart Contents

The Contents dialog box allows the user to select which simulation objects will be shown in the TimeView chart. Select an object by clicking on it and then clicking the right arrow (>) to add it to the chart. Click on the double right arrow (>>) to add all available objects. Use the move up and move down buttons (finger pointing up or down) to change the order that the various objects appear in the chart. Click the OK button when ready to view the TimeView chart.

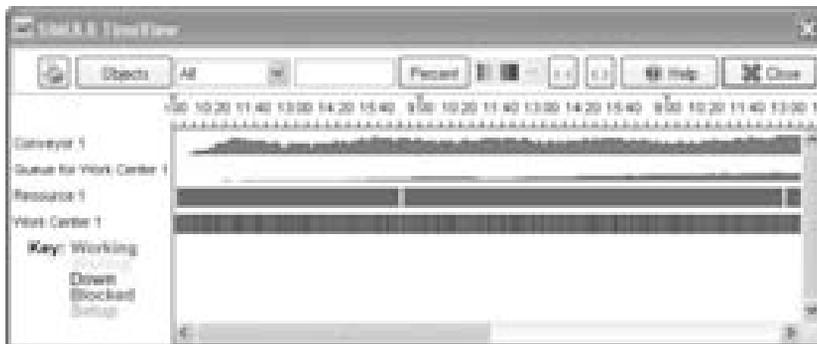


Figure 22-33: TimeView Chart

■ TimeView can be accessed in a simulation either mid-run (after stopping it first) or at the end of the run. ■

The chart shows six various states (working, waiting, down, blocked, and setup, plus blank space for off-shift) for Work Centers and Resources (by color code, as shown in the key) and displays the volume of Work Items and/or capacity at Storage Bins and Conveyors (as red-colored area charts) over the simulated time.

Press the *Print* button (left-most button) to print the current chart. Press the *Objects* button to open the *TimeView Charts Contents* dialog box to reconfigure (add or remove) the results of the various simulation objects displayed in the chart. Click the down arrow on the drop down list as another way to configure objects to be shown in the chart.



Figure 22-34: TimeView Objects Selection

Choose a criterion from the list and type the desired text data, if necessary, in the field to the right of the drop down list. For example, to view all Work Centers in the simulation only, select Work Centers from the drop down list. To view all objects that have specific text or numbers in the name, select the Contains: option and type the target text in the search field next to the list.

Click the Percent button to view a summary of the results data in percent format (instead of on a time scale).



Figure 22-35: TimeView Summary

To change the order of colors/states displayed for Work Centers, select the desired color/state scheme from the drop down list to the right of the 'Summary' button. If the scale (time or percentage) is not at a desirable size, use the '> <' button to shrink it or press the '< >' button to expand it. Press the 'Close' button when finished viewing the TimeView chart.

Finance

The Finance feature in SIMUL8 provides a quick and simple method of performing activity-based cost analysis. Costs can be associated with various processes or queuing times through Work Entry Points, Storage Bins, Resources, and overhead while revenues can be associated with Work Exit Points or can be fixed to obtain an income/(loss) statement for the simulation.

Set the properties of any of these simulation objects and press the 'Finance' button to associate costs and/or revenues to them.

Costs

Costs can be associated with the following simulation objects:

- Work Entry
- Storage Bin/Queue
- Work Center
- Resource

● Monetary units can be changed to display a different currency by pasting the correct symbol into the field in File > Preferences > Finance. ●

● Costs cannot be associated with Conveyors or Tanks in SIMUL8. ●

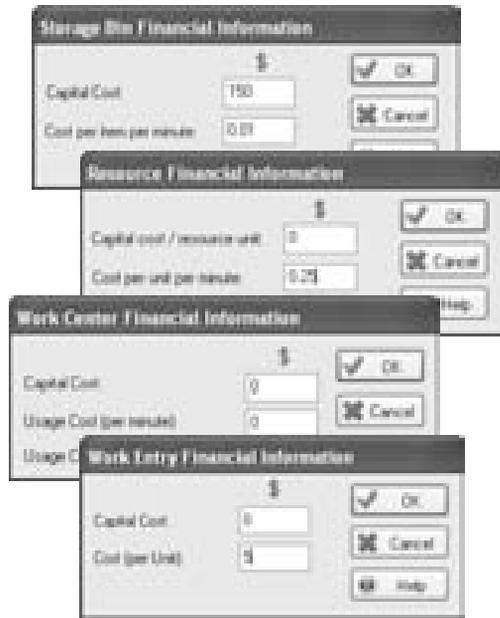


Figure 22-36: Financial Information - Costs

The user can specify the following costs:

1. Capital Cost – Cost of owning/employing the item over the results collection period
2. Cost or Usage Cost (per Unit) – Cost charged for each Work Item that passes through the object
3. Cost per item per minute – Carrying cost per specified time unit in simulation
4. Usage Cost (per minute) – Cost, charged on a time-basis, for use of a Work Center
5. Cost per unit per minute – Cost, charged on a time-basis, for use of a Resource

Revenues

The only simulation object with which revenues can be associated is the Work Exit Point.



Figure 22-37: Financial Information – Revenue

The user can specify capital cost for the Work Exit Point but also revenue for every Work Item that departs the simulation from that point. The amount of revenue to be gained per unit sold must be estimated for this calculation. The revenue value, however, can be left blank, and a cost analysis performed instead of a profit statement.

Overhead Costs and Revenues

Costs or revenues that are not driven by a specific process or object in the simulation can be included in the financial analysis as a fixed cost or fixed revenue in the Overheads dialog box from the Finance menu.

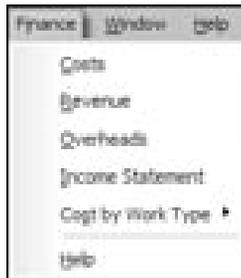


Figure 22-38: Finance Menu

Figure 22-39: Financial Information – Overhead

◆ Cost and Revenue values cannot be set through spreadsheets or Visual Logic. They must be entered manually. ◆

Income Statement

The income statement shows all costs and revenues specified by the user based on the number of Work Items and amount of time they spend in the system. Select Income Statement from the Finance menu or press the Finance button to view the Income Statement.



Figure 22-40: Finance Button

The report defaults to only show the total costs, revenues, and the profit or loss. To view more detail about costs or revenues, double-click on the 'Costs' and 'Revenue' titles in the statement.

■ The Income/(Loss) Statement only displays financial results for the most recent simulation run and does not display results for trials / multiple runs. ■

Sample Simulation	
Costs	
Work Entry Point 1	\$ 795.00
Queue for Work Center 1	\$ 187.14
Work Center 1	\$ 790.00
Work Complete 1	\$ 500.00
Overhead Fixed Costs	\$ 4,000.00
	<hr/>
	\$ 1,052.14
Revenues	
Work Complete 1	\$ 4,255.00
Fixed Revenue	\$ 3,000.00
	<hr/>
	\$ 7,255.00
Profit:	<hr/>
	\$ 1,402.86

Figure 22-41: Finance Income (Loss) Statement

The data can be copied to the clipboard by pressing the copy button (leftmost button) or can be printed by clicking the printer icon. Also, the results data from the Income Statement can be shown in the Results Summary by right clicking the title of the desired result. Press 'OK' when finished viewing the financial report.

The costs and revenues can be accessed and edited through the Finance menu after initially including the simulation objects in the financial report. Note that selecting and pressing the 'Erase' button while in the dialog box shown below will actually erase the simulation object and not simply remove it from the Income Statement.



Figure 22-42: Finance Costs

Cost by Work Type

Costs can also be segregated by work type for analysis. This is useful in models where multiple work types exist, such as when using the Jobs Matrix. To activate this feature, select Finance > Cost by Work Type > Analyze During Runs and then run the simulation model. When the run has completed, select Finance > Cost by Work Type > Review, and the Cost by Type table will appear. This table can help the user to learn which product types are more costly, which have greater cost variability, and other important activity-based costing results.

Cost Type	Average Cost	Highest Cost	Lowest Cost	Minimum Cost	Maximum Cost	Total Cost
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Figure 22-43: Cost by Type window

Dashboard

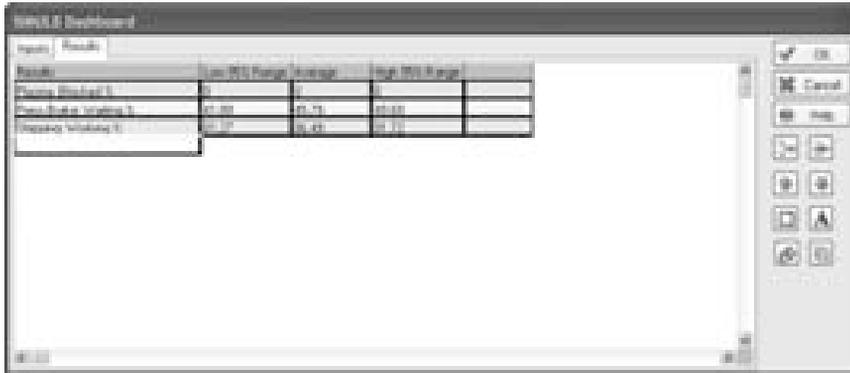
The SIMUL8 Dashboard allows the user to view Global Data Item and Results Summary information in a consolidated set of tables. It also allows for greater flexibility than the standard Information Store and Result Summary dialogs, in terms of display and formatting.

The Dashboard can be displayed by selecting Results > SIMUL8 Dashboard. The Input tab displays information on Global Data Items added from the Information Store including variable names, user memos, on-reset values, and a list of places where the variable is referenced.

Global Data Item	Memos	On-Reset Value	Referenced By
1	on-reset	0	DL, Visual Logic, Dashboard On-Off and Logic

Figure 22-44: Dashboard Inputs tab

The Results tab displays data added from the Results Summary including result names, average values, and confidence intervals if a trial has been run.



Result	Low 95% Range	Average	High 95% Range
Queue Length 1	0.00	0.75	0.00
Queue Length 2	0.00	0.42	0.00
Queue Length 3	0.00	0.42	0.00

Figure 22-45: Dashboard Results tab

Using the buttons to the right of the table, the user can customize both of these tabs. The top two buttons add or remove rows. The next two buttons move the selected row up or down within the sheet. The square button controls the cell borders, while the text button controls font style and size. The paint bucket fills cells with either a solid color or a pattern, and the bottom right button copies the sheet to the clipboard so it can be pasted into an external software package.

The user can right-click a cell to add a Result or Global Data Item to the table, hide or un-hide a column, and to select which confidence interval he or she wishes to view (e.g. 95%, 99%, etc.).

Chapter 23: Information Store

Definition

SIMUL8's Information Store is a repository for user-specified variables or data. The user can store information in the form of numbers, text, time, spreadsheets, or simulation objects.

An Information Store can also be called a Global Data Item or a variable.

Variable Types

To create a new variable or to edit current variables, open Objects > Information Store to view a list of the current Information Stores. Press the 'Properties' button to view or edit a variable, 'New' to create a new Global Data Item, 'Copy' to copy a variable, and 'Erase' to erase the selected item in the list.

SIMUL8 Data

Every simulation will automatically have some standard items in the Information Store (see below). This SIMUL8 Data is basic information used by the simulation to store data needed for a typical simulation run. The user should not adjust this data. Instead, press the New button to create a new variable in the Information Store.

- The current value of the variable will be displayed when passing the mouse over the items in the list ●

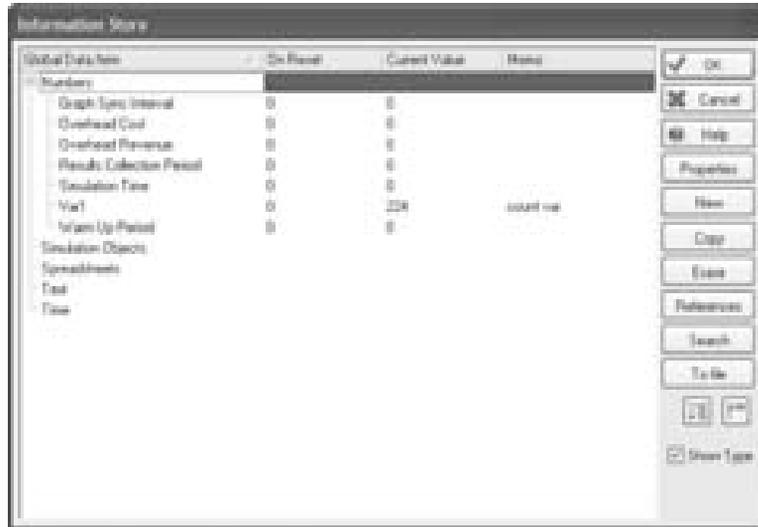


Figure 23-1: Information Store Dialog

Number

Naming Conventions Number variables are the first option in the list of possible Global Data Item types. After clicking the New button, create an appropriate name for the variable (see Naming Conventions) and assign a current value for the variable, if desired. A “reset” value can also be specified. The variable will revert to this value when the simulation is reset.

- Recommended naming Convention:
- lbl_ = Label
- dist_ = Distribution
- ss_ = Spreadsheet
- int_ = Local Integer
- gbl_ = Global Integer
- str_ = Text String
- obj_ = Object Variable ■



Figure 23-2: Adding a New Number Variable

If the 'on reset' field is left blank (rather than zero), the variable value will not change when the reset button is pressed.

Text

A text variable is an alphanumeric (text and/or numbers) string of data that the user can read and write to. They cannot be used for mathematical calculations. Again, the user can assign a name and the values for the current content of the variable and the value to take on reset.



Figure 23-3: Adding a New Text Variable

If the default “NOCHANGE” is specified in the 'on reset' field, the string value will not change when the simulation is reset.

Time

Time variables in SIMUL8 are rarely used since they provide limited functionality. They are similar to number variables in that the variable contains a number of time units differing only in that each time the variable is viewed through the Information Store dialog box it is multiplied by 60. Otherwise, if the variable is changed through a custom dialog box or Visual Logic, it acts identical to a number variable. For example if a time variable is set to 5 through the Objects menu and then closed, the next time it is opened the value will be 300, and not some other clock-formatted time value.

Spreadsheet

The most commonly used Global Data Item for input parameters and simulation results is the spreadsheet. The user only needs to specify a name to create the spreadsheet.



