# SIMPROCESS Instructional Lab Manual

# For Manufacturing Systems Program



Prepared by Professor Samuel C. Obi

Department of Aviation and Technology

San Jose State University

San Jose, California

December 2015.

Table of Contents

**Introduction**

Webster's Dictionary (2015) defined simulation as "the imitative representation of the functioning of one system or process by means of the functioning of another". In other words, simulation functions to imitate a process or system by acting as the system's elements to yield similar results as the system. CACI (2015) defined process simulation more broadly as the technique that allows representation of processes, people, and technology in a dynamic computer model. CACI's definition broadens simulation in such a way that it can be applied to systems, processes, people, businesses, ideas etc.

In a more simplified way, there are essentially four steps to doing process simulation: 1) building or designing a model, 2) running the model, 3) analyzing the performance measures, and 4) evaluating alternative scenarios. A good model, when simulated, mimics the operations of the system it represents. This is accomplished by stepping through the events in compressed time while displaying an animated picture of the flow. Because simulation software keeps track of statistics about model elements, performance metrics can be evaluated by analyzing the model output data. Manufacturing systems and their subsystems and processes are very suited for simulation applications of this nature.

This report will provide an overview of the applications of simulation in manufacturing systems. It will then detail a case example conducted at San Jose State University in the fall of 2015, to illustrate an example for programs that may need to employ these techniques. A popular software called SIMPROCESS is used in the case example. A trial version can be downloaded from http://simprocess.com/trial-version/.

**Advantages and Uses of Simulation in Manufacturing**

Simulation has many advantages and uses. Some of them include the following:

- Simulation saves money in studying a typical proposed expensive facility. Manufacturing facilities are expensive initiatives. It is in the best interest of manufacturing companies to use simulation studies to understand how to build better, more efficient and least expensive facilities, systems, and processes. Such feasibility studies can help in better determining the usefulness, profitability, and efficiency of such manufacturing projects.
- Once designed, a simulation can be modified and updated. It can be saved on a file so that it can be replicated and modified for future similar studies. This saves time and money in designing a new simulation.
- Simulation can be used to predict how a proposed facility will function. It can reveal problem areas in time before they occur. For example, potential areas for bottleneck and safety concerns can be revealed and corrected in time before implementation.
- Simulation can help to adjust the amount of resources (personnel, machines etc.) to yield needed level.

**Potential Areas of Application of Simulation in Manufacturing Systems**
Since manufacturing systems, by nature, are made up of systems components (Obi, 2013), simulation can be effectively designed for the various components or subsystems which have promising potential for reaping the benefits of simulations. Those components can be found in the following areas identified by Obi (2013).

**Products and Manufacturing Materials**: Most application areas here are in supply chain logistics, management and scheduling. In material and product purchase, distribution and acquisition, purchasing will need to know when to expect orders and how efficient the plan or schedule is, for example. They will also need to know where each entity (order) is in the system at any specific time in the schedule.

**Equipment and Facilities:** Machines, tooling, equipment and facilities as applied in material processing and facility layout are critical application areas for manufacturing simulation. Material processing rates, resource utilization and flow analysis need to be identified for capacity planning, takt time etc. There is need to identify potential areas where bottleneck may develop so that the system can be improved.

**Production Methods:** There is need to develop and compare different production methods so that the most optimum system can be selected. Different process analysis and comparison options like 3-D printing Vs machining can be accomplished by process simulation. This may involve relative automated cost analysis, resource analysis and equipment utilization analysis.

**Material Handling:** There is need to study material handling or material moving systems so that a better and most efficient system can be developed. Also cost analysis can be undertaken in the process in order to justify the least expensive option.

**Labor:** Like in other resources, there is need to use simulation to determine how busy personnel are at each workstation. Adjustments can be made as needed for optimal utilization. This also applies to personnel scheduling, management and performance of work.

**Limitations of Simulation**
It is important to also note that a simulation is as good as the quality of the design and the information used to program it. Sometimes, it is described as *garbage-in-garbage-out*. The better the design and the information (or data) used, the closer the simulation will be to the intended target, and therefore the more useful it will be. However, the following limitations apply.

- A simulation cannot optimize your system's performance; it can only describe the results of "what if" questions. The results will help you to make valid decisions.
- Simulations cannot solve problems. They can only provide information from which solutions can be developed.

- Data collection is crucial. As already indicated, you cannot give accurate results if the data is not accurate. The more accurate the data used is, the better the approximations and simulation.

## Brief Description of SIMPROCESS

According to CACI (2015) which developed the software, SIMPROCESS is a graphical block diagramming tool for modeling, analyzing and simulating. Its main characteristic is that it can be used for making abstract models that may help to learn more about activities based on objects, services, resources or supply. These models can take place in situations when we are trying to understand some specific problem about activities which mainly need some resources. SIMPROCESS allows one to create a computer simulation model and see what happens if we make changes in our abstract model. It is a representation of the system of interest and is used to investigate possible improvements in the real system, or to discover the effect of different policies on that system.
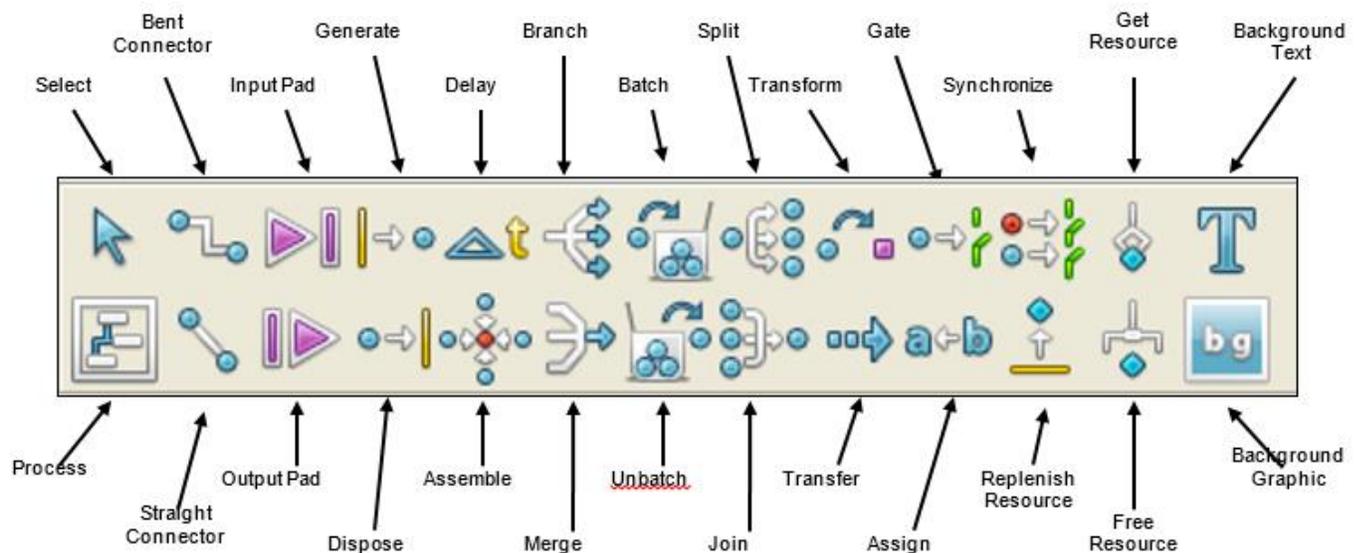


