Computer Simulation in the Workplace and Technology Classes

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The infusion of new and relevant technologies into the classroom should parallel the introduction of technologies into business and industries. When today's students graduate, they will be charged with the operation, control, and improvement of these systems. Therefore, students need a curriculum that is current, including new and innovative approaches to teaching, which increase student involvement and interest and enhance students' learning.

An important example of the new systems knowledge that must be included in the curriculum is computer simulation and modeling. These are becoming important for the manufacturing and service segment of American industry. As a result of market dynamics and fierce global competition, manufacturing and service enterprises are forced to provide a better quality product or service on a more cost effective basis while significantly reducing production or service lead time. The quest for the competitive edge requires continuous improvement and changes in the processes and implementation of new technologies. Unfortunately, even the most carefully planned, highly automated, sophisticated manufacturing systems are not always immune from costly design blunders or unanticipated failures. Among the common examples of these costly mistakes are insufficient space to hold in-process inventory, mismatches in machine capacities, inefficient material flow, and congested paths for automatic guided vehicles (AGVs).

Although computer simulation and modeling are not new to solving complicated mathematical problems or providing insights into sophisticated statistical distributions, the power of new generation software has dramatically increased the application of computer modeling as a problem-solving tool. Simulation packages currently available no longer require a strong background in mathematics or computer programming languages to perform real world simulations. There are a number of user-friendly advanced simulation packages available that allow the user to simulate either the working of a factory, a just-in-time inventory environment, a warehousing and logistics problem, or the behavior of a group technology system. These simulation packages are valuable aids in the decision-making processes. They also require a relatively small investment of time on the part of the novice to develop a working knowledge of the simulation process.

The use of computer simulation packages is not limited to the manufacturing environment. For example, as managed healthcare, public policy issues, and reform initiatives gain momentum, the healthcare industry is facing pressure to reduce costs and provide better service. Many healthcare facilities are turning to computer simulation as a route toward salvation. Models to study emergency-room activities, patient tracking procedures, outpatient surgery systems, and physician and other resource allocations are concerns.

CHARACTERISTICS

Simulation is defined as an experimental technique, usually performed on a computer, to analyze the behavior of any real world operating system. According to Schriber (1987), "Simulation involves the modeling of a process or system in such a way that the model mimics the response of the actual system to events that take place over time."

Simulation can be used to predict the behavior of complex manufacturing or service by actually tracking the movements and the interaction of the system components. The simulation software generates reports and detailed statistics describing the behavior of the system under study. Based on these reports, the physical layouts, equipment selection, operating procedures, resource allocation and utilization, inventory policies, and other important system characteristics can be evaluated.

Two important characteristics set simulation modeling apart from other forms of analysis. Simulation modeling is dynamic, in that the behavior of the model is tracked over simulated time. A simple what-if analysis is static in nature. The state of a static model does not change as a function of time. If we were to simulate the roll of a die, then the output of the model would not be affected by time. However, if we were to simulate utilization or breakdown of a machine, then this would not be the case. Equipment utilization or breakdown is dynamic in nature, and the output of such models is a function of time.

Second, simulation is a stochastic model rather than a deterministic one. If, for example, the mean time to failure (MTTF) for a piece of equipment is 1,000 hours, then it does not mean that the equipment will necessarily fail once every 1,000 hours. Such an expectation would create a deterministic model. In the

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real world, however, the breakdown follows a particular statistical distribution (i.e., exponential, weibull, etc.). A random simulation model allows for these real-life breakdowns or other random occurrences.

Advantages/Disadvantages

Because it is relatively flexible and straightforward, simulation enjoys widespread acceptability. It can be used to analyze large and complex systems that may not easily lend themselves to mathematical models. It also allows for the study of interactive effects of many components in a dynamic and a stochastic environment, with the distinct advantage of providing the investigator with a clear visual effect. Because its basic concepts are easily comprehended, a simulation model is often easier to justify to management and customers than most analytical and mathematical models. Likewise, in an educational setting, computer simulation can be used to add a life-like dimension when difficult and abstract models are studied. When students can "see" how a Kanban (an inventory management strategy) system actually works in a simulated environment, the underlying theories are more easily understood. When a simulated model of the central limit theorem dances in front of the students' eyes, it often engenders awe and appreciation rather than disbelief and confusion.