Figure 23-4: Adding a New Spreadsheet

In order to view the contents of the spreadsheet, press the View button and the following window will appear.

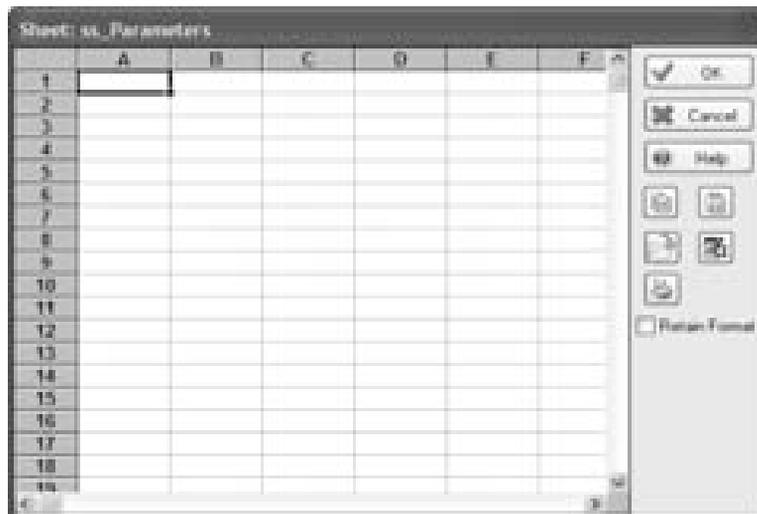


Figure 23-5: Viewing/Editing a Spreadsheet

All cells in the spreadsheet accept alphanumeric data. There are 256 columns and 16,384 rows in each sheet. When referencing the spreadsheet in Visual Logic, `ss_Parameters[5,2]` translates to the cell in the fifth column and second row.

Double-click the grey colored headers to change the name that appears in the top column or leftmost row.

◆ 16,384 rows can be viewed, but Visual Logic can reference approximately 65,000 rows. ◆

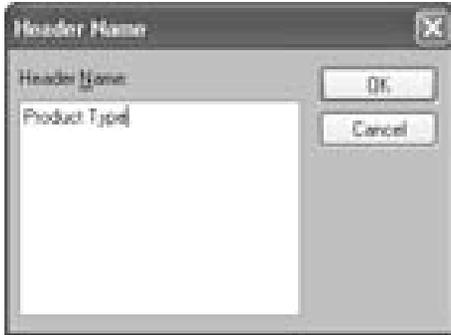


Figure 23-6: Edit Header Name in Spreadsheet

The other buttons on the spreadsheet window are used for the following

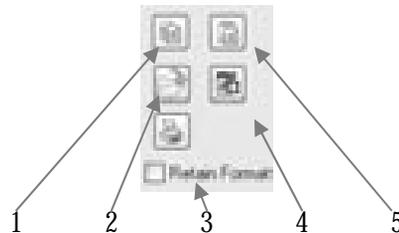


Figure 23-7: Spreadsheet Options

- 1) Copy the current data to the clipboard
- 2) Open/import an Excel™ spreadsheet to the SIMUL8 spreadsheet
- 3) Print the current sheet
- 4) Edit formatting
- 5) Paste the current clipboard contents to the sheet.

Checking the Retain Format box ensures that when the spreadsheet is closed, user-defined formatting will not be lost.

◆ Use sequential names (i.e. Load 1, Load 2, etc.) for like objects for easy referencing in Visual Logic. Set obj_WC = “Load”+int_var ◆

Simulation Object

A Simulation Object is a variable that represents a specific type of Objects within SIMUL8. It is similar to a pronoun. Just as the pronoun “He” can take on various meanings (of different males), a Simulation Object of type Work Center, can refer to various Work Centers. Object variables are used when properties of many objects have to be gathered. Instead of referencing the Objects one by one, the variable can be repeatedly set to different Objects.

Using a Simulation Object as a variable is a somewhat advanced feature within SIMUL8; Simulation Objects can only be set using Visual Logic. Typically, users employ object variables to set some aspect of an object that is referenced using the literal name from a spreadsheet.



Figure 23-8: Adding a new Object Variable

Along with the variable name, selected object type, and the current content, on reset the user can choose the type of simulation object or can select to ‘Auto Reference’ the simulation object. When the variable is referenced

using Visual Logic, Auto Reference sets its value to that of the calling object.

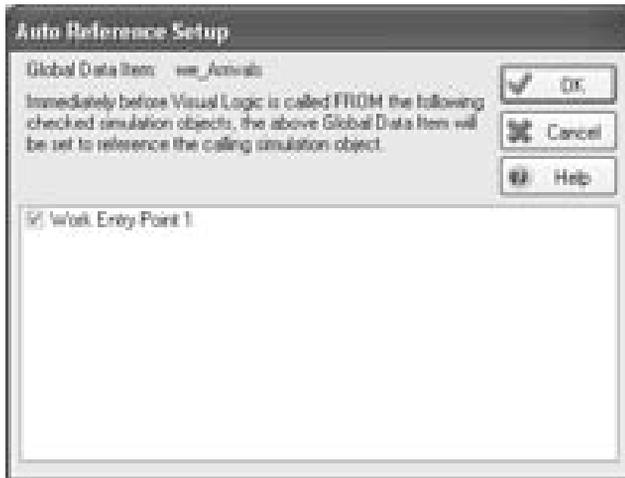


Figure 23-9: Simulation Object Variable Auto Reference Setup

Variables vs. Labels

It is sometimes easy to confuse variables and labels in a simulation. The key point to remember is that a variable is globally available and/or constant through the entire simulation (i.e. only one instance of a variable exists), whereas a label is a piece of datum specific to a Work Item. For example, if there are currently 15 Work Items in a simulation, then 15 label values can exist at one time in the simulation. Each value is associated with a particular Work Item. For a variable, however, there can only be one global value at any specific point in time. Hence, the items in the Information Store are called Global Data Items. For example, each person in a room has a label called age, with a different value. However, there can only be one variable representing the average age of everyone in the room.

Erasing Variables

When erasing variables using the 'Erase' button in the main Information Store dialog, the following message may appear.

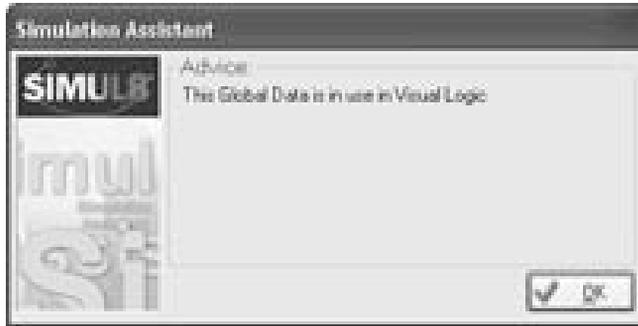


Figure 23-10: Global Data In Use Message

The variable that the user is attempting to erase is in use by Visual Logic. Either the piece of Visual Logic code must be modified to no longer reference the variable or the code must be deleted before the Global Data Item can be erased.

Chapter 24: Dialog Boxes

User Interface

When creating a simulation model, it is possible to provide a custom-tailored, user-friendly interface with buttons, spreadsheets, and dialog boxes. Dialog boxes can be called from Visual Logic or provided as a part of a command menu.

Dialog Benefits

Dialogs are extremely useful for providing user-friendly interfaces. They ensure that simulations can be easily deployed allowing end-users to quickly change simulation parameters and options without having knowledge of building simulations. Also, dialogs can be operational even if the main body of the simulation is password protected to safeguard the source code. Additionally, the use of dialogs allows the simulation administrator more control over the altering of these parameters by using validity checks and specific input options.

Creating Dialogs

New dialog boxes can be created by using Tools > Dialogs > List and Create. This can also be accessed using Ctrl + Alt + D.

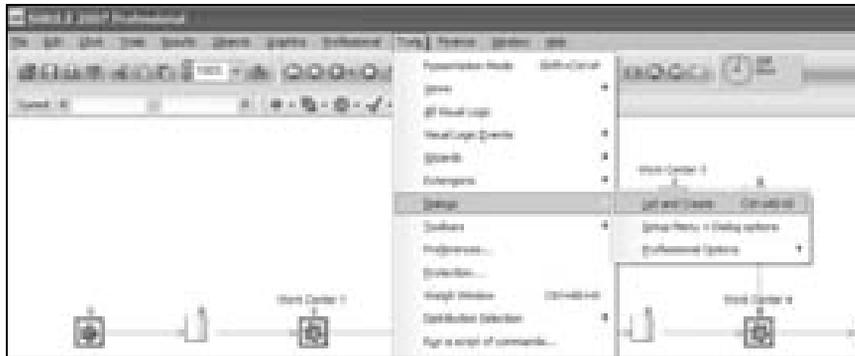


Figure 24-1: Creating Dialogs

1. Properties – Displays the properties of the dialog box. This is where the dialog box controls are created.
2. New – Creates a new dialog box and opens its properties.
3. Erase – Erases the dialog box. If the dialog box is referenced in Visual Logic, it will not erase.
4. Copy – Creates a duplicate of the selected dialog box and opens its properties.
5. Add to Menu – Adds the Dialog to the Command Menu (See Setup Menu and Dialog Options below)



Figure 24-2: Custom Dialogs List

Properties – Main

Properties contain information about the content, appearance, and executable actions of the dialog box. The “Main” tab is where basic information about the appearance of the dialog box is specified.

1. Main Title – The name of the dialog is entered. This will be displayed at the top left of the open dialog.
2. Preview – Displays the dialog box.



Figure 24-3: Dialog Preview

3. Picture – Allows browsing for images to display on the left of the dialog box in place of the standard image. It is best to use a .bmp file.
4. Show as Wizard – If this box is unchecked, the dialog box will be displayed with OK and Cancel buttons and no image at the side. If the box is checked, the dialog box will be displayed with Back, Next, and Cancel buttons and the option for displaying an image.
5. Finish Button – If this box is checked, a Finish button will be displayed instead of a Next button.
6. Cancel Button – You can specify a cancel, close, or no additional button.

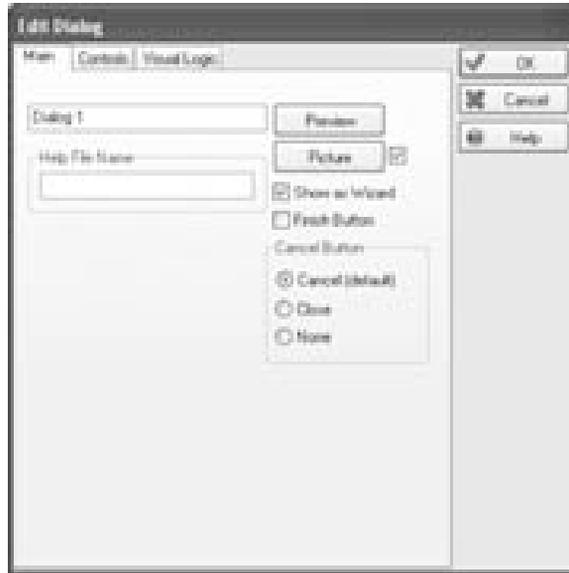


Figure 24-4: Dialog Properties Main

Properties – Controls

Control Options

Controls allow objects to be added to the dialog box, which can serve as user inputs. The objects added will sequentially appear on the open dialog box. The dialog can be previewed from the Main tab.

1. Title – Displays text for instruction, explanation, or titles. Text is entered in the *Text to Display* box.
2. Data Field – The user will enter Data here. There is a validity check available, which can ensure that a number is entered and that it is of a certain range. In the Global Data Item box, a number, text or spreadsheet variable can be entered where the entered data will be stored.
3. Check Box – The check box will return a binary value to the Global Data Item selected. The number returned will be 1 for checked and 0 for unchecked.

4. Radio Group – The radio group will return a number to the Global Data Item selected. The number returned will be 1 for the first choice, 2 for the second choice etc.
5. Button – If a button is added, it can be used with *On Button Click* Logic. The name of the button will be “Dialog Name:Text on Button.”
6. Object Button – The object button is used to display the properties of an Object.
7. Dropdown – The dropdown will return text to the Global Data Item selected corresponding to the text option selected. Only text is returned, not numerical values. In the *Global Data Item* box, the name of the variable, which will receive the returned text, is entered. To return numerical values, use the Radio Group.



Figure 24-5: Dialog Properties Controls

Moving and Deleting Controls

The position of controls on the dialog box can be changed by using the up and down pointers at the side of the control display box. Selecting and clicking on the trash icon at the side of the control box can delete controls.

Validity Check

The Validity Check is used when a Global Data Item is a number. It is used in conjunction with the Data Field control. The check box “Must be a number” ensures that the user enters a number into the data field. Allowing minimum and maximum numerical values can also restrict the user. If the user fails to enter a valid number, the dialog box will not close when the OK button is clicked until a valid number is entered.

Properties – Visual Logic

Visual Logic can be called at various points from the dialog box.

1. On Open Dialog – Visual Logic will be called when the dialog box is opened before the dialog box is displayed.
2. On OK Dialog – Visual Logic will be called on clicking the *OK* button on the dialog box.
3. On Back Dialog – Visual Logic will be called on clicking the *Back* button on the dialog box.
4. Cancel halts calling Visual Logic – If this is checked, the Visual Logic from which the dialog box is opened will not be completed. Otherwise, SIMUL8 will run through the rest of that section of Visual Logic.



Figure 24-6: Dialog Properties Visual Logic

Setup Menu and Dialog Options

Dialog boxes can be displayed by Visual Logic commands. However, they can also be displayed when a simulation is opened or closed or inserted into command menus at the top of the simulation screen.

1. Display dialog when simulation opened – The dialog box selected from the dropdown menu will appear when the simulation is opened.
2. Display dialog when protected simulation closed – The dialog box selected from the dropdown menu will appear when the simulation is closed if the simulation has been protected using SIMUL8-Professional.
3. Include Command menu – The named command menu will be included in SIMUL8's main command bar.
4. Disable during run – The command menu cannot be accessed while the simulation is running.
5. Name of menu – The name entered will appear in SIMUL8's main command bar.

6. Menu – Up to three command menus can be specified. Using this selection box each can be edited.
7. Dialogs in command menu – Dialogs can be added to the command menu by selecting and using the left pointer. Selecting and using the right pointer removes them. The position of the dialogs within the command menu is changed by selecting the dialog and using the up or down pointers. Dialogs can be edited by clicking on the edit button to the right hand side.