Figure 1. SIMPROCESS Tool Pallet (Courtesy of CACI, 2015)

Programming in SIMPROCESS is facilitated by the availability of a tool pallet shown in Figure 1. The programmer simply clicks at any of its pallet tools and places it on the layout area as needed. Each of the tools can be further defined and equipped with further capabilities to behave as the programmer wants. A complete description of these pallet tools is shown in Appendix A of this manual. In addition, SIMPROCESS also has many other pull-down menu tools which the programmer can use to extend, add, or supplement the tools in the pallet. They include File, Edit, Layout, View, Create, Define, Simulate, Report, Experiment, Tools, Window, and Help pull-down menus with numerous tools and capabilities. A complete description of these tools and other capabilities cannot be accomplished in a report of this size. However, some of these tools and their capabilities will be described in the simulation programming case example described in the following sections. The

descriptions used in this case study are only a partial portion of the capabilities of SIMPROCESS. Additional help can be obtained by visiting SIMPROCESS' help site at: http://simprocess.com/Documentation/SPHelp/sphelp.htm.

<div align="center">

**General Description of the Case Example Model**
</div>

It is important to understand the model used in this case example in order to follow the material presented in this report. In this model, a facility, its schedules, equipment, operators, materials and products are employed.

## Description of the Facility

The facility is a small job shop that mass-produces steel hammers for many domestic and foreign retail hardware dealers. It has only a few very busy machines and two operators who work for the owner who manages the business herself. The operators are highly experienced ones and have worked for this owner for a long time. They are covered by the company's health insurance, and each has also a life insurance as additional benefit.

## Description of the Shift Schedule

Only one shift, the morning (day) shift, is used in this case study. The five-day work schedule starts at 8 AM and ends at 5 PM every workday. The machines are stopped at noon time so that operators can take a one-hour lunch break. Work resumes at 1 PM and continues till 5 PM when the facility is shut down for the day. Maintenance is routinely undertaken after work hours.

## Description of the Entities

The entities represent the number of hammer parts (hammer head stock material, hammer handle stock material, finished hammer heads and finished hammer handles) and the assembled hammers. Each of these categories must be defined and represented in the model. The hammer head stock material and hammer handle stock material will be machined into the finished hammer head and the finished hammer handle. The stock materials must be generated at the Generate icon. In this model, the materials will be generated for 8 hours each workday for one year.

Black dots are used to represent the hammer head stock material at the generation point. Blue dots represent hammer handle stock material. After being machined at the CNC lathe workstations, the parts are now transformed into finished hammer heads and finished hammer handles respectively. At this point, their entity colors change to red for the head and yellow for the handle. The last change in color takes place after the head and the handle are assembled. This is represented by the green color. The hammers are then moved to a location where they are stored.

## Description of the Operators

The CNC lathe operator attends to the two CNC lathes where he alternates in unloading, inspecting, loading and restarting each machine in the order of its need. He uses any in-between time to clean the machined parts and to manage (monitor) the workstations.

The CNC lathe operator is scheduled to be available for the two CNC machines at all time during the work day. The CNC lathe for the head is scheduled to operate a total of 4.75 minutes per cycle, and then to wait for 1 minute to allow the operator to unload a finished part and load another workpiece material. The CNC lathe for the handle is scheduled to operate for 5 minutes and to wait for 1 minute to allow the operator to unload a finished handle and to load another material for the next handle.

The role of the Joining station is simply to ensure that there is one head and one handle passing through to the assembly station at all time. This is to ensure that the assembler gets the correct parts for assembly at all times.

At the assembly station, the assembler uses the heading machine to assemble the heads and the handles. He also sands and buffs the assembly to finish it. The processes take about 4.5 minutes but he is actually scheduled for the entire 8 hour work day so he can have the flexibility needed to perform other managerial duties. The heading machine is scheduled for 4.5 minutes for assembling each hammer.