On the other hand, development of simulations of very complex models may be quite expensive and time consuming. According to Heizer and Render (1991), a corporate planning model may take "years" to develop. An analyst may, therefore, settle for a "quick and dirty" estimate. Another disadvantage is that simulation does not generate optimal solutions to problems as do mathematical models. Allowance for the randomness of the process coupled with the trial and error approach can produce different results in repeated runs, which may lead to difficulty in interpretation of the output. The need to develop complex models is rarely, if ever, encountered in educational settings, and an astute instructor can take advantage of the randomness of the output to emphasize the randomness of most real-life occurrences.

SIMULATION IN EDUCATION

In the educational environment, simulation can be utilized to study facilities design, capacity planning, just-in-time (JIT) inventory policies, material handling systems, quality and reliability systems, warehousing and logistics planning, and maintenance scheduling, to name a few possibilities. Students may determine where the bottlenecks in an assembly line are, or they may evaluate a JIT or a Kanban inventory system. In addition, they can develop an appreciation for the task of the materials handling engineer who is responsible for setting up the transporters. These transporters may include fork trucks, automated guided vehicles (AGVs), automated storage and retrieval systems (ASRS), and transport and accumulation conveyors. Students can use simulation to compare different alternatives and study various scenarios to determine, for example, whether in a given situation a conveyor would be more effective than a robot or an AGV. They can discover how simulation can aid warehousing and distribution engineers. One of the frequently encountered problems for big distribution centers is to determine the proper inventory levels for various items and how to dispatch and distribute products from these centers to the appropriate destination in a timely fashion. Simulation can be used to determine the best routes, means of transportation, and the amount of resources needed. Simulating a warehousing operation or the activities of a distribution center allows students to experiment with how bar coding or other automatic identification and data-capture procedures can be utilized to effectively ship different products based on their attributes and destinations. The working of a factory or a group technology workcell, the behavior of a financial system, or manpower studies lend themselves to simulation.

A number of user-friendly advanced simulation packages are available to educational institutions at minimal costs. While the use of these software packages for instructional purposes, especially in technical areas, may be limited only by imagination, one must realize their tremendous potentials in aiding classroom instruction and, hence, enhancing the students' learning experiences.

Simulation can be used to teach the workings of a Flexible Manufacturing System (FMS) environment. The purpose of an FMS is to produce a wide variety of parts where the production schedule can change quite often. An FMS consists of complex software and an integrated network of material handling systems. The system assigns different parts to different machines and allocates different resources to obtain maximum efficiency. Students' appreciation for the process and their understanding of the system can greatly improve by observing, through simulation, what kind of products are selected and how the products are made. Furthermore, they can be made aware of the problems that can arise and the corrective actions to be taken when the schedule or the quantity of parts is changed.

Using computer simulation and modeling in the classroom can also facilitate and provide an avenue for developing an understanding for non-normal probability distributions such as exponential, poisson, or binomial. Teaching and using simulation can provide a hands-on and a tangible approach to understanding some of the statistical concepts and probability distributions. Contrary to popular belief or wishes, not all phenomena in business or industry have a normal probability distribution. Since most simulation packages are capable of analyzing the preliminary data to determine the most appropriate probability distribution for a given dataset, students will develop a better appreciation for such stochastic processes.

Such a hands-on approach to system development and process-in-animation increases the students' understanding of the process and greatly facilitates the learning and retention of the theories. Machine utilization ratios, inventory policies, material handling systems, and statistical theories are no longer distant and abstract concepts; instead, they are tangible and living images operating in virtual reality where the student can manipulate and control them at will.

HOW IT WORKS

The purpose of simulation is to help the decision maker solve a particular problem. Pegden, Shannon, and Sadowski (1990) proposed a basic outline for building a simulation model. This process of model building has been modified and restated here for the purposes of classroom instruction. The approach can be used to instill in the students the ability to systematically approach a problem and work toward a logical solution.