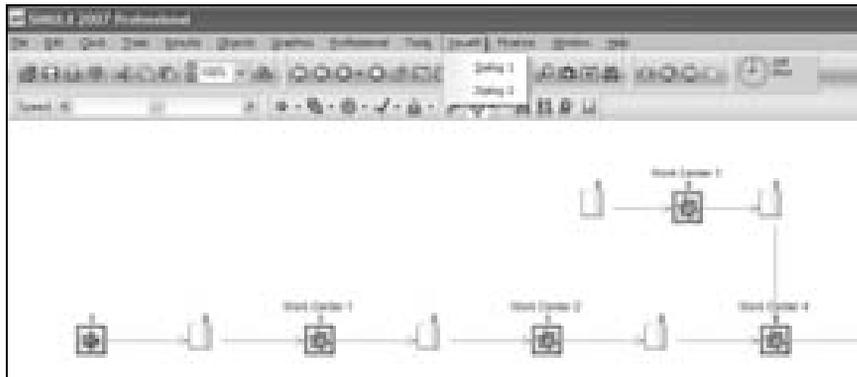


Figure 24-7: Dialogs in Command Menu



Figure 24-8: Select Dialogs

Chapter 25: Visual Logic

An Introduction to Visual Logic

The entire SIMUL8 functionality is not available as a simple dialog input or button click; there are an infinite number of configurations for a myriad of industries, and the basic menu options can not incorporate them all. As a result, SIMUL8 has an internal programming language called Visual Logic to handle advanced user requirements. Unlike many other programming languages, Visual Logic provides a dialog driven generation of code, thus allowing a non-programmer to learn and use the code easily.

The following is intended as an introduction to Visual Logic. Visual Logic is an extremely powerful programming language with many commands. However, as they all have dialog driven syntax, exploring can be done without the step-by-step guidance of a manual.

Accessing Visual Logic

Within SIMUL8, there are multiple events that trigger Visual Logic during a model run. The majority of Visual Logic commands are used to make decisions or track information while the model is running. The following is a list of Visual Logic commands that can be used for these purposes:

- Work Entry Inter-Arrival Time Pre-Sample Logic
- Work Center / Conveyor Before Selecting Logic
- Work Center / Conveyor After Loading Logic
- Work Center Changeover Pre-Sample Logic
- Work Center Processing Time Pre-Sample Logic

- Work Center On Work Complete Logic
- Work Center / Work Entry Batch Pre-Sample Logic
- Work Center / Conveyor / Work Entry On Action Logic
- Work Center Before Exit Logic
- Work Center On Exit Logic
- Storage Bin On Entry Logic
- Storage Bin On Exit Logic

Each Visual Logic command listed above is triggered by a certain event in a specific timed order. The order of these events is important. For example, all decisions about a Work Item's processing time must be made before processing has begun, so Action Logic cannot be used to make these decisions. The following important chart provides information on the order of these Visual Logic events as well as some examples of what they are typically used for:

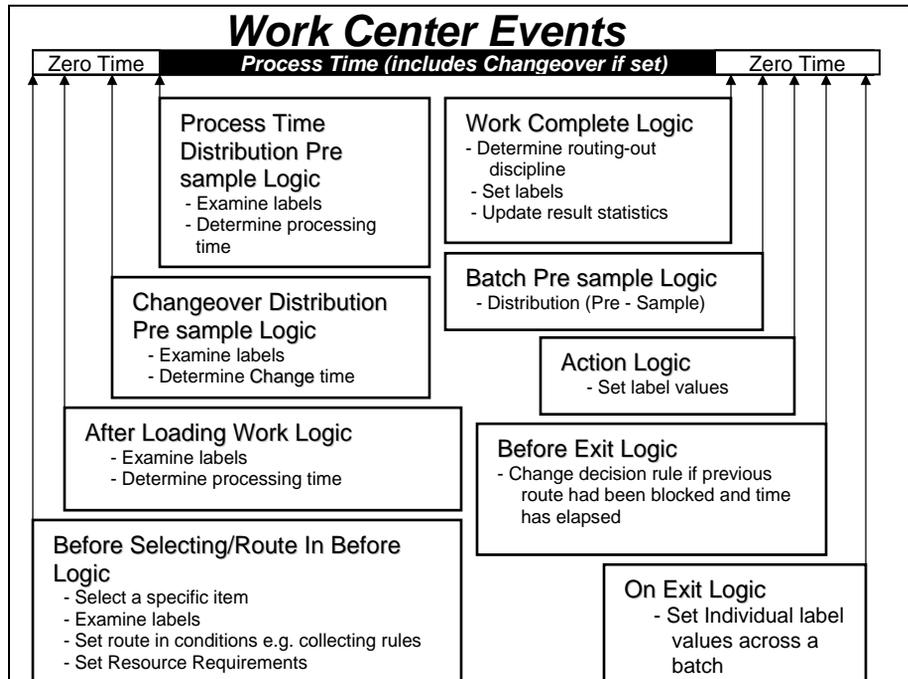


Figure 25-1: Visual Logic Work Center Time Line of Events

Special Events Visual Logic

In addition to calling Visual Logic from specific processing stages in Work Centers, there are simulation events that can trigger Visual Logic. These are one-off events that typically either occur once in the simulation model, or are manually generated, such as an on-screen button click or Dialog Box button click. The following is a list of these events:

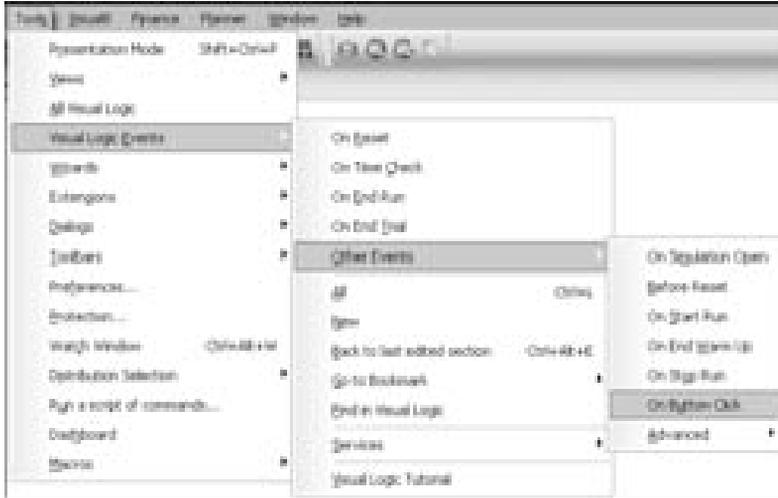


Figure 25-2: Visual Logic Special Events

These events are typically used for setting up a simulation, providing user-friendly inputs, and calculating reports. As a result, specific events are used for certain activities depending on when these events are called. Also included in this list of simulation clock events are variable logic calls. Time Check, Breakdown, and Repair logic are events scheduled to be triggered at various times during the simulation. The following is a time line of these events:

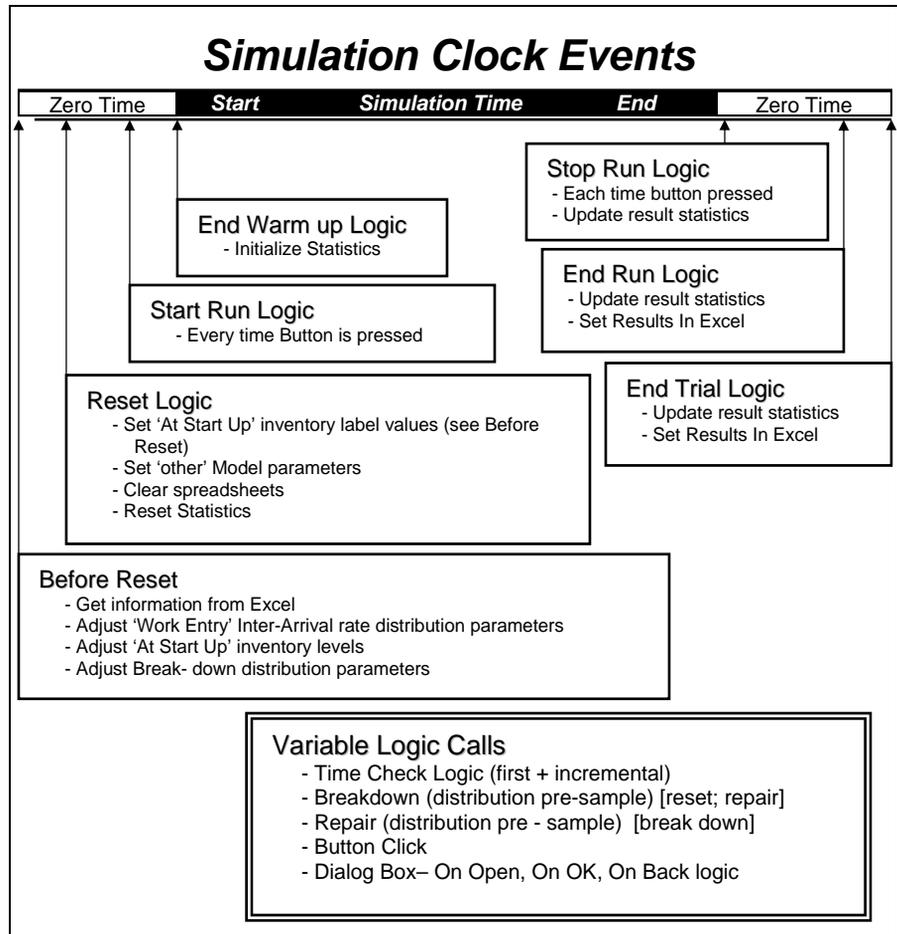


Figure 25-3: Visual Logic Special Events Timeline

Creating Visual Logic Code

Once within a Visual Logic window, click the right mouse button or press the Insert button on the keyboard to access the list of Visual Logic Commands.



Figure 25-4: Creating Visual Logic Code

Almost all parameters of a simulation model can be changed from within Visual Logic. All simulation objects and elements can be accessed and altered through the Command Menu. The Command menu is divided into three main sections:

- Object – includes all simulation objects and their properties;
- Simulation – includes all external access commands, simulation controls, results collection, and special logic for calculations and debugging;
- Any – includes a drop-down menu of all Visual Logic commands.

Other elements of the Visual Logic structure include the following:

- The Conditional Block Editor – Provided through the 'IF' statement;

- The Set Command – Often used for writing information to a spreadsheet, calculations, and setting variables;
- The Formula Editor – Provides a list of all simulation objects, information stores, and mathematical functions;
- The Loop Control – Used for creating loops; and
- The Call Function – Used for calling generic pieces of code, including functions, or for sectioning large pieces of code into manageable sizes.

The Conditional Block Editor

To access the Conditional Block Editor, click on the *IF* option in the Command menu. The Block Editor will provide both sides of an inequality statement as shown below:



Figure 25-5: The Conditional Block Editor

These two parameters can be changed by double-clicking on the question marks or by clicking the button to the right - "...". This will open the Formula Editor, which will be introduced shortly. The top row is the test portion, whereas the bottom row is the parameter that it is being tested against. The drop down list will provide several different equalities and inequalities.



Figure 25-6: Equalities and Inequalities

The following is a sample *IF* statement:

If Storage Bin 1.Count Contents > Storage Bin 2.Count Contents

Of course, this statement checks to see if the contents of Storage Bin 1 are greater than the contents of Storage Bin 2. If the statement is found to be true, VL code indented below the IF statement is executed. If the statement is false, indented code is skipped and execution proceeds to the next non-indented line.

Complex logic can also be used by clicking on the checkbox at the bottom. This allows for the use of AND, and OR statements (& and | symbols respectively), which greatly reduces the number of lines of code that must be written. When typing in formulae, ensure that there is one space between each variable name, mathematical symbol, and number.

The Set Command

The Set Value Editor is opened when the SET Command is selected from the Command menu. Clicking on either side of the SET command will open the Formula Editor. The Set Value Editor allows parameters to be changed while the model is running. It can be used to alter Label values, and to change the value of various Work Center or Information Store parameters. It should not be used to change the values of Named Distributions. This can be done with its own Visual Logic Command.

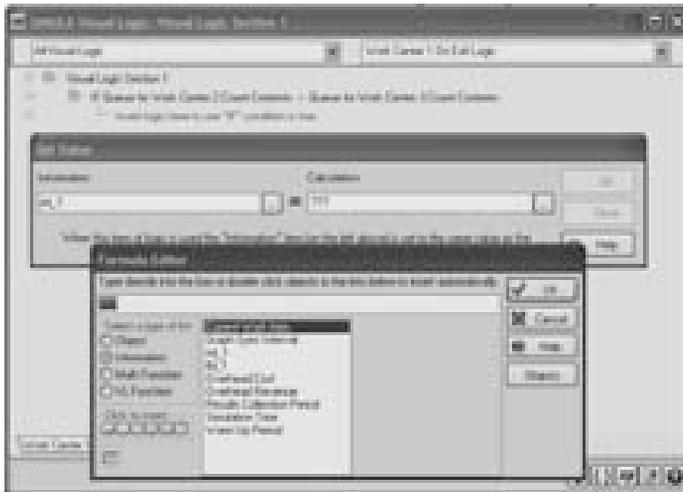


Figure 25-7: The Set Command

Accessing Formula Editor

■ Sometimes the Formula Editor can be accessed from other edit boxes, for example a Process Time in a Work Center. Double-click while holding down shift to access these options. ■

Double clicking on an edit box with question marks, or clicking on the square button to the right – “...” – can access the formula editor.



Figure 25-8: Accessing the Formula Editor

The Formula Editor helps the user to create complex equations by providing easy access to three different lists:

- Information – Information Stores including spreadsheets, variables, and global SIMUL8 items such as simulation time.
- Objects – all simulation objects created, including Work Entry Points, Storage Bins, Work Centers, Work Exit Points, Resources, Conveyors, Labels, Distributions, and Information Store objects.
- Math Functions – provides a number of mathematical functions which convert numbers, for example Rand[0] will convert 0 to a random number between 0 and 1.