For this case study, the CNC lathe operator earns $20 an hour. The assembler/finisher earns $18 an hour. The material cost is embedded in the cost of operating the production machines. The CNC lathe for the hammer head is scheduled to get $.50 for each part it processed. The CNC lathe for the handle is scheduled to get $.70 for each handle it processed. The heading machine is scheduled to cost $.50 for each hammer assembled.
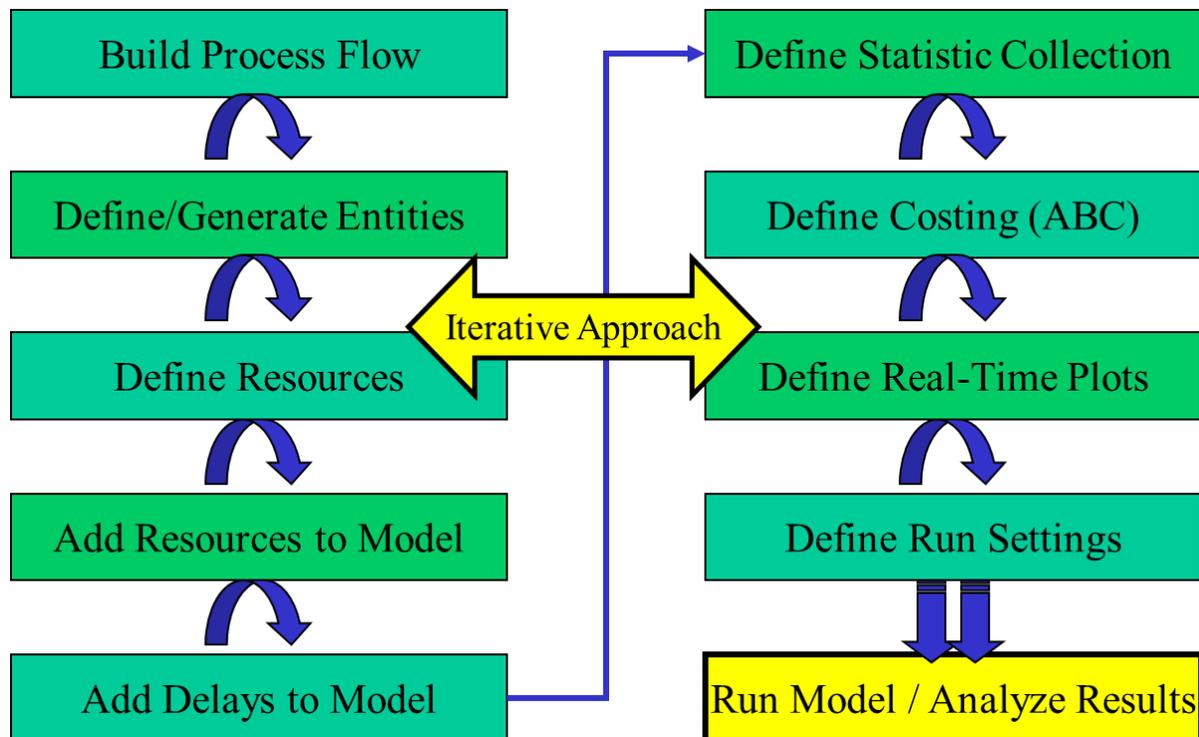
Figure 2. Steps to Simulation in SIMPROCESS (Courtesy of CACI, 2015)

**Steps in Simulation Programming**

There are many steps to programming manufacturing process simulation. While many simulation sources have their specific steps, they do not agree on what can be described as a standard procedure for simulation. Therefore, the examples used here are the ones recommended by CACI (2015) as shown in Figure 2. This model is simple, easier to understand, and straightforward to the tasks needed in programming. This is the format used in the construction of the case model used in this report.

Also, the hammer parts shown in Figure 3 will be used in the case example. The parts will also be assembled in the process. The dimensions and numbers in balloons will serve for reference purposes in clarifying operations.
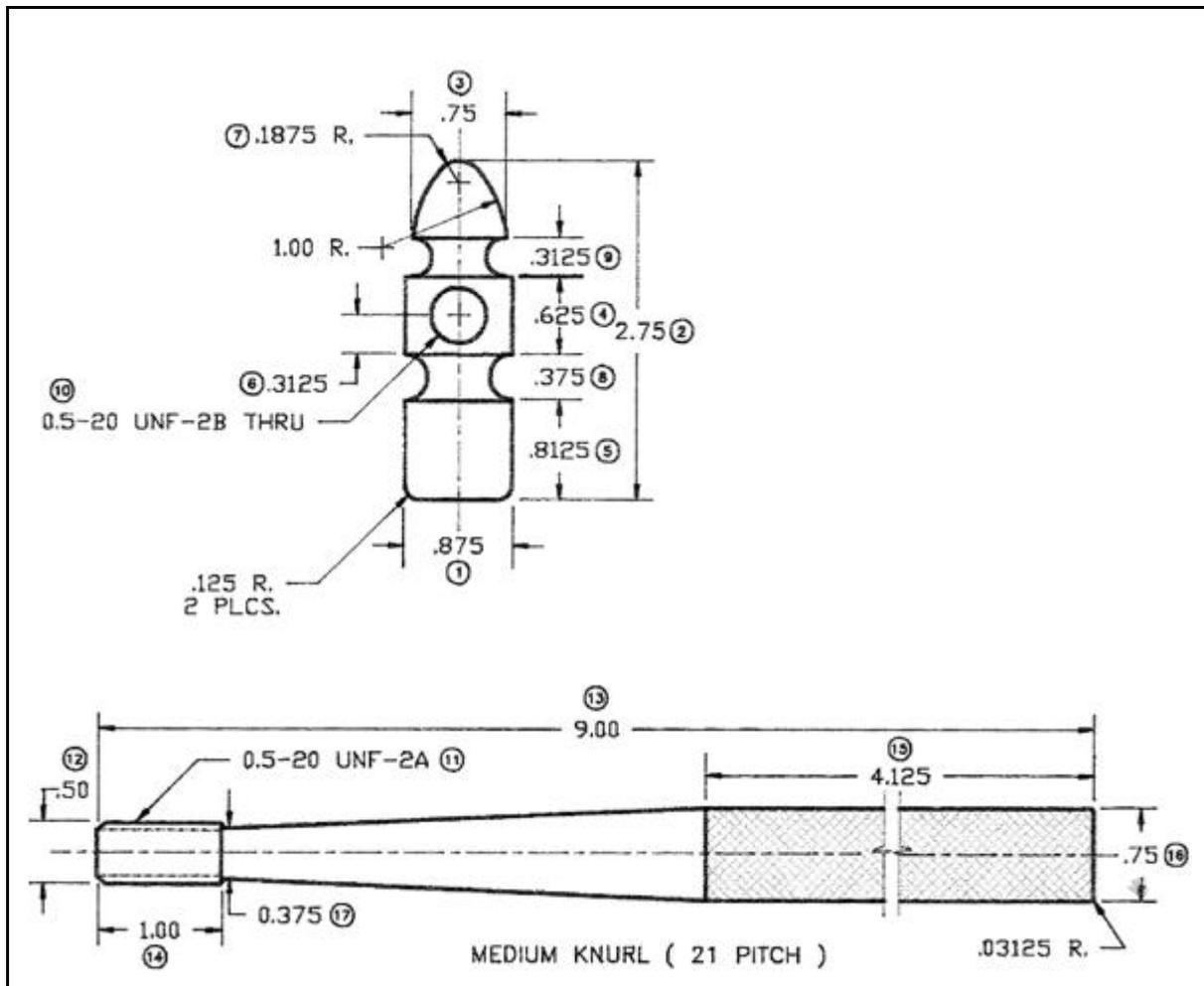
Figure 3: Hammer Parts: Head and Handle