1. Problem Definition. Teach the students to clearly define the problem and state the goals of the study so that they know the purpose, i.e., why are they studying this problem, what do they hope to find out, and to what questions do they wish to find answers.
2. System Definition. Allow the students to define the boundaries and the restrictions of the system in terms of resource availability. Lest they forget that every real-life system faces time, space, and financial constraints among others.
3. Conceptual Model. Develop a graphical model to define system components, variables, and their interactions that constitute the system. Students have an opportunity to use logic to construct the behavior of the system under study and determine how these components will perform in concert or disarray.
4. Preliminary Design. Students will have to decide on and select those factors which they think are critical in the performance of the system, and select the levels at which these factors are to be investigated, i.e., what data need to be gathered from the model, in what form, and to what extent.
5. Input Data Preparation. Let the students develop an appreciation for validity and integrity of input data. They will identify and collect the data needed by the model and understand that the output of the system is only as reliable as the input data.
6. Model Translation. At this point the students will develop a working knowledge of the simulation package by formulating the model in the appropriate simulation language.
7. Verification and Validation. Students will learn to be responsible for the quality of their own work. They will confirm that the model indeed represents the system it intended to represent and operates as expected and that the output is representative of the real system.
8. Experimentation. Now the students can truly learn the power of experimentation and investigation. They can manipulate the system in a real-time environment and learn how the underlying theories work. The animated process brings dry and abstract concepts to reality and enhances the student learning experience. The process transforms what can often be a soon-to-forget rote memorization into a fun learning experience.
9. Analysis and Interpretation. Students will learn how to draw inferences from the data generated by the simulation. Once again they can appreciate the conditions under which the input data was collected and they can realize to what extent the validity of the output is dependent on the validity of the input data. The concepts of generalization of results should now have a much more clear meaning to these student practitioners.
10. Implementation and Documentation. Now they can develop the skills to put the results to use—record and document the model, its use, and limitations.

Because these simulation exercises are often performed by a team of students, they have the additional benefit of offering the students an appreciation for teamwork, cooperation, and compromise. The importance of working successfully in a group and performing well as a team member is emphasized by business and industrial managers who hire these graduates. Performing a simulation project can have an added benefit of honing teamwork skills in addition to teaching a new technical expertise.

Students can be taught to perform simulation modeling for a variety of reasons, among which are:

1. Evaluation: Which teaches students to determine and measure how well a proposed system design performs in an absolute sense when compared against a set criteria. Does the system meet these criteria, i.e., does it meet the production requirement, can it perform within the budget, etc.?
2. Comparison: Comparing alternative designs to carry out a specific function. Students can select from various alternatives by critically comparing them for cost, performance, and other factors.
3. Prediction: Teaches the students the importance of prediction and forecasting. It allows them to investigate the performance of a proposed system under specific conditions.
4. Sensitivity Analysis: While there may be many variables operating in a system, only a few may be critically affecting the performance of the process. Sensitivity analysis helps determine which of the many factors and variables have the greatest effect on the overall operations of the system.
5. Optimization: Once the critical factors have been isolated, students can learn the process of optimization by establishing what factors or which combination of factors produce the best overall system response.
6. Bottleneck Analysis: Students will discover the nature and the location of bottlenecks affecting the flow of the system.

CASE STUDIES

Three case studies from distinctly different areas of manufacturing and healthcare industries are presented below to illustrate the applicability of computer simulation and modeling. Given the apparent and increasing proliferation of this discipline into the business world, we can graduate more technically competent and marketable students by incorporating simulation techniques into our curriculum and classrooms.

Webb (1995) reported how Cooper Tire and Rubber Company used computer simulation to assist in the implementation of a scheduling package in a high-volume facility. The purpose of the project was to develop an analysis tool with which the production planning team could pilot and evaluate a production schedule and handle other issues such as storage capacity and utilization, tooling constraints, and the need for additional equipment. The model simulated various stages of tire building and curing operations and the relevant work-in-process storage areas. It was also capable of varying the production schedule and the product mix, as well as the critical production parameters which would allow for reduction of critical changeover costs, especially those costs due to labor and scrap.

Webb (1995) reported that the model allowed Cooper Tire Company “to adequately compare alternative scheduling scenarios on an equal playing field” and provided for testing and debugging of the schedules prior to implementation.

Simulation and Healthcare

Simulation is also one of the most powerful techniques used today for hospital management and other service industries. Cashman (1995) reported on a simulation study to assess and improve the operations of the emergency department at Sarasota Memorial Hospital. The facility handles nearly 60,000 patients per year and is composed of 33 rooms divided into three units. Each unit is staffed separately and has different hours of operation. The purpose of the simulation was to examine the sequencing of triage and registration activities, examine the effect of bedside registration on nurse and physician utilization, and provide for a more timely decision support system.

The model examined 10 different scenarios focusing on sequencing and location of triage and registration functions, using x-ray equipment, operation hours, standing physician orders, and improving laboratory turnaround times. Cashman (1995) reported that the model provided four primary results. First, both triage and registrations were shown to be activities on the critical path. That is, the amount of time required for each activity significantly affected the overall turnaround time. In addition, the model showed that the location of these activities did not affect the overall performance of the system. It was decided, therefore, to combine mobile registration units and triage in the room for all patients. Although this did not significantly reduce the overall length of stay (LOS), it did improve the patients’ perception of LOS.