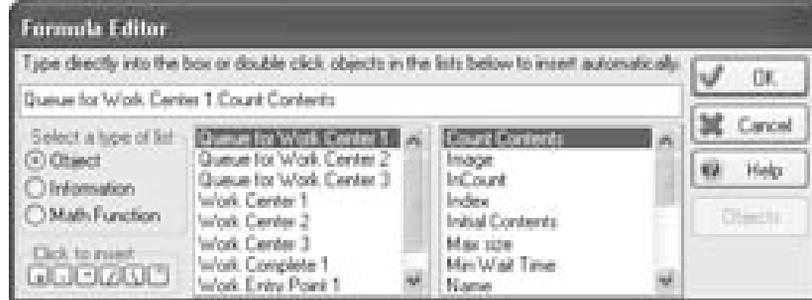


Figure 25-9: The Formula Editor

The Object section has an extra list box that adapts and changes depending upon the properties of the Object selected on the left hand list box. This second list box provides a list of all readable and/or adaptable properties of the Object selected.

Double-clicking within these lists adds the clicked item to the main equation line. This is much faster and more accurate than typing in object names, spreadsheet cell locations, and math functions from memory.

The Call Function

When generic Visual Logic code has been developed to be used in more than one place in the simulation, it does not have to be pasted into every section where it will be used. Instead, use the Call Function to execute that piece of Visual Logic. This is helpful because if a Visual Logic function needs to be changed, the called function can be changed once, eliminating the need to make the change in multiple locations. This increases model building speed and lowers the chance of making an error that could be difficult to track.

The Call Function provides a drop-down list of all Visual Logic sections within the simulation model. Select the appropriate piece of Logic and it will be executed when called. Click Properties to view and edit the code within the Call Function.

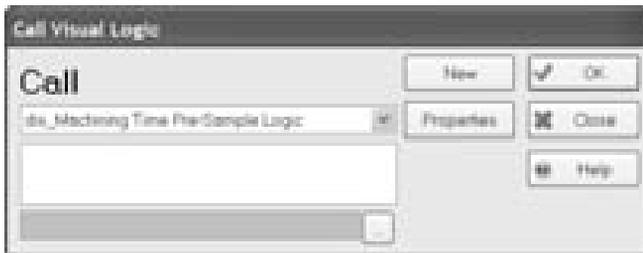


Figure 25-10: The Call Function

The Loop Function

When there are multiple options and using a series of If Statements is going to produce an extremely large piece of code, a Loop Function is required. This function allows the user to loop through a set of numbers or a set of objects. Most likely, the user will loop through a series of numbers. However, by using object variables, described in Chapter 23: Information Store, the user can even loop through different simulation objects. Depending on the size of the simulation model, looping through all Work Centers or Storage Bins can be quite a large task, resulting in a slower simulation model. Nonetheless, Loop functions used in conjunction with objects in the Information Store provide a powerful method for looking through multiple objects in a simulation.

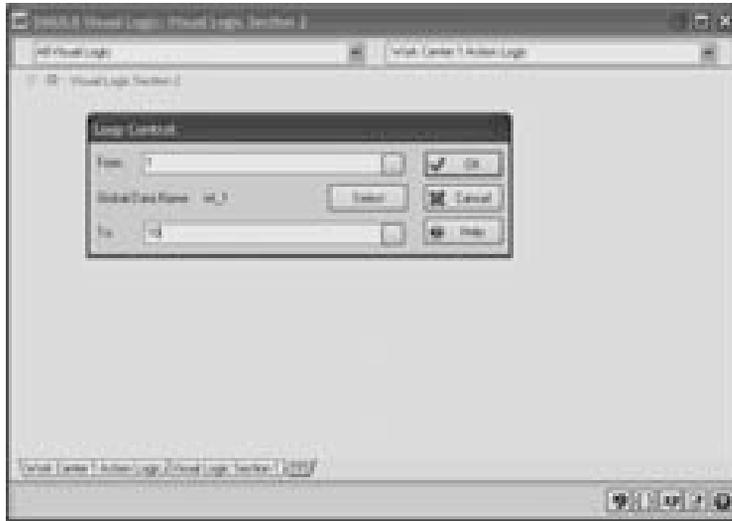


Figure 25-11: The Loop Command - looping on a number variable

In the figure above, the user is looping through a set of numbers. The variable selected as the Global Data Name is the reference point from within the loop. In the example above, the variable “int_1” will first start at the From variable (i.e., value 1), and will continue to update in increments of one until the To variable (i.e., value 10) has been reached. In order to loop through several Storage Bins, a global Information Store object of type Storage Bin would be repeatedly set to the names of the desired Storage Bins.

Implementing Visual Logic

The two major pieces of information required to use Visual Logic are the name of the command you want to use and where you want to use it. By marrying these two items together, a user can exert almost unlimited control over a simulation model. This section will present some useful areas where model logic can be applied, and some commands which are frequently used in each area. Detailed Visual Logic (VL) examples will also be interspersed throughout the section. These examples will follow the development of a model from the initial stages through to more complex logic examples demonstrating results generation and graphical user interface creation.

VL Example 1 – Using the Set Command

One of the first things to be integrated into a simulation model is often some form of variable user input. It is much easier to implement support for this during the model creation stages, rather than going back and adding this functionality once the model is nearly complete. User input is often stored in spreadsheets, where it can be easily viewed and modified. In order to set model parameters according to input sheets, use the Visual Logic, SET command.

The next step is to determine where the Visual Logic code should be inserted. Often setting model parameters can be performed through the On Reset Visual Logic section. This section is executed whenever the model is reset, which generally takes place before the start of a run. Hence, the parameters will be set before each run and any changes the user has made will be incorporated. VL Example 1 demonstrates using the SET command within On Reset logic.

The following model can be used to illustrate how the set command can be used to change model parameters. This model will be used throughout the examples in this section of the text. In this example, user input will be provided to allow the setting of Storage Bin capacities.

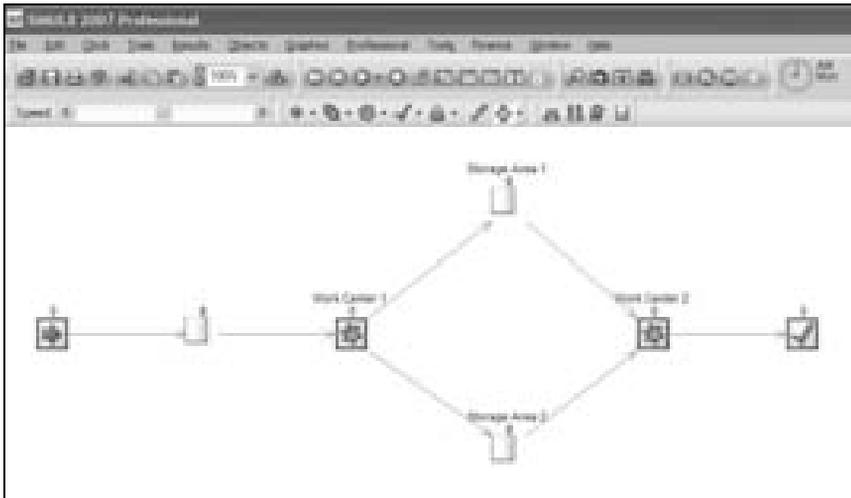


Figure 25-12: VL Example 1 Model Structure

1. Build the model as pictured above. Set the Processing Time of Work Center 2 to 25 minutes on average. Keep all other settings at their defaults.
2. Create a new spreadsheet variable by going to the objects menu and selecting Information Store.

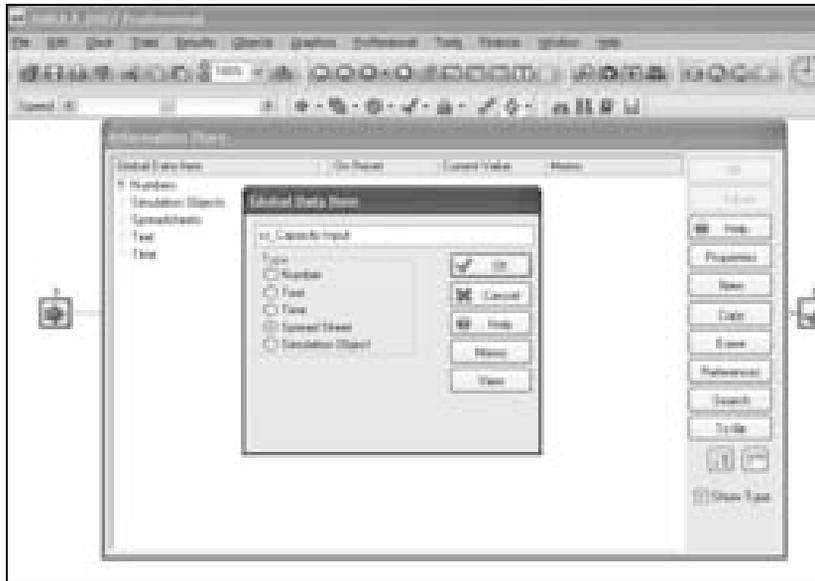


Figure 25-13: VL Example 1 - Creating the User Input Sheet

3. Name the spreadsheet (i.e., ss_Capacity Input).
4. Enter data into the spreadsheet as follows:

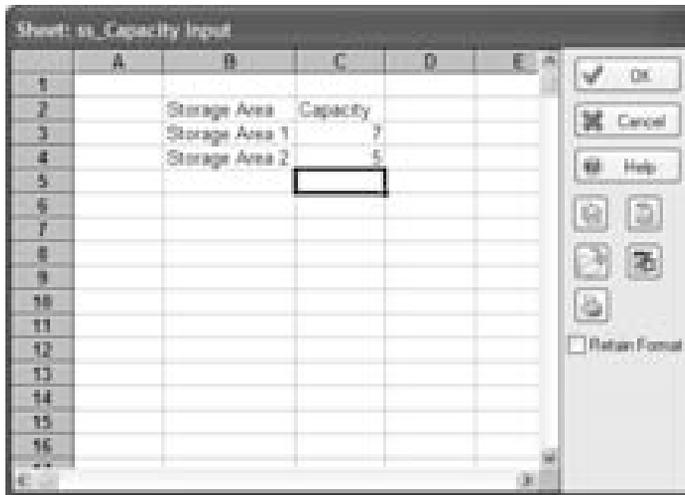


Figure 25-14: VL Example 1 - User Input Sheet

5. If desired, format the spreadsheet by clicking the *Edit Formats* button on the right and using the Formats menu.
6. Display the input sheet by clicking the *Show Data Sheet* button on the Run Tools toolbar on the main screen. Enter the desired storage capacities for the two Storage Bins in the appropriate cells.
7. Use Visual Logic to set the storage capacity according to the spreadsheet. As mentioned above, it is a good idea to use On Reset Visual Logic for this purpose. Select On Reset Logic under Tools > Visual Logic Events > On Reset.
8. Enter the code shown in the diagram below. First, choose the Set Command by right clicking inside the Visual Logic Window.
9. Enter the name of the Storage Bin into the left edit box or click the button to the right and choose it from the list.
10. Choose the Max Size property from the list of properties on the right.
11. In the right edit box of the Set Command dialog Box, enter the spreadsheet location of the Max Size data.

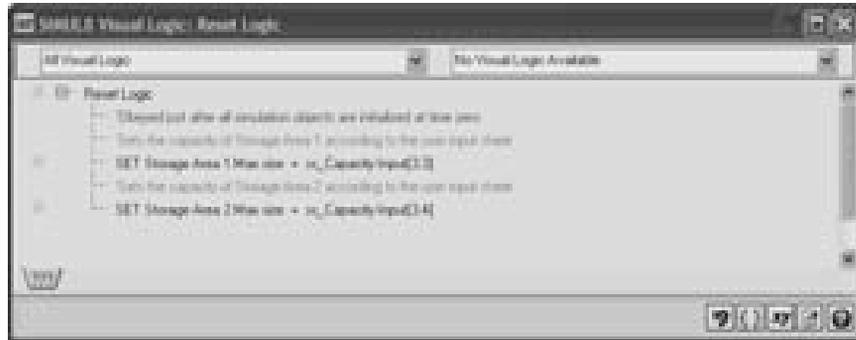


Figure 25-15: VL Example 1 - Set Command Visual Logic

After repeating for both Storage Areas, and inserting comments, the code will appear as shown above. The capacity of the two Storage Bins will now be set each time the simulation is reset. The user can test this by resetting the model, double-clicking on one of the storage bins and examining the capacity.

VL Example 2 – Setting Distribution Parameters

In addition to the SET command, there are several other ways that user data can be incorporated into the model. In fact, if the change to be made requires the specification of several parameters at once (e.g. target object, distribution type, average, standard deviation, etc.), then the SET command cannot generally be used. Instead, use one of SIMUL8's built-in Visual Logic commands, such as Set Object Distribution Type or Set Prob-Profile Column Parameters. In the following example, both the Set Object Distribution Type and the Set Prob-Profile Column Parameters commands will be used to take user input data from a spreadsheet and apply it to the appropriate simulation objects.

We will continue from where we left off in Example 1. The simple model started above will now be set up to produce multiple products simultaneously. There are a total of 4 product types to be processed on this line. The proportion of production devoted to each line is set by the user before the simulation run. Each product type has a different processing time at Work Center 1. We would like to set all of these parameters from the input spreadsheet using Visual Logic, because this will allow the

simulation user (who may not be a simulation expert) to easily model different scenarios.

1. Open the information store and double-click on the spreadsheet `ss_Capacity Input` that was created in Example 1. Rename the spreadsheet `ss_Input`. SIMUL8 will automatically update all Visual Logic references to this spreadsheet to use the new name.



Figure 25-16: VL Example 2 - Renaming a spreadsheet

2. Update the spreadsheet to include sample user input information for product proportions and processing times. Check the Retain Format check box if you would like the columns to retain their width settings after the spreadsheet has been closed. Make sure to leave a number of rows between the storage bin and product information areas of the sheet in case you want to add data later.