**Step 1: Build Process Flow**
It is important that the process flow of the operations that will be used to produce the product is sequentially mapped out before anything else in simulation programming. This is illustrated in Figure 4 where the operations for the hammer head and handle have been sequenced. The assembly processes have also been sequenced. Not only are the operations correctly sequenced, but the time (in minutes) assigned to each operation must be the actual amount of time needed for that operation. These times can be measured from actual operations using a stop watch or retrieved from filed or published time standards.

To complete the process flow of the manufacturing process, it is helpful to do a flow layout as well using SIMPROCESS' pallet tools. The layout in Figure 5 shows the location and function of all the items in the facility where the product will be produced. The layout shown in Figure 5 shows that the production begins with stock material supply that goes to two different CNC turning machines where they are processed. Then from there they are regrouped and routed to an assembly system where they are assembled before moving to a storage.

Double-clicking each of the CNC lathe activity icons will show another level of activities (delays and transform) shown in Figure 6. These activities represent what actually happen in the CNC lathe workstation.

| Hammer Head | Process | Balloon Number | Time | | Hammer Handle | Process | Balloon Number | Time |
|---|---|---|---|---|---|---|---|---|
| Task 1 | Face end of part | 3 | 0.5 | | Task 1 | Face end of part | 14 | 0.5 |
| Task 2 | Turn outside diameter | 1 | 0.75 | | Task 2 | Turn diameter of handle | 16 | 0.75 |
| Task 3 | Form two groves | 8 & 9 | 0.75 | | Task 3 | Turn taper | 17 | 0.75 |
| Task 4 | Form ball peen end | 7 | 1.0 | | Task 4 | Turn thread end of handle | 12 | 1.0 |
| Task 5 | Drill hole | 10 | 0.75 | | Task 5 | Thread end of handle | 11 | 0.75 |
| Task 6 | Tap hole | 10 | 0.25 | | Task 6 | Knurl handle | 15 | 0.5 |
| Task 7 | Cut off finished handle | 2 | 0.75 | | Task 7 | Cut off finished handle | 13 | 0.75 |
| Total Time | | | 4.75 | | Total Time | | | 5.0 |

| Assembly | Process | Time |
|---|---|---|
| Task 1 | Deburr head and handle | 0.1 |
| Task 2 | Screw head to handle | 0.5 |
| Task 3 | Cold-head end of hammer | 1.5 |
| Task 4 | File and sand end of hammer | 1.0 |
| Task 5 | Inspect finished hammer | 0.5 |
| Total Time | | 4.5 |

Figure 4: Process Flow of Hammer Production Sequence
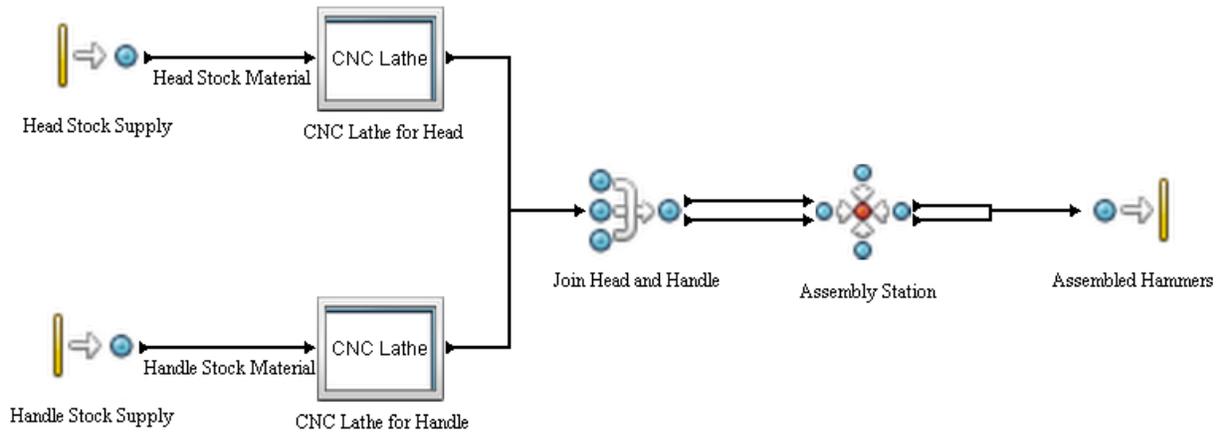
Figure 5: Flow Layout of the Hammer production Process
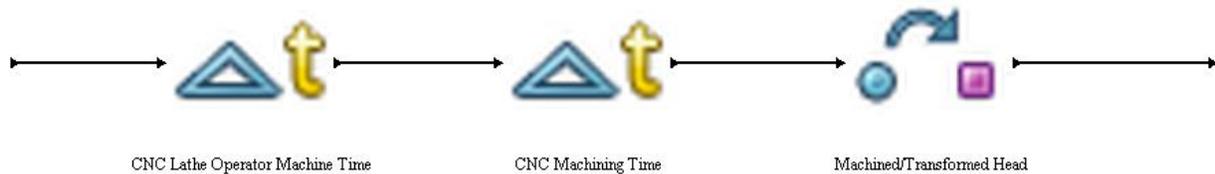


Figure 6: Delay Icon

**Step 2: Define and Generate Entities**
Entities represent the order or quantity of items to acquire, produce or manage. They have to be defined and generated so that they will be available in the system. In this example, entities are the quantities of material for hammer heads and handles that need to be produced. This can also be accomplished by selecting the Entities form the Define pull-down menu.