The model also illustrated that additional x-ray facilities were not required for non-urgent patients regardless of the general belief that these patients were constantly bumped back for x-rays. The third point demonstrated by the model was that reduction of the operating hours in two of the units did not affect the third unit. The study showed that the hours could be cut back and adequate capacity for proper patient flow could still be maintained.

Finally, the simulation stressed the necessity to use physician standing orders. In the past many staff members had been hesitant to use the orders; however, after the model showed dramatic reduction in LOS, standing orders were developed where possible.

Waste Handling and Simulation

After the Congress changed the regulatory requirements and the U.S. Department of Energy (DOE) decided to eliminate the start-up period for the Waste Isolation Pilot Plant (WIPP), the need for an analytical tool capable of simulating material handling activities under varying conditions became apparent. Palanca (1995) discussed a simulation model to study a DOE facility developed to provide safe and permanent disposal of defense-generated waste. According to Palanca (1995), a start-up period beginning in 1989 and lasting for five years was planned in preparation for full-scale operation. During the test period, the receipt of waste would have started at a low rate and would have continued to increase until full design capacity was demonstrated. This would have provided an opportunity to evaluate and make necessary design modifications. According to Palanca (1995), however, the start-up period was eliminated and a fully operational start date of 1998 was established.

A simulation model was successfully designed and used to determine the optimum configuration and utilization of the existing facility, identify necessary equipment and process modifications, and determine the required resources to meet an initial reduced waste receipt rate.

Simulation in the Classroom

As part of a requirement for a senior-level course in facilities planning and material handling, the author's students are expected to design a prototype manufacturing facility. The facility plans should include all the productive and auxiliary functions. Full regard is expected for efficient material flow, resource and space utilization, inventory management, and safety and ergonomics. All activities, from product development to line balancing activity relationships, and space and resource allocations are expected to be fully documented and justified.

Students also learn the use of the computer simulation software ProModelPC. Using the simulation software, the students are able to bring their facility to "life" and observe the workings of their manufacturing environment. They can experience first-hand manpower and equipment utilization, bottleneck operations, insufficiencies of their workcells, and the problem areas associated with material handling.

The simulation package allows the student to define an entire manufacturing facility, a distribution center, or a simple production center through an elaborate library of icons. Figure 1 displays a representative sample of icons available to the modeler. Using realistic facsimiles of equipment, material handling systems, and parts, the student can define the physical layout and arrangement of the facilities. The autobuild feature guides students to define the quantity, the routing, and, finally, the destination of each part. Figure 2 displays a simple workcell featuring NC machining operations, a degreaser, and an inspection center. Figure 3 shows a simplified Kanban system. Once the layout and the routings have been defined, the system can be animated.

Not only does the system provide visual and live animation of the facility, but also the software provides statistical analyses and reports pertaining to the performance of the plant. The process allows the student to observe the flow of material through the production facility and to study the vital statistics that are collected by the software.

The data that are collected and analyzed by the program allow the user to make an informed decision regarding layout improvements and modification. Figure 4 provides just a brief glimpse of some of the statistics collected by the system.

If the student proposes to improve the efficiency of the layout by adding personnel or a certain piece of equipment, then he or she can make these modifications to the model. By playing various "what-if" scenarios and running the simulation, one can determine whether the proposed changes indeed have a positive effect on the manufacturing facility before implementing such changes on the factory floor. The activity provides an enhanced opportunity for the students to do and learn by doing. It provides a great opportunity to master the concepts by actually seeing the theory in action.