The screenshot shows a spreadsheet with the following data:

	A	B	C	D	E
1					
2		Storage Area	Capacity		
3		Storage Area 1	7		
4		Storage Area 2	5		
5					
6					
7					
8					
9					
10					
11					
12		Product Type	Proportion of Total Production	Work Centre 1 Processing Time (mins)	
13		1	25	15	
14		2	35	19	
15		3	30	17	
16		4	10	24	
17					
18					
19					

Figure 25-17: VL Example 2 - ss_Input

3. Create a label named `lbl_product`. To do this, select Labels from the Objects menu and click New. Enter the name and set the label type as Number, then click OK.
4. Use a probability distribution to set the product type of each Work Item as it arrives from the Work Entry Point. To create a new distribution, select Objects > Distributions > New. Give the distribution a name according to a naming convention, for example `dispp_Product Type`. Select the Probability Profile type. Click Next. Right-click on the default probability profile that is displayed, select Multiple, and then select “Delete all except 2”.

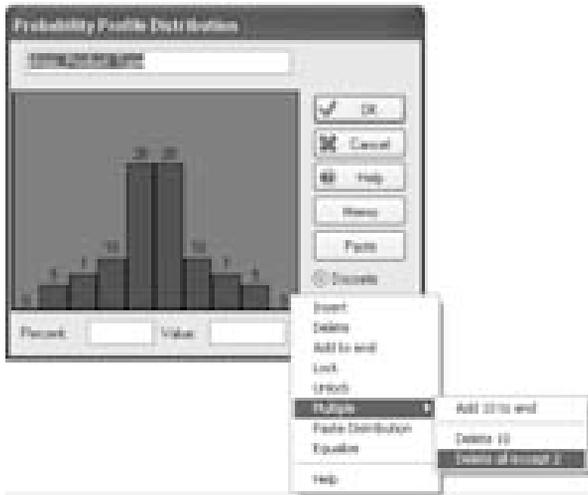


Figure 25-18 VL Example 2 - Probability Profile setup

- Right click on the profile again, and select “Add to end”. Repeat this step, so that you have a probability profile with four columns. Do not worry about the values or percentages; these will be set later using Visual Logic.



Figure 25-19: VL Example 2 - Completed Probability Profile

- The parameters of `dispp_Product` Type should be set at the beginning of each simulation run. As in Example 1, we will use On Reset Logic to accomplish this. Open the On Reset Logic window (Tools > Visual Logic Events > On Reset) and add the following code:

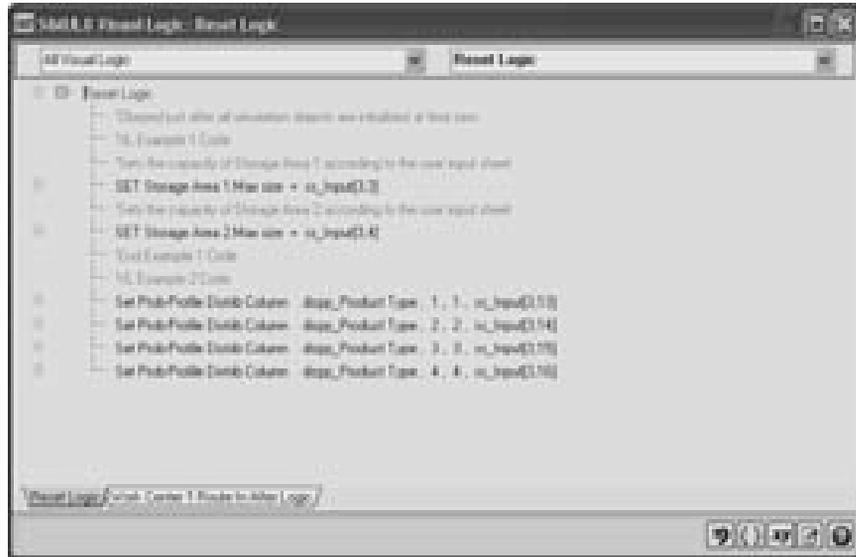


Figure 25-20: VL Example 2 - On Reset Logic

The “Set Prob-Profile Column” command can be found by right-clicking the VL window and selecting Command > Object > Distributions > Set Prob-Profile Column Parameters. In the window that pops up, enter a value for each of the four parameters required by the command. The first parameter is the name of the distribution to set (click on the grey “???” box to select the distribution from a list). The column number is the column within the probability profile to edit (i.e., 4 columns were created in steps 4 and 5). The value is the number returned by the distribution. In this case, we want to return a “1” for product 1, a “2” for product 2, and so on. Finally, Percentage Chance is the value which the user has input to the spreadsheet `ss_Input`.

To quickly reference the appropriate spreadsheet cell, click on the grey “???” box to open the Formula Editor. Double-click on `ss_Input` in the list, and then click the spreadsheet button (circled

in the image below). In the spreadsheet window that opens, click the appropriate cell and then click OK to close the window.



Figure 25-21: VL Example 2 - Formula Editor Spreadsheet Button

7. Now it is necessary to tell the simulation when to assign the lbl_Product Type. The logical place to do this is as soon as Work Items enter the model, at the Work Entry point. Double-click on the Work Entry Point, select Label Actions, and select Add to create a new label action. Choose lbl_Product Type and click OK. Select “Set To” and then choose dispp_Product Type from the distributions drop down menu. Each Work Item will now be assigned a value of 1, 2, 3, or 4 when it enters the model, as sampled from the distribution dispp_Product Type.

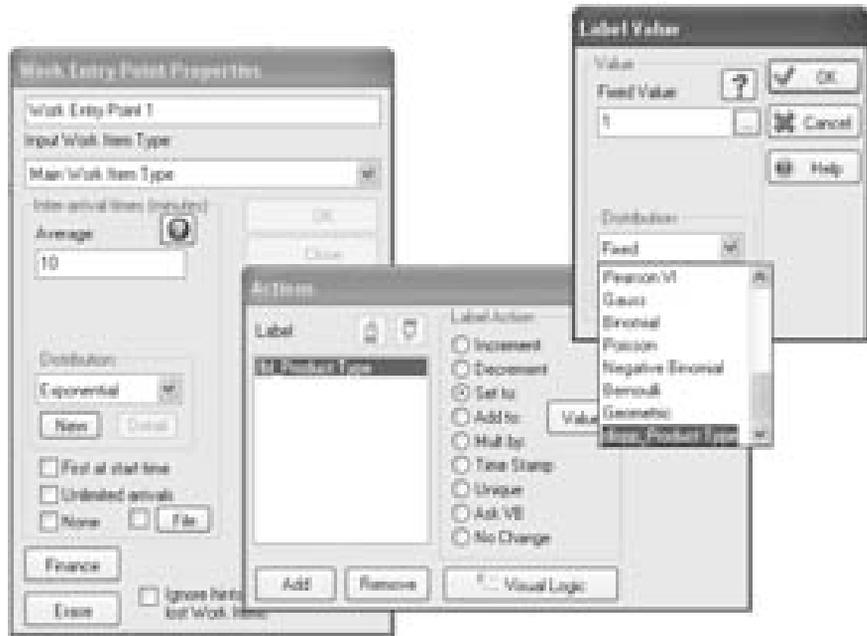


Figure 25-22: VL Example 2 - Setting lbl_Product Type

8. Now that the product type label is set according to user input from our Input spreadsheet, the label can be used to set Work Center 1's processing time. To do this, use the "Set Object Distribution Parameters" command. The best place to perform this operation is in After Loading Work Logic, under the Routing In dialog. This is because the logic is executed after work has been routed into the Work Center, but before processing has begun.

There are two approaches to writing this code. A series of IF statements could be created, in the form of "If lbl_product = 1, set processing time = x". However, a much more efficient approach is to take advantage of the product type label in referring to the appropriate row from the spreadsheet. This way we need only use one line of Visual Logic code.

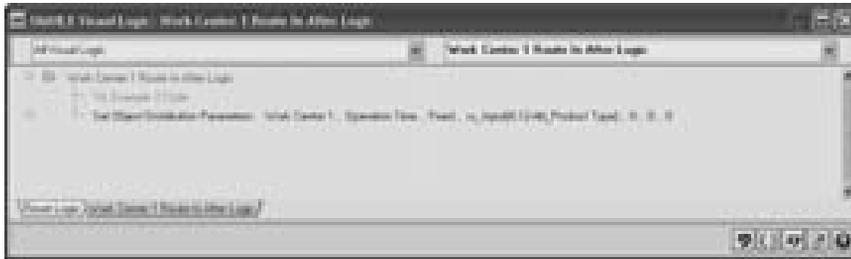


Figure 25-23: VL Example 2 - Set Processing Time Logic

To enter this command, right click in the VL window and select Command > Object > Distributions > Object Distribution Parameters. In the window displayed, select the object where the change is to be made (i.e., Work Center 1), the distribution to be changed (i.e., Operation Time), the new distribution type (i.e., Fixed), and then choose the parameters of the new distribution. A fixed distribution has only one parameter, so we will set parameter 1 to reference the appropriate spreadsheet cell. In this case, the cell always references column 4, and computes the row based on the formula $[12+|b|_Product\ Type]$. This will cause the Visual Logic to read the label for the current work item and add 12 to find the row reference. For example, if the label is set to 2, then the Visual Logic will compute row 14, which is the correct cell for product two's processing time. This approach can significantly speed up both model development time and execution speed.

VL Example 3 – Routing Using the If Statement

Visual Logic is also commonly used when making routing decisions, and the options provided in the Work Center routing dialogs do not offer the level of control that is required to implement complex routing logic.

There are two potential locations for implementing Routing In logic within the Work Center dialog. One option is Before Selecting Logic on the Options tab of the Routing In dialog and the other option is On Exit logic on the Routing Out dialog. Although On Exit logic may not seem like the natural place to implement routing in decisions, it is in fact often preferable over using Before Selecting logic. This is because Before Selecting logic runs continuously during model execution, and consequently can slow a model down considerably. Before Selecting Logic is run continuously

because there is no precise time “before” a work item enters a Work Center, just as there is no precise time “before” tomorrow. On Exit logic, however, runs at the point in time when a work item leaves the work center. In many situations, this is also the precise time when a new routing in decision must be made. Frequently used routing in commands include: Set Route in Discipline, Set Route in Priority, and Set Collect Number.

The usual location for implementing Routing Out logic is On Work Complete logic on the Routing Out tab. Frequently used routing out commands include: Set Route Out Discipline, Set Route Out Priority, Set Route Out Percent, and Set Route Out Label. At that point, if the routing out discipline of the Work Center is set to Label, it is possible to control work item routing by setting the value of that label in Visual Logic using the SET command. The next example demonstrates this technique.

Using the model from the previous example, it is possible to illustrate how the IF statement and the SET Command can be used to control model behavior.

Storage Bin 1 has a capacity of 7 and Storage Bin 2 has a capacity of 5. The objective is to send work to the Storage Bin with the maximum space.

1. Create a label which will be used to decide which route the Work Item will follow.

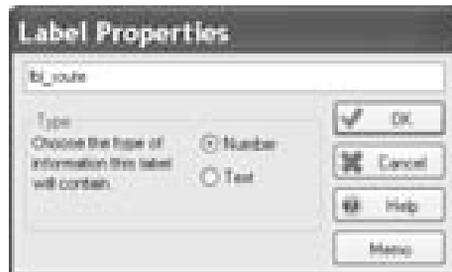


Figure 25-24: VL Example 3 - Creating a label

2. In Work Center 1, select the Label Routing Out discipline, and select lbl_Route as the controlling label.

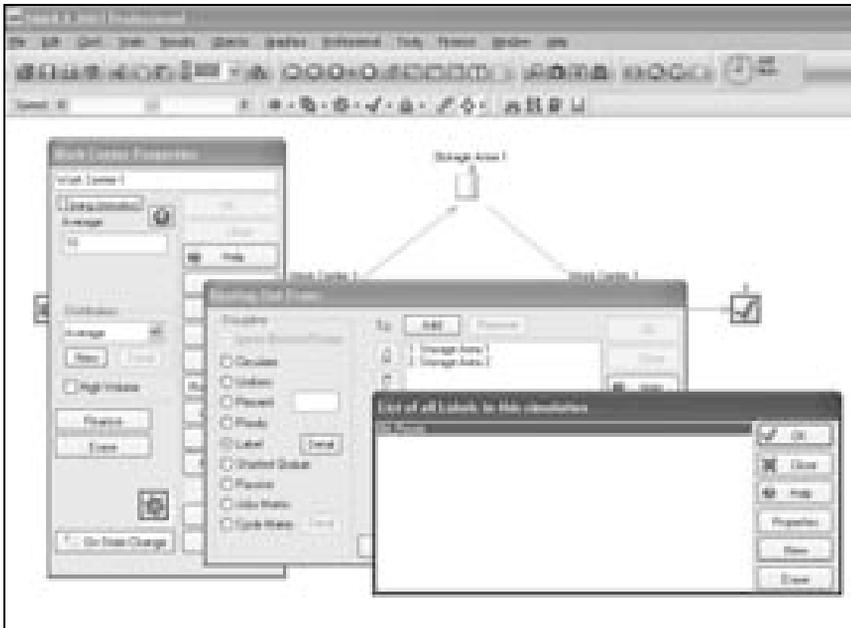


Figure 25-25: VL Example 3 - Routing out by label

3. Now it is necessary to set the label so that the Work Item will be routed to the Storage Bin with the most available space. In order to do this Visual Logic must be used.
4. At Work Center 1, use the Routing Out On Work Complete Visual Logic access point.
5. Choose the IF command and enter the information below in its various edit boxes. Ensure that the SET lbl_Route command is indented within the IF statement.

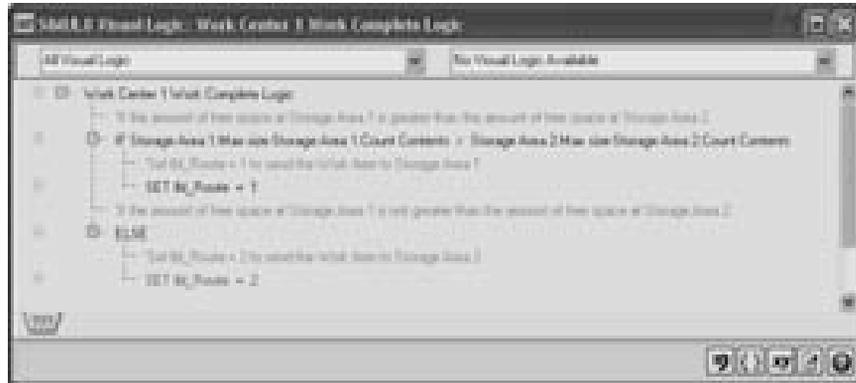


Figure 25-26: VL Example 3 - If Statement Visual Logic

The simulation will now route Work Items to the Storage Bin with the maximum space.