In this example, five (5) different entities will be defined to represent five different categories of items at various stages of their manufacturing processes. They are:
   a)  Hammer head stock material represented by black dots.
   b)  Hammer handle stock material represented by blue dots.
   c)  Machined or finished hammer heads represented by red dots.
   d)  Machined or finished hammer handles represented by yellow dots.
   e)  Assembled hammers represented by green dots.

These categories of dots are shown in Figure 7. Each of these entities can be further refined by clicking at the Edit tab. These entities will be stored and available for the programmer during the design of the simulation. Each defined entity dot will be called out and selected when needed at various stages of the programming. For example, double-clicking the stock supply (generate) icons in Figure 5 will open to
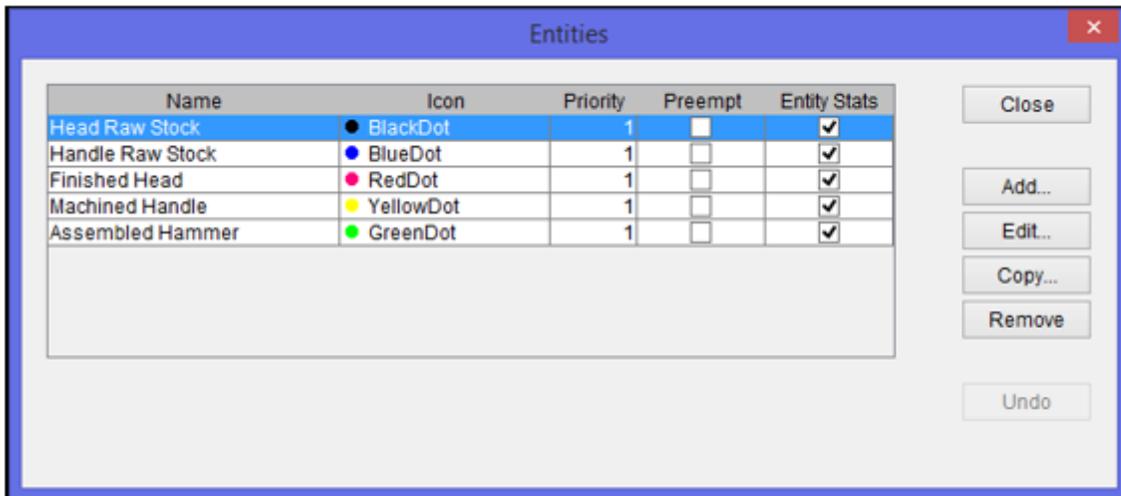
Figure 7: Case Model Entities

Generate Properties windows so that the hammer head and handle stock materials entities can be selected, assigned and further defined since they will be used to initiate the process. Figure 8 shows the Generate Properties window for the hammer head stock material. It is at this point that the quantities to be generated will be assigned. The rest of the unassigned entities will be selected and assigned at their respective stations when their turn is reached.
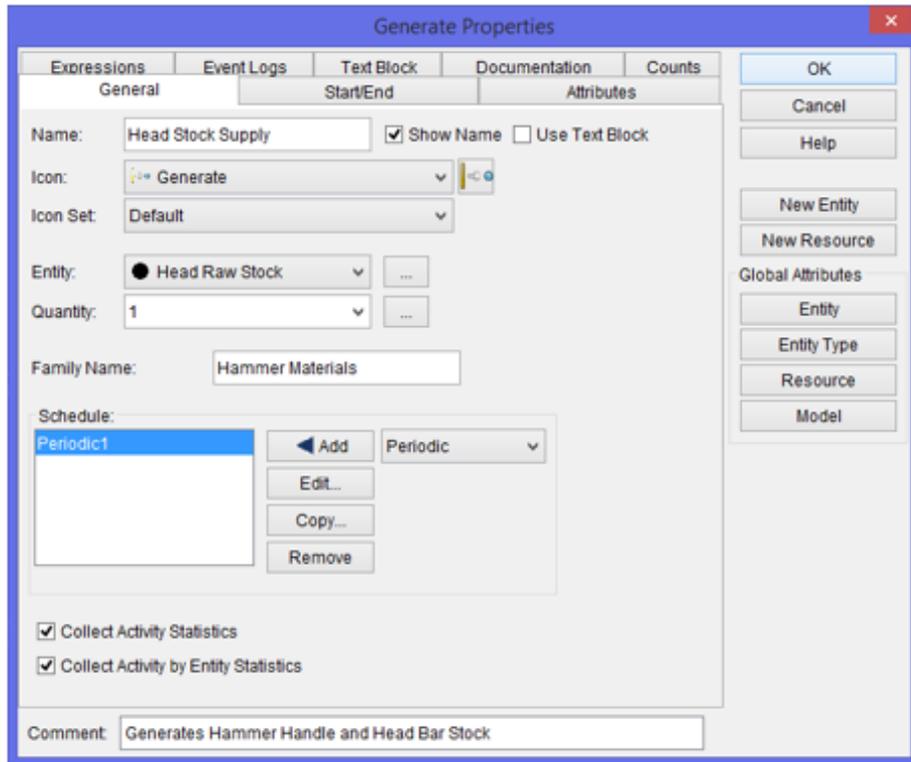


Figure 8: Hammer Head Stock Generate Properties Window.

**Step 3: Define Resources**
Resources are the machines and personnel needed to accomplish the production tasks in creating the hammer. Like Entities, these resources have to be defined so that they can be assigned at their needed stages. To do this, Resources is selected from the Define pull-down menu. In this example, five different resources will be used as follows:
   a) A CNC lathe to machine all the features on the hammer heads.
   b) A CNC lathe to machine all the features on the hammer handles.
   c) An operator to operate and manage the two CNC lathes where the hammer heads and handles are processed.
   d) A heading machine to cold-head the assembled hammers at the assembly station.
   e) An assembly person to operate the heading machine

Each of these resource is also further defined to establish their units, costs etc.