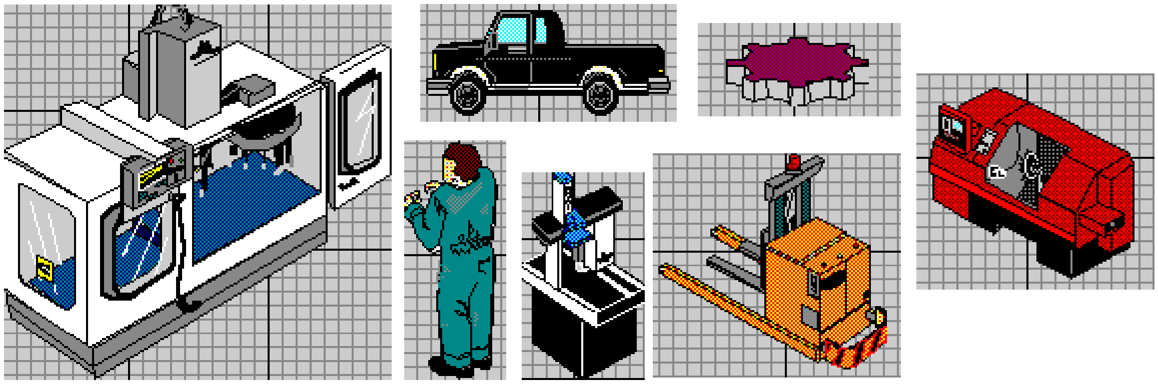


Figure 1. A Sample of Icons Available to Modeler

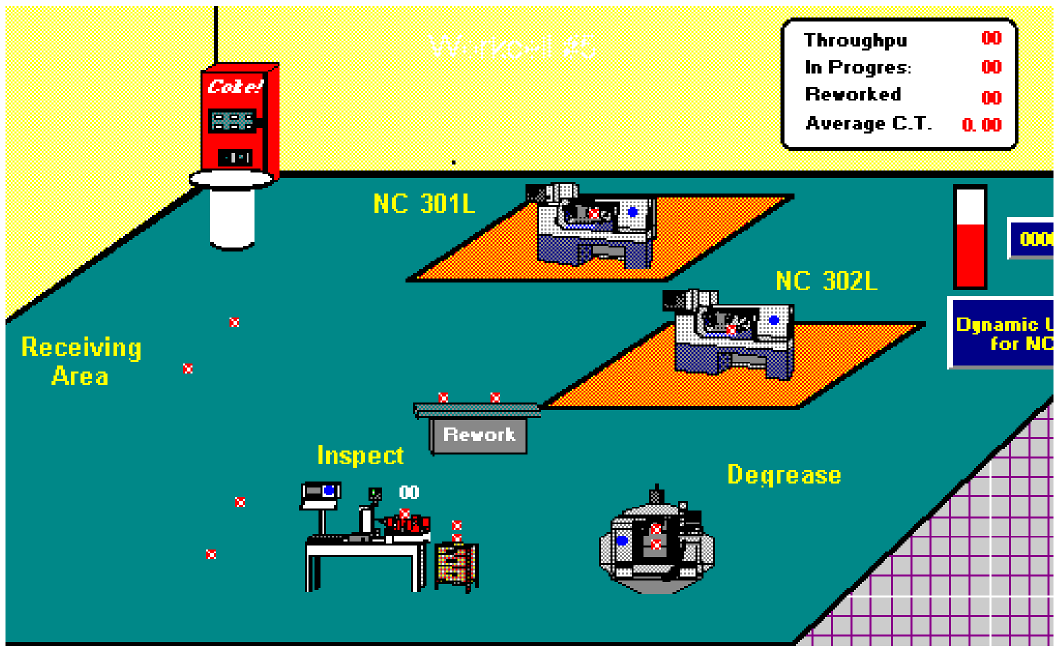


Figure 2. A CNC Machining Center

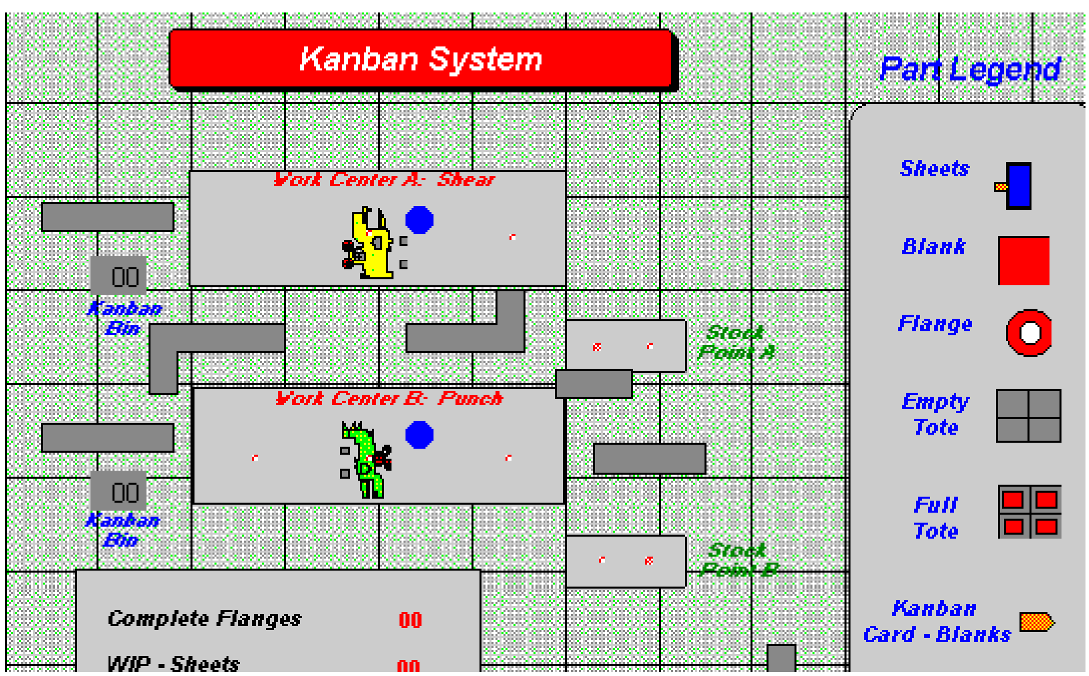
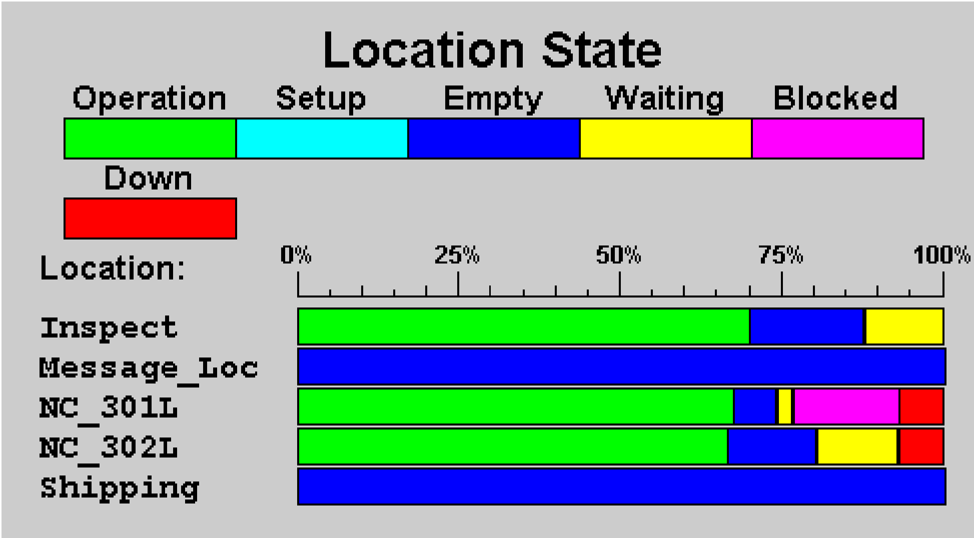