VL Example 4 – Routing using a Loop

Using an IF statement in the above situation works well if there are only two possible destinations. However, if the number of destinations were to grow, it is easy to imagine how complicated it could become to route items using IF statements. A large number of IF statements would be required to consider all the routing options. The previous example can be expanded to show six Storage Bins. Once again, the objective is to send Work Items to the Storage Bin with the fewest items already waiting.

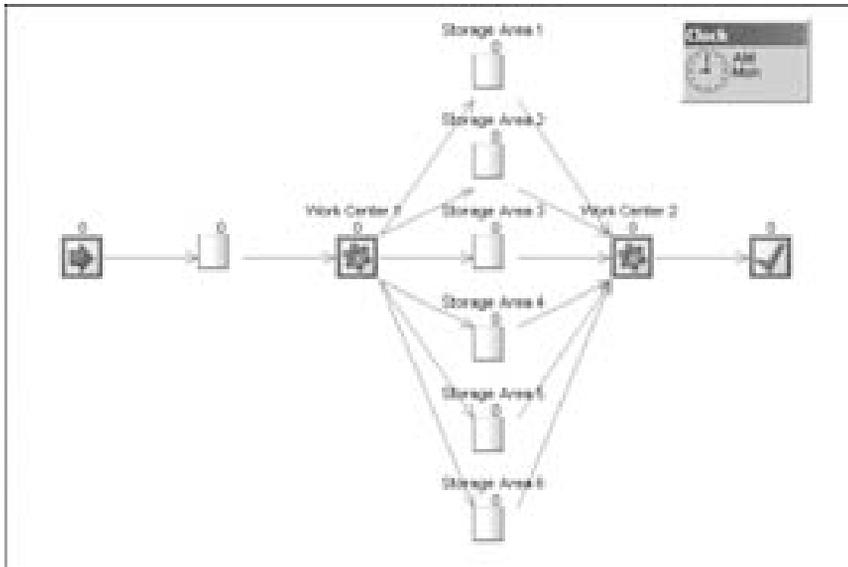


Figure 25-27: VL Example 4 - Model Structure

Again, each of the Storage Bins has a capacity set from the spreadsheet `ss_Input` on reset.

1. The spreadsheet `ss_Input`, from the previous examples, can be extended to encompass all of the Storage Bins (this is why it is always a good idea to leave extra space in your spreadsheets!).

The screenshot shows a spreadsheet with the following data:

	A	B	C	D	E
1					
2		Storage Area	Capacity		
3		Storage Area 1	7		
4		Storage Area 2	5		
5		Storage Area 3	5		
6		Storage Area 4	5		
7		Storage Area 5	5		
8		Storage Area 6	5		
9					
10					
11					
12		Product Type	Proportion of Total Production	Work Centre 1 Processing Time (mins)	
13		1	25	15	
14		2	35	19	
15		3	10	17	
16		4	30	24	
17					

Figure 25-28: VL Example 4 - User Input Sheet

2. A Global object should be created so that we can use the loop function to quickly set the storage area capacities on reset. This can be done by going to Objects > Information Store > New. Choose Simulation Object and select Storage Bin. This creates a variable that can be set to represent different Storage Bins.
3. The global object should be named according to a chosen naming convention (i.e., obj_SB).



Figure 25-29: VL Example 4 - Creating the Object Variable

4. In order to use a loop, an integer variable must also be created. Again, a new information store is created and is named according to the chosen naming convention (i.e., int_loopvar).



Figure 25-30: VL Example 4 - Creating the Loop variable

5. A loop can now be constructed to set storage area capacities on reset. Note that you should delete the code from VL Example 1 which set capacities individually.

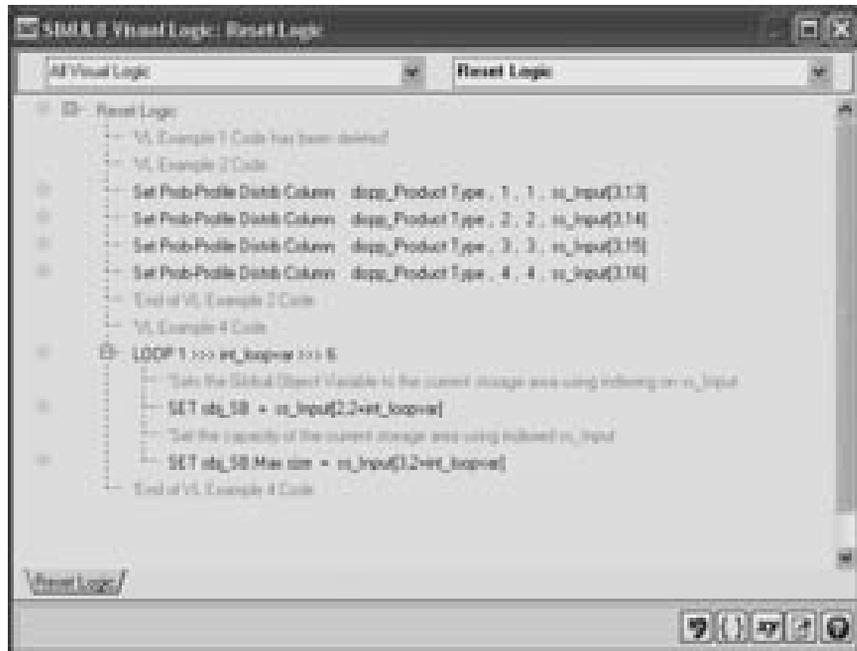


Figure 25-31: VL Example 4 - Loop Visual Logic

- A loop can also be applied when routing the Work Items from Work Center 1. Another variable should be created which will hold the count of spaces available.



Figure 25-32: VL Example 4 - Creating the Count Variable

- The following code ensures that the Work Item is sent to the Storage Bin with the most available space. If none of the bins has

any available space, the Work Item is routed to Storage Bin 1. Remove the code from VL Example 3 which controlled routing using an IF statement. Writing comments, as in the code below, will make the code below easy to follow. For every time the loop is run, the first command in the loop sets the obj_SB variable to the next Storage Bin named in the spreadsheet. The IF statement checks if the Storage Bin's available space (i.e., max size – current contents) is greater than the maximum available space found so far. The maximum available space is stored in int_count, which has been initialized to zero. If greater available space is found, int_count is updated and the routing label (lbl_Route) is set to the current destination number, which is identical to int_loopvar. Finally, the label is set to 1 if none of the storage bins have available space.



Figure 25-33: VL Example 4 - Loop Visual Logic for Routing

VL Example 5 – Writing Results to a Spreadsheet

For a variety of reasons, it is often useful to write simulation results to a spreadsheet. Results that could be scattered through different work objects in the model can be collected in a single place, allowing for easy viewing. The spreadsheet results can also be formatted to highlight important information. Spreadsheets also allow the results to be easily copied or exported into an external spreadsheet program such as MS Excel, where they can be further analyzed or stored for later examination. Using the mathematical functions of the Visual Logic SET command, the user can create results that are not collected automatically within SIMUL8. For example, results that must be calculated based multiple simulation objects can be written to a spreadsheet.

In this example (continued from Example 3), write the following results to a spreadsheet for each of the six Storage Areas in the model:

- Maximum Queue Size
- Average Queue Size
- Total number of items processed
- Utilization % of the storage area throughout the simulation run

Another useful piece of information for the results spreadsheet is the Capacity of the Storage Areas, which was set on the input sheet (see example 1). It will help us to better understand our results by comparing the maximum queue size with the maximum queue capacity.

1. Create a new spreadsheet, titled `ss_Results`, to store the calculated results. Input column headings, leaving space for future title blocks if desired.

1	A	B	C	D	E	F	G
2		Storage Area	Capacity	Max Output Size	Average Queue Size	Number of Items Processed	Utilization %
3		Storage Area 1					
4		Storage Area 2					
5		Storage Area 3					
6		Storage Area 4					
7		Storage Area 5					
8		Storage Area 6					

Figure 25-34 VL Example 5 - Results Spreadsheet setup

2. The commands to write the results information to the spreadsheet should run only once, after the model has finished running, so use On End Run Logic (Tools > Visual Logic Events > On End Run):



Figure 25-35 VL Example 5 - On End Run Visual Logic

3. Input the following code into the On End Run Visual Logic dialog:

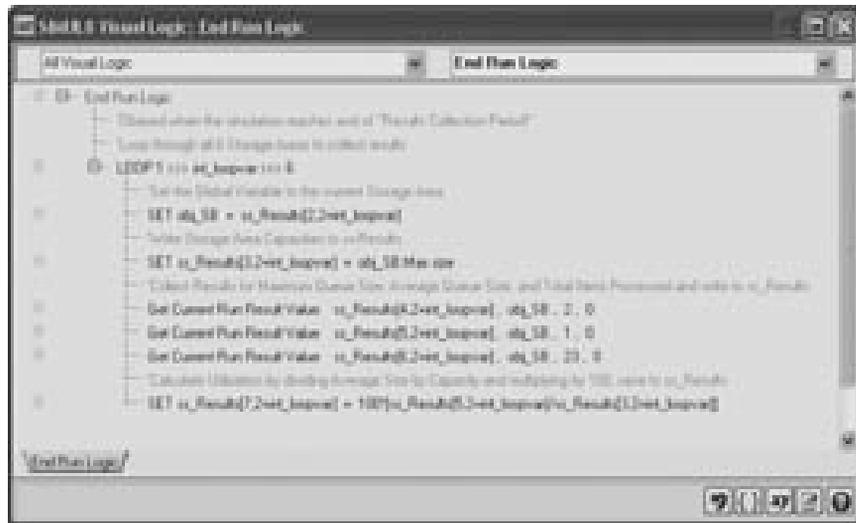


Figure 25-36 VL Example 5 - Results writing to spreadsheet code

This code works as follows. As in VL Example 4, the code will loop through the six Storage Areas in the model and write the results for each of them in turn. The first command inside the loop sets the Simulation Object variable equal to the object we are interested in looking at during this iteration of the loop. This information is taken from column 2 of the `ss_Results` spreadsheet. The next command writes the capacity of the storage area to the spreadsheet using the SET Command. The following three lines of code use the Get Current Run Result Value command (i.e., Command > Simulation > Results > Get Current Run Results), which has four parameters: the location where you want to save the result (in this case a spreadsheet cell), the simulation object from which the result will be taken, and 2 result codes.

Each result in a simulation object's results dialog has a pair result codes that identify it; to determine the code for the result you are interested in, add the result to the Results Summary and right click (see Figure 25-37).



Figure 25-37 VL Example 5 – Result Codes from the Results Summary

The final line of code in the loop uses the SET Command to calculate the utilization, (percentage of capacity used) of the Storage Area. This result must be calculated by the user, since it is not recorded by SIMUL8 automatically in the storage bin's results dialog. In this case, set the cell where the result will be stored equal to the average queue size (located in column 5) divided by the maximum queue size (located in column 3). Then multiply by 100 to get a percentage.

4. After running the simulation model, we can examine our spreadsheet and see the results that have been saved. Note that if the simulation is re-run, the new results will overwrite the previously-recorded results.

	A	B	C	D	E	F	G
1							
2		Storage Area	Capacity	Max Queue Size	Average Queue Size	Number of Items Processed	Utilization %
3		Storage Area 1	7	74.04312863	5.2379820437	96.57759055	5.47672409
4		Storage Area 2	5	5.2379820437	5.48571992	5.42613042	5.39429066
5		Storage Area 3	5	5.1976453302	5.1800599995	5.37612	5.37612
6		Storage Area 4	5	5.1800599995	5.1800599995	5.37612	5.37612
7		Storage Area 5	5	5.1800599995	5.1800599995	5.37612	5.37612
8							
9							
10							
11							

Figure 25-38 VL Example 5 - The completed Results spreadsheet

VL Example 6 – Creating Buttons

An important part of any simulation model, as we have mentioned previously, is the user interface. With a good user interface, the potential of a model can be fully realized as users will find it easier to modify model parameters. In this example, buttons are added to the simulation window in order to make the model easier for a non-expert to use. These buttons will open our input and results spreadsheets.

1. Click the Load Graphics from Disk icon on the graphics palette and then click within the simulation window where you would like to place the upper left corner of the button image. Select an image to use for the Input button. The SIMUL8 image library provides many suitable images in the “Buttons” folder (this is typically accessible through C:\Program Files\SIMUL8\Examples\Images\Button). Repeat this step and select an image for the Results button.
2. If desired, use the text tool on the graphics palette to label the buttons

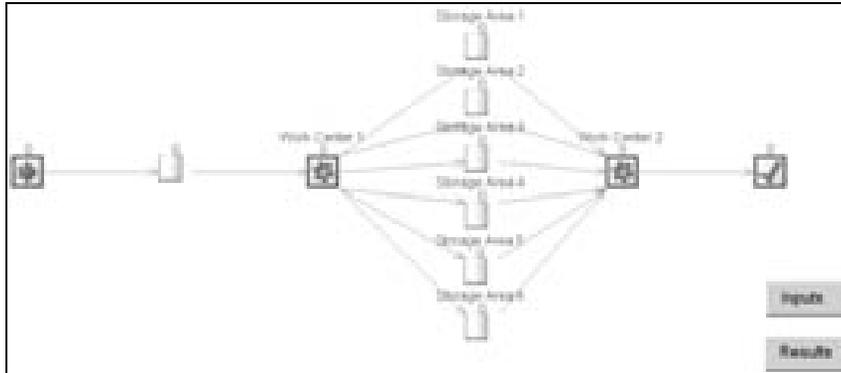


Figure 25-39: VL Example 6 – simulation window with buttons created

3. Hold the control key and double-click on the top left corner of the Inputs button image you created. In the URL dialog that appears, type Inputs.