**Step 4: Add Resources to Model**
After Resources are defined within a model, they must be assigned to their tasks within the process model. This is accomplished by right-clicking and opening the Properties window of each of the delays shown in Figure 6, and then assigning them their respective resources that were already defined in step 3. For example, right-clicking at any of the delays will show a window like the one shown in Figure 9. To add the
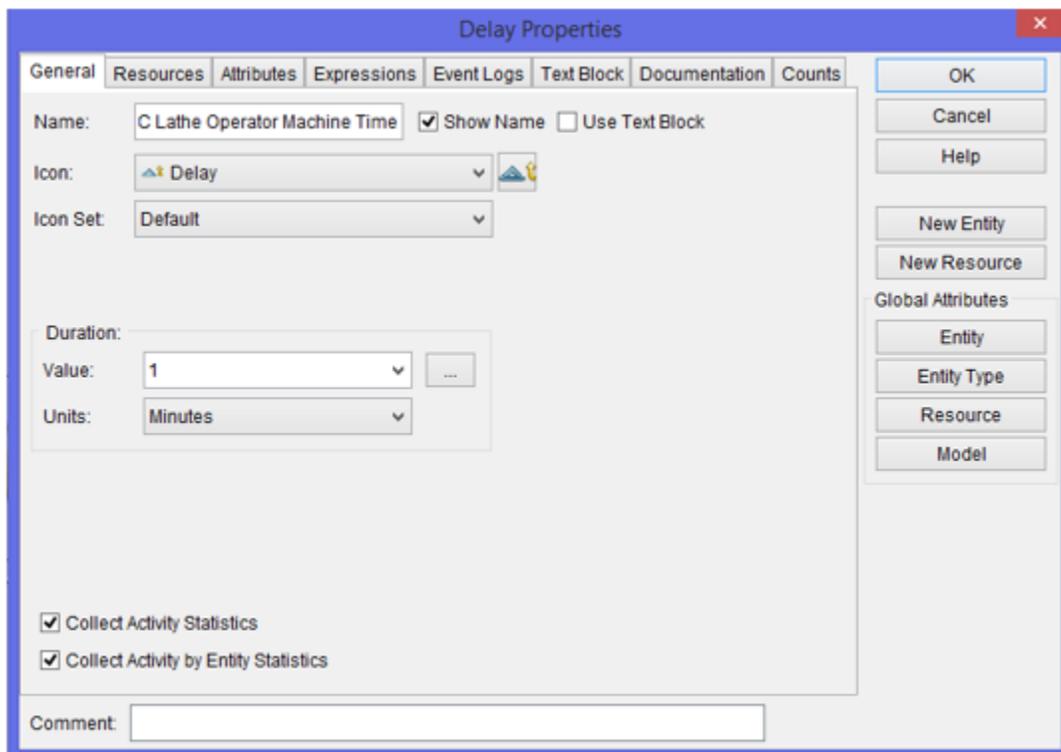


Figure 9: Delay Property Window

resources that were already defined for this activity, the programmer simply clicks at Resources tab, select the specific resource from the list of resources, and then click at Add. The associated cost of each of the resources should also be noted while in this window. Downtime schedules may need to be defined, and then assigned to the appropriate Resources.

**Step 5: Add Delays to Model**

Delays are one of the most common and useful activities. A delay in SIMPROCESS models any activity that takes time to complete. An entity will arrive in a delay and wait there until all resources needed to process it are available, and then for the additional time necessary to complete the process. The cycle time of an entity traversing the model is the sum of the delays it encounters, i.e., the time spent at the activities in its path, plus any hold time for a condition to be met, and the wait time for any resources.

Double-clicking on any of the two Delay icons in Figure 6 will show the Delay Properties box shown in Figure 9. The delays here represent the times the CNC lathe's operator used to unload and load the respective machines with the hammer head and handle, and the times the machines used to machine the respective parts. In this case example, 1 minute should be entered for the time the CNC lathe operator spent in loading and off-loading each machine. For the other respective delays, 4.75 minutes will be entered for the head and 5 minutes for the handle.
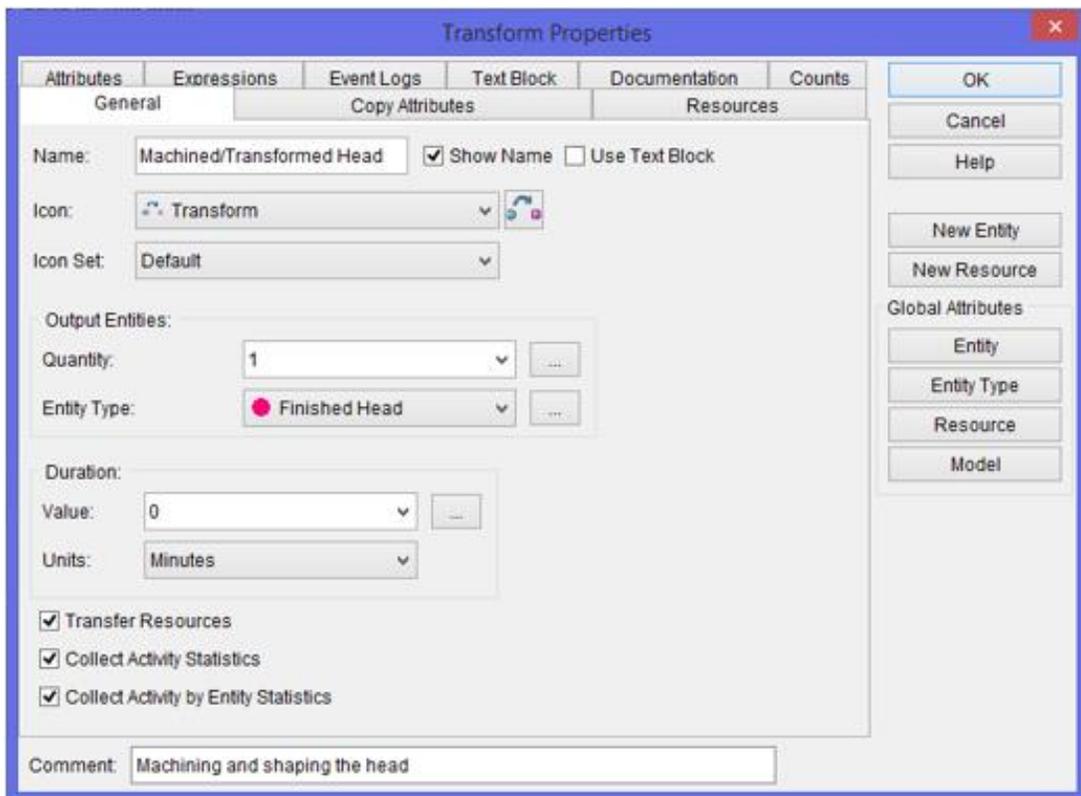


Figure 10: Transform Properties Window

13

The Delay Properties dialogue window shows important time-related fields to fill. **Value** is the amount of time required to perform this activity. To be useful, this time must be the actual measured or published standard time for the activity. Use the combo box to select a statistical distribution or enter a constant value directly in this field. Use **Units** in this field to specify whether the Value of the duration entered will be measured in Nanoseconds, Microseconds, Milliseconds, Seconds, Minutes, Hours, Days, Weeks, Months or Years. The **Collect Activity Statistics** option should be selected if statistics are desired for this activity. Also the **Collect Activity by Entity Statistics** should be selected if "by entity" statistics are desired.

Also, the Transform (or Machined) icon shown in Figure 6 indicates the transformation of the workpieces at the CNC lathes. Double-clicking any of them will indicate that another value (in minutes) needs to be entered as shown in Figure 10. But 0 minute will

be entered this time since the machining times have already been entered in the Delay Properties window. The Transform serves to facilitate the change in color of the black and blue dots (or hammer head and handle stock materials) to red and yellow dots which represent the machined hammer heads and handles.
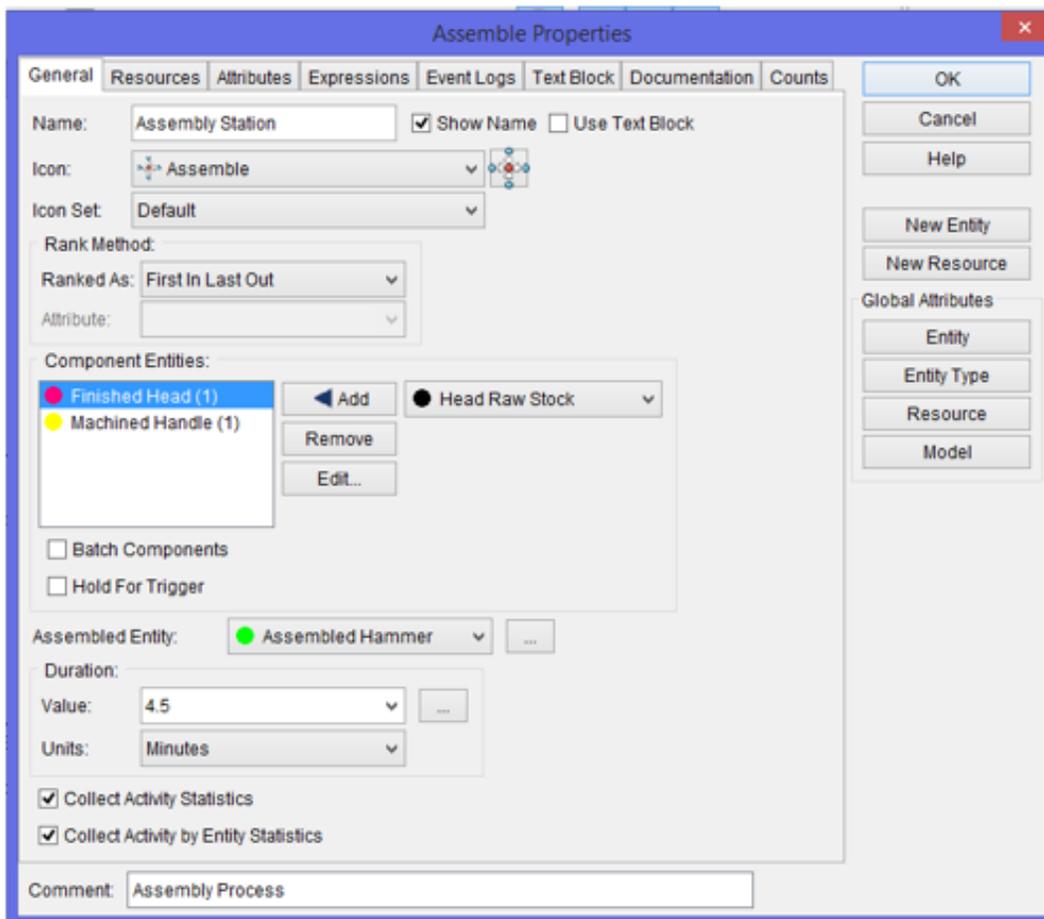


Figure 11: Assembly Dialogue Window

14

The Assembly icon shown in Figure 5 is used to assemble the hammer head and handle. Double-clicking at it will open the Properties dialogue box shown in Figure 11 so that the following information is entered:

Under **Rank Method,** select FIFO for first in first out. For **Component Entities,** select a list of input entities (i.e. machined head and handle) to be converted to output entities. The selected entities will be assembled to become one assembled entity. Click on **Add** to add the selected entity, or **Remove** to remove a selected component entity from the list. Use the **Edit** to open a dialog to modify the selected component entity's quantity.

**Assembled Entity** (or assembled hammer) represents the entity type to be released. A combo box provides a list of defined entity types. Click on the More Data (triple dot) button next to the combo box to modify the properties of the selected entity if desired. The **Duration** is the delay time of the activity. The **Value** to be entered is the amount of time required to perform this activity, i.e. assemble the head and handle which has been calculated as 4.5 minutes.

Note that **Assemble** icon has two input pads and two output pads that determine entity behavior. Component and Trigger are input pads. Out and NoMatch are output pads. The Component pad places incoming entities into a queue until all entities to be assembled have arrived. If an entity entering the Component pad is not on the component entity list, it will immediately leave the Assemble activity through the NoMatch pad.

**Step 6: Define Statistic Collection**
At each state of the model's construction, there are options for collecting specific statistics. The programmer indicates which type of statistics that are needed at each phase. This is accomplished by checking the box(s) of interest. For example, the "Collect Activity Statistics" and "Collect Activity by Entity Statistics" boxes were checked in Figure 11. Also, double-clicking the Delay icon of Figure 6 will show more statistic option, i.e. resource time and cost. SIMPROCESS tracks and collects all the selected statistics and displays them in a report that it generates after each simulation run of the model.

In this model, the following statistics were collected: entities' generation counts, entities' movements at every level, operators' activity times, and equipment (machines') operation times. The system uses these statistics to determine informative answers like percent resource utilization, number of entities that was processed at each workstation, idle times, and so forth.

**Step 7: Define Costing (ABC)**
Activity-Based Costing (ABC) is a technique for accumulating cost for a given cost that represents the resources required or consumed by the object. It occurs when cost data is determined by the programmer and is recognized by the system. The amounts in the cost pools are assigned to products, services or other cost objects. SIMPROCESS

allows you to specify costs for each resource in the model. You do not have to specify costs for all resources. SIMPROCESS will calculate costs at simulation time for any resources that have cost data entered. You can specify both fixed and variable costs for non-consumable resources and variable costs for consumable resources.

To do this for resources used in this case study (as were selected in step 4), select the **Define/Resources** option from the Define pull-down menu. Then pick any of the previously defined resources from the list for editing. From there, selecting the Cost tab will allow you to define costs for the resource.
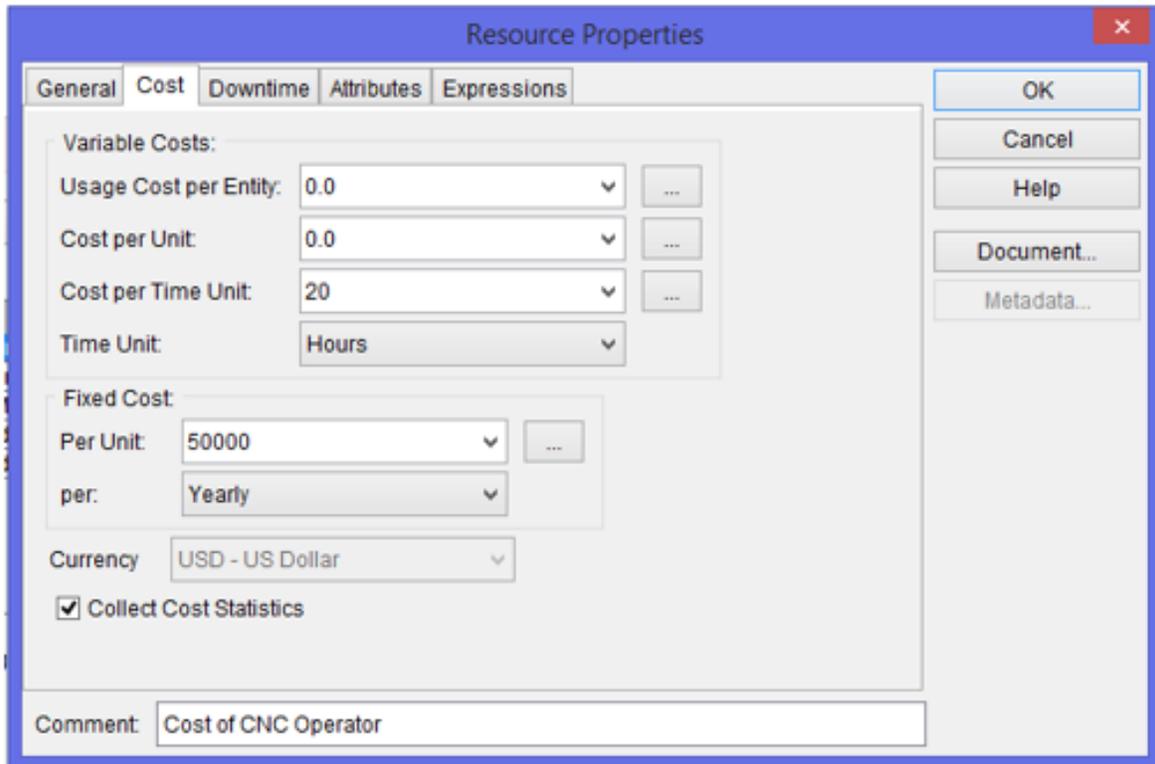


Figure 12: Resource Properties Window

Figure 12 shows the Cost tab when a resource is non-consumable in the **Resource Properties** window. The top fields show the Variable Costs, and those below show the Fixed Costs. Three types of variable costs can be specified for non-consumable resources. The **Usage Cost per Entity** is the cost applied to each entity that is processed by the resource. It is used to represent "flat fee" type charging schemes. The same cost is assigned regardless of the amount of the resource's capacity that is used or the duration of the activity. The **Cost per Unit** is the cost applied to each entity that is processed based only on the amount of the resource's capacity that is used to process the entity. The cost is not calculated based on the time that the activity takes to complete. The **Cost per Time Unit** is the cost calculated based on the amount of resource capacity used and the time used. An example will be machine rental charges or hourly salaries paid to employees which, in this case, is $20 per hour. The **Time Unit**

is the time unit that is applied to the **Cost per Time Unit**. For the **Fixed Cost** section of the figure, machine depreciation or fixed salaries are common examples of such costs that will be entered in the Per Unit value box. The fixed cost entered her is $50,000.

For consumable resources, the **Usage Cost per Entity** is the cost applied to each entity that is processed by the resource. It is used to represent "flat fee" type charging schemes. The **Cost Per Unit** is the cost applied to each entity that is processed based only on the amount of the resource's capacity that is used to process the entity. The cost is not calculated based