Figure 3. A Kanaban Inventory Management System



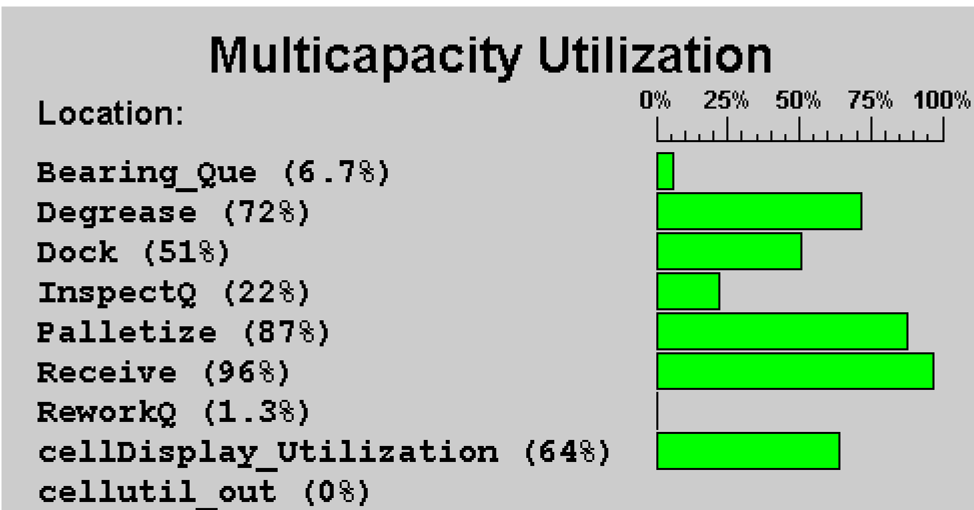


Figure 4. **Some Statistics Provided by Simulation Regarding the Machining Center**

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