Figure 25-40: VL Example 6 - URL Dialog

4. Repeat step 3 for the Results button, typing Results into the URL dialog
5. Create a new information store. Name it Button and select the type text. The name Button has special meaning in SIMUL8 so SIMUL8 knows to use this information store with the On Button Click Logic.
6. Open the On Button Click Logic (i.e., Tools > Visual Logic Events > Other Events > On Button Click).
7. Input the following code into the VL window:

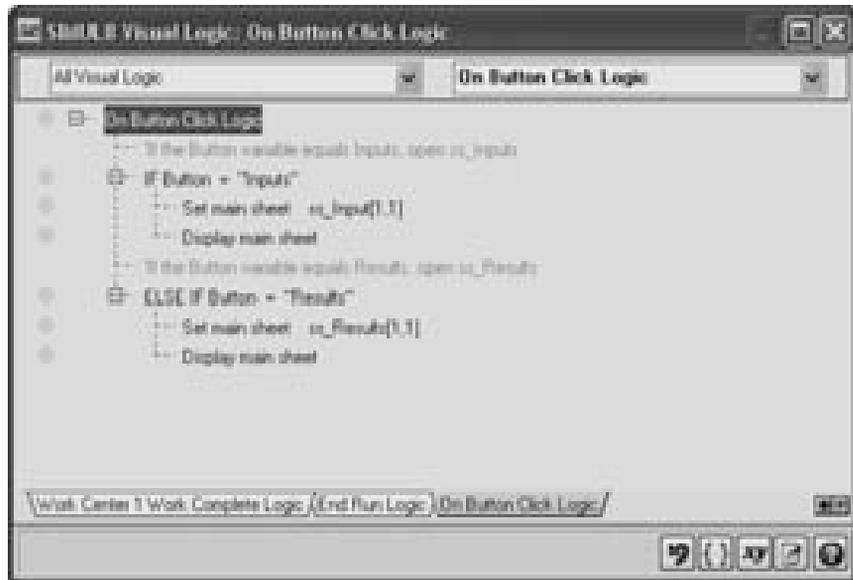


Figure 25-41: VL Example 6 - On Button Click Logic

The Set Main Sheet and Display Main Sheet commands can be found under Command > Simulation > Information Store > Main Sheet.

8. Clicking on the buttons in the simulation window will now open the appropriate spreadsheet for easy data entry or results retrieval.

Chapter 26:

General SIMUL8 Information

Preventing Model Crashes

Although, SIMUL8, like any other program, will occasionally crash if put under stress, the user should not panic since the model can be recovered. If a model does crash, the first thing to do is to restart SIMUL8. Most models are recovered automatically by SIMUL8 without the user having to attempt any recovery. It is recommended that the model be saved under a different name, as it is possible that the model is now corrupt. The model should be checked for structural integrity before continuing with development.

After examination, if the model is deemed corrupt, there are several other options available to the user. The first is the SIMUL8 back-up file named a *.bk8. This file should be located in the same file / folder location as the original model, and will have the same name as the original file. Renaming this file to *.s8, provides the SIMUL8 file in the last state prior to the crash, i.e. the last un-do option.

On searching, if no .bk8 file is found or it does not contain an up-to-date version of the model, there is a third and final option. A temporary file will be stored in Windows > Temp directory called an emsave_.s8 file. The Temp directory should be found at C:\Documents and Settings > Administrator > Local Settings > Temp > s8temp. If not, try C:\WINNT\Temp\s8temp. In this file location, there will be smaller temp directories that should contain a copy of the emsave_.s8.

There are preventative measures that can be taken to avoid this extreme action. It is encouraged that as models are developed, model saves are completed regularly, different versions of the model are saved, and that multiple changes are not completed without re-saving of the model. By always taking these precautionary measures, system crashes will not be fatal.

And always remember to reset the model before you save!

Undo and Redo

During development of a SIMUL8 simulation model, there will be occasions when mistakes are made that must be removed. SIMUL8 provides a feature which allows the user to return to the model state prior to the most recent change. Up to 20 previous model states are saved so that the user can use the Undo feature to remove several mistakes. To access this feature, choose Edit. The list of states will appear below Select All, starting with the last known state.

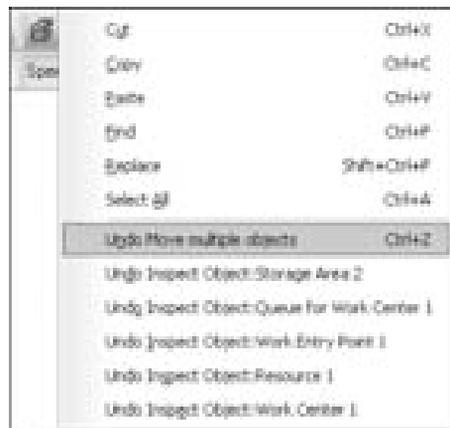


Figure 26-1: Undo Feature

This feature can be switched off to speed up development work significantly. However, if this feature is switched off, mistakes cannot be undone without returning to the last saved version of the model. To switch off this feature, select File > Preferences > Undo.

Monitor Simulation

For de-bugging purposes, a Simulation Monitor is provided so that each timed event in the simulation can be seen as it is running. To switch on this feature, select Clock > Simulation Monitor or Ctrl-M. The timed events will be sectioned into History, Now, and Future. It is recommended that the Trying Steps be ignored, as these are not events, but attempts. The

model can now be run from the monitor, displaying each time-based event during the simulation run.

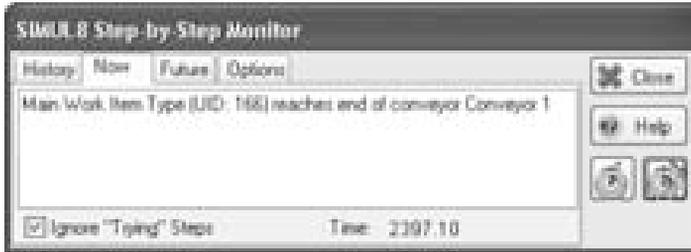


Figure 26-2: SIMUL8 Simulation Monitor

View Documentation

The view documentation options provide a text document including the properties of all objects within the simulation, simulation settings, Information Stores and Visual Logic. Access these options by selecting File > Documentation.

1. View Full Documentation – All documentation will be opened in Notepad or WordPad depending on the size of the file. This is extremely useful for searching through the entire simulation, for example, to find every instance in which a certain label was used.
2. Save Full Documentation – All documentation will be saved in .txt format.
3. All memos – Documentation of all memos within objects will be opened in Notepad or WordPad depending on the size of the file.
4. View Object Settings – An Information Store spreadsheet is created in SIMUL8 called “Summarize Input Data.” It contains a summary of the parameters for each object in the simulation.

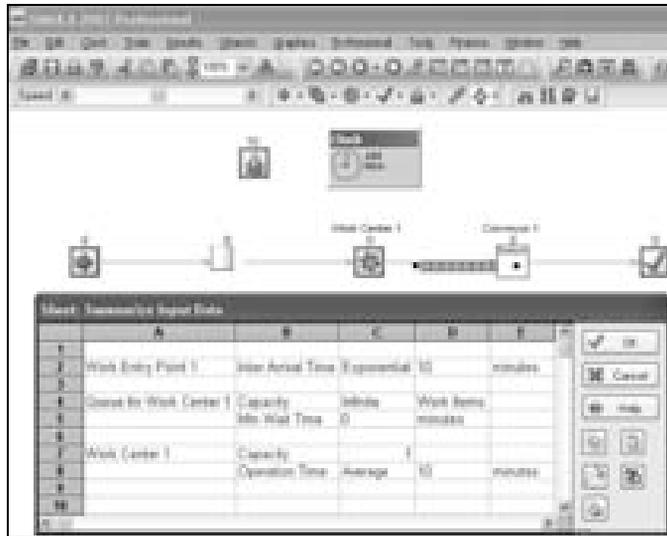


Figure 26-3: SIMUL8 Object Summary Data

5. View as XML – All properties of the simulation will be displayed as XML code.
6. All Visual Logic – A text document containing all the Visual Logic in the model will open in Notepad or WordPad.

Simulation Properties

SIMUL8 provides the ability to assign properties and information to any developed simulation model. This includes a model title, which can be displayed on the top left hand corner of the screen, and notes surrounding the model and/or its development. This can be accessed through File > Simulation Properties.

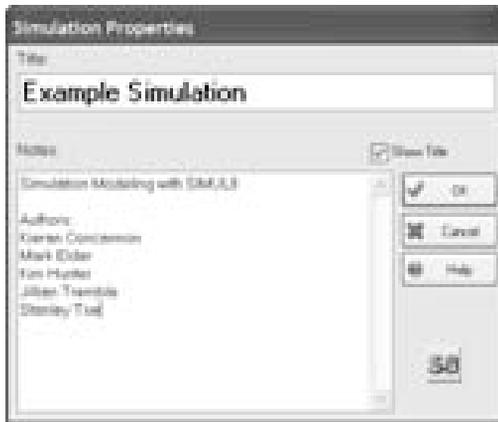


Figure 26-4: SIMUL8 Simulation Properties

Find Function

A Find function is provided to help retrieve objects within the simulation model by searching for a specific word. Once the search is complete, a list of SIMUL8 objects containing the search word will be provided. Clicking on this list will activate the properties of the selected item. It will also highlight its location on the screen. This feature is therefore useful for locating an object in a large simulation model. To access this feature, select Edit > Find, and type in the search word.

Graphics / Images

The images within SIMUL8 are all contained within an Image Library. The library holds all the images used in the open model, and will always contain the default SIMUL8 images as well.

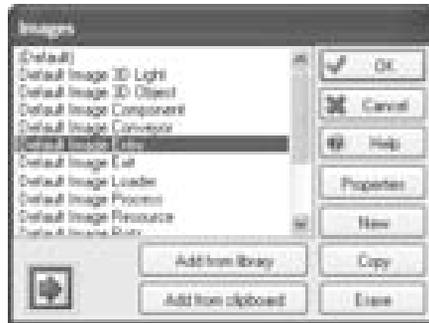


Figure 26-5: List of Model Images

- Change the image of a Work Item when exiting a Work Center through Work Center Properties → Graphics. ■

The user can import images from the SIMUL8 library, which is found under Program Files > SIMUL8 > Examples, or import other images through a Browse option. There are many websites that offer icons for free download. SIMUL8 will accept *.bmp, *.wmf, or *.ico images. Other file types will not appear properly on the screen and should be converted with a graphics software package. The user can also create graphics in external graphics packages provided the images are saved in the correct format and are no larger than 100 pixels in any direction.



Figure 26-6: Import an Image

The user can also make use of the SIMUL8 Image Editor, which can be accessed under Graphics > Images > New. This provides a limited set of drawing utilities for drawing lines, squares, free drawing, text, and fill options, similar to those which can be found in standard graphics packages such as Microsoft Paint™ and Paint Shop Pro™. This allows the user to create basic images within the software to meet the individual needs of the model, without the need to import images through the browse option.



Figure 26-7: SIMUL8 Image Editor

Data Graphics

SIMUL8 Data Graphics are a feature that allows the user to create on-screen graphics that display changing parameters of the model. The graphics can be text, charts, or icons and are automatically updated as the model runs.

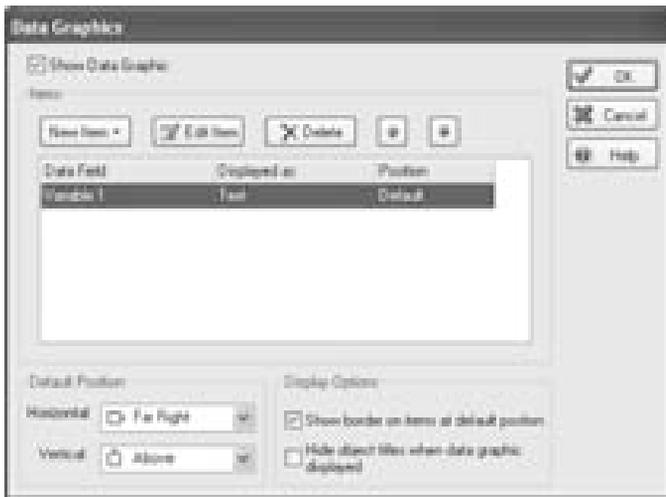


Figure 26-8: Main Data Graphics Dialog

Data Graphics can be accessed by clicking on Object Properties > Graphics > Data Graphics (or DG Detail in a Work Center). The main Data Graphics window is shown in Figure 26-10.

As mentioned above, data can be displayed in textual, chart, or iconic form. Text form is useful for displaying the current value of a SIMUL8 Variable, spreadsheet cell, or Object Property.



Figure 26-9: Data Graphics Data Types

Data Bar allows you to create various forms of charts including stacked bar charts. There are many tools for modifying charts to display the information that the user requires.

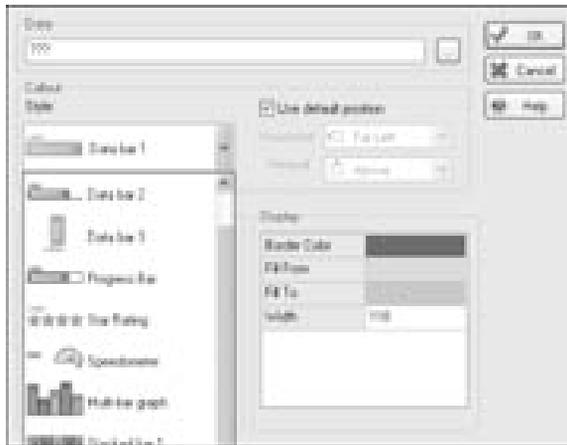


Figure 26-10: Data Graphics Data Bar Types

Finally, the Icon Set allows the user to display a symbol that changes color in response to changing simulation conditions.

All data graphics are linked to information store variables and can be updated using Visual Logic, accessed from wherever the user desires. Typically data graphics for an object will hold results or information specific to the work item currently being processed at that object.

SIMUL8 Explorer / Quickview

SIMUL8 Quickview provides the ability to select and view the properties of an object without actually opening the object's properties window. By selecting multiple objects (Ctrl-Select), Quickview can be used to make changes to several objects at once. This feature is essential to speedy model development when creating large models. Quick Click options allow the user to directly access some object property dialog boxes, eliminating the need to click through several dialog screens to get there. To access this feature, select Objects > Quickview or press F11. This window can be docked to the side of the simulation window or placed anywhere on the screen during development work.



Figure 26-11: SIMUL8 Quickview

SIMUL8 Explorer provides a complete list of SIMUL8 objects and access to those objects through a list similar to Windows Explorer. To access this feature, click on Objects > SIMUL8 Explorer. This will open the Explorer window which can also be placed anywhere on the screen while model development continues.

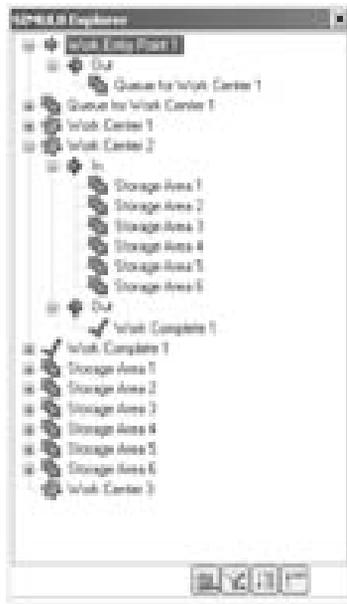


Figure 26-12 SIMUL8 Explorer

Multi-Object Changer

Users have the ability to change the properties of several objects at once using the Multi-Object Changer functionality within SIMUL8. Instead of individually changing each simulation object, all desired objects can simply be selected and their properties can be adjusted at once. The objects do not even have to be of the same type, as long as the property to be adjusted is common to the entire selection (e.g., High Volume is used by Storage Bins but not Work Entry Points).

To adjust the values of several objects, select the desired items on screen. Either use the Quickview (i.e., F11), right-click and select “Properties – all selected objects”, or select multiple objects from one of the dialogs within the Objects menu to inspect the properties of the selected objects.

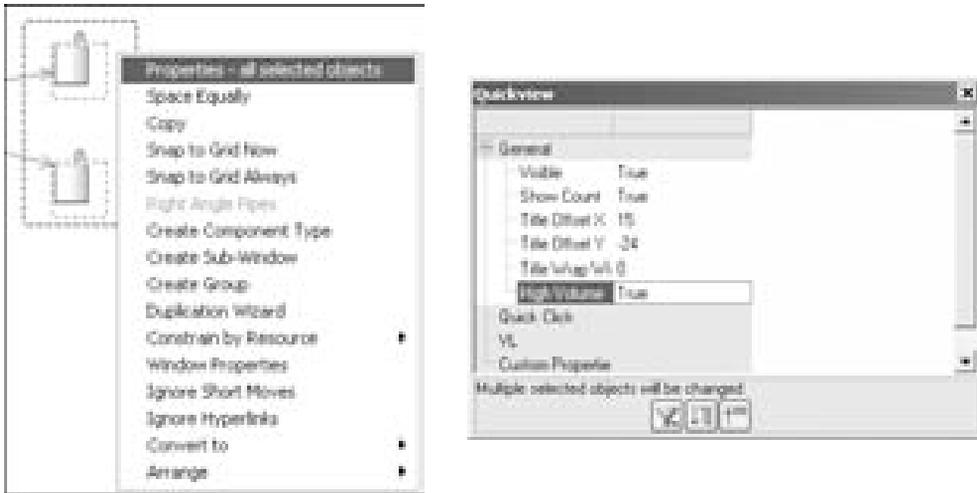


Figure 26-13: Multi-Object Changer Using Right-click Options and Quickview.

Certain objects have more properties in common than others and are more easily changed using the Multi-Object Changer (i.e. Storage Bins are highly adjustable whereas Work Centers can rarely be adjusted simultaneously). And, although several objects may be chosen when viewing their properties, only one Properties dialog box will appear from the selected objects.



Figure 26-14: Selecting Objects with the Multi-Object Changer

For example, although a Storage Bin and a Work Entry Point are chosen, only the Storage Bin's properties are shown.

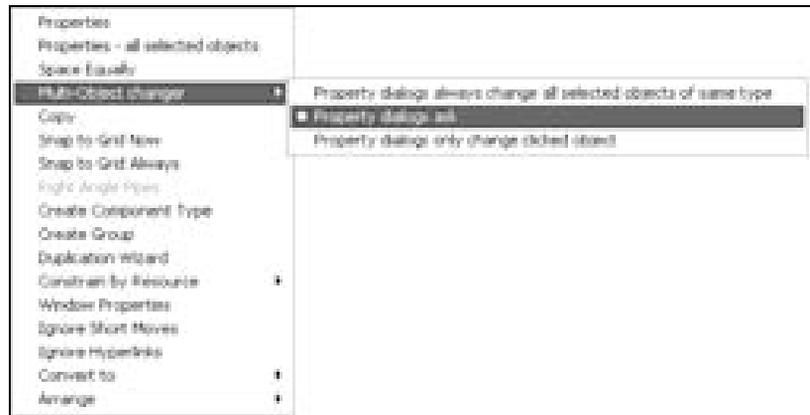


Figure 26-15: Multi-Object Changer Right Click Options

When selecting multiple objects in a dialog in the objects menu, the user has the option to apply the changes to all selected objects of a certain type or only to an individual object.

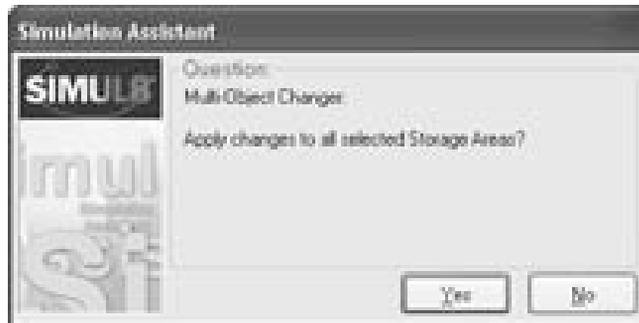


Figure 26-16: Multi-Object Changer Confirmation Message

The Multi-Object Changer is useful for making quick changes to multiple object properties, but a quick inspection of a sampling of the objects is always a good idea to ensure the appropriate changes have been applied if substantial adjustments were made.

Watch Window

One of the most useful Visual Logic de-bugging tools is the Watch Window. This permits the user to see the values in an Information Store at

any time during a simulation run, or Visual Logic code execution. This is invaluable for determining where an error in the Visual Logic code lies. To access this feature, select Tools > Watch Window or Ctrl-Alt-W. To select variables, formulas, and information store values to be seen, double-click on the Formula section of the window.

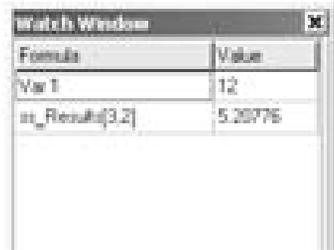


Figure 26-17: SIMUL8 Watch Window

Track Changes

If there are several versions of the same model and / or different model builders are making changes to a model, then Track Changes is a useful feature to identify differences between similar models. By opening the second model through the Track Changes feature, a Summary of the model structure will be provided with all differences highlighted. A summary of these differences is also provided. An example of a tracked change is provided below. Track_Changes_1 has an inter-arrival time of 10 minutes, while Track_Changes_2 has an inter-arrival time of 15 minutes.

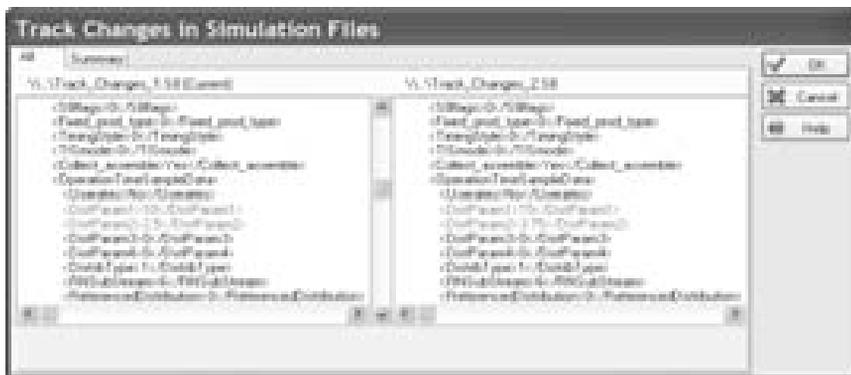


Figure 26-18: SIMUL8 Track Changes Example

Input Summary

The Input Summary provides detailed information about all of the objects in a simulation model. The information is provided in a convenient tabular format, with each object type displayed in its own tab in order to simplify comparison of object properties. The summary can be displayed by selecting Input Summary from the Objects menu (see Figure 26-19).

Name	Index	Position	Timing				Type	P1	P2	P3	P4	Distribution	High Intensity	Reschedule
			From Left	From Top	From	To								
Dispatcher	0	80	140	Transfer	0	0	0	0	0	0	Fixed	<input type="checkbox"/>	<input type="checkbox"/>	
Waiting Point	1	100	140	Job Move	10	20	0	0	0	0	Average	<input type="checkbox"/>	<input type="checkbox"/>	
Flow Buffer	2	100	140	Job Move	10	20	0	0	0	0	Average	<input type="checkbox"/>	<input type="checkbox"/>	
Queue	3	100	140	Job Move	10	20	0	0	0	0	Average	<input type="checkbox"/>	<input type="checkbox"/>	
Shipping	11	140	200	Job Move	10	20	0	0	0	0	Average	<input type="checkbox"/>	<input type="checkbox"/>	

Figure 26-19: Input Summary window

The input summary is useful when debugging a simulation model, allowing the user to quickly find object properties that have been set incorrectly.

Object properties cannot be edited from within the Input Summary window. However double-clicking a cell in the Input Summary table will open the corresponding simulation object dialog box. Clicking the copy button copies the contents of the current summary table to the clipboard, allowing them to be pasted into an external software package.

Additional Features

This textbook can not cover all of the features in SIMUL8. The reader is encouraged to select from the various menus at the top of the SIMUL8 main window and explore the depth of functionality that SIMUL8 offers. The latest changes option in the help menu is a good overview of some interesting features, too.

Appendix A: Tips and Tricks

Refer to the page number for additional information.

Tips and Tricks Key

- Tips for new users ●
- Tips for experienced users ■
- ◆ Tips for expert users ◆

● **Throughout this book, the term “simulation” refers to visual interactive computer simulation modeling.** ● 17

● **A stochastic or probabilistic simulation can act like a deterministic model by using fixed distributions.** ● 20

● **Use the Simulation Software Survey from OR/MS Today as a starting point when evaluating simulation packages** ● 25

● **Recommended units of time:** 27

- **Seconds for less than 1 day** 27
- **Minutes for less than 6 months** 27
- **Hours for less than 2 years** 27
- **Days for more than 2 years** ● 27

● **See the Institute for Operations Research and Management Science website (www.informs.org) for more information on OR** ● 30

● **SIMUL8-Planner is a software package that combines simulation with planning and scheduling tools.** ● 31

● **A computer simulation provides a risk-free arena to test various scenarios, so try many different situations including extremes.** ● 40

■ **Recommended naming Convention:** 45

lbl_ = Label 45

dist_ = Distribution 45

ss_ = Spreadsheet 45

int_ = Local Integer 45

gbl_ = Global Integer 45

str_ = Text String 45

obj_ = Object Variable ■ 45

● Use Ctrl+Z to undo ● 177

● Use Shift+Ctrl+Z to redo ● 177

● Use the mouse wheel inside the active window to change the size of window contents ● 178

◆ Ctrl+B to move the simulation back 1 minute ◆ 179

◆ Ctrl+H to move the simulation forward 1 minute ◆ 179

■ To lock images on the screen and prevent accidental editing, close the Graphics Palette. ■ 182

● A number variable must be created in the Information Store before it can be displayed on the screen ● 182

■ Since all properties of a Work Item can be manipulated using labels (i.e. graphics and size), multiple Work Item types are rarely used. ■ 188

◆ Minimum wait time only functions when using labels as part of the reference if Work Items flow into the Storage Bin. If they are added using Visual Logic, no wait time will be applied. ◆ 192

■ Change the image of a Work Center depending on its state (working, blocked, etc.) through Work Center Properties → Graphics. ■ 195

■ Double-click on the units beside the Length or Speed input box to change units ■ 199

■ To quickly link and unlink Objects, hold down the Shift key ■ 203

■ Hold down Ctrl while clicking and dragging to quickly copy objects ■ 204

◆ Preface all labels with “lbl_” when assigning names to labels (i.e. use a naming convention) ◆ 207

■ Shift Patterns can be applied to both Resources and Work Centers ■ 242

- When collecting and assembling multiple Work Items, final label values are set to the highest of the collected values unless otherwise specified. ■ 258
- ◆ The maximum collect number is 32,000 when set in Visual Logic ◆ 259
- The maximum collect number is 10,000 if using manual input ■ 259
- Leaving the 'Ignore Blocked' option unchecked could block the Work Center unnecessarily ■ 268
- ◆ Note that Shortest Queue routes to the destination object with the least Work Items and NOT the smallest proportion of capacity ◆ 271
- Create a user-defined distribution to use for the batch size ● 272
- Alternative Routing Methods can be used in a simulation alongside conventional flow routing ■ 275
- ◆ A group must be created and selected before any Work Centers can use indexing ◆ 298
- Click the range titles to choose confidence intervals from 80 to 99.9 ■ 312
- Click and drag the edges of a chart to re-size the plot ● 317
- Select multiple objects and create a plot of their contents in one chart ■ 318
- TimeView can be accessed in a simulation either mid-run (after stopping it first) or at the end of the run. ■ 319
- Monetary units can be changed to display a different currency by pasting the correct symbol into the field in File > Preferences > Finance. ● 321
- Costs cannot be associated with Conveyors or Tanks in SIMUL8. ● 321
- ◆ Cost and Revenue values cannot be set through spreadsheets or Visual Logic. They must be entered manually. ◆ 324
- The Income/(Loss) Statement only displays financial results for the most recent simulation run and does not display results for trials / multiple runs. ■ 324
- The current value of the variable will be displayed when passing the mouse over the items in the list ● 330
- ◆ 16,384 rows can be viewed, but Visual Logic can reference approximately 65,000 rows. ◆ 333
- ◆ Use sequential names (i.e. Load 1, Load 2, etc.) for like objects for easy referencing in Visual Logic. Set obj_WC = "Load"+int_var ◆ 334

■ Sometimes the Formula Editor can be accessed from other edit boxes, for example a Process Time in a Work Center. Double-click while holding down shift to access these options. ■ 352

■ Change the image of a Work Item when exiting a Work Center through Work Center Properties → Graphics. ■ 386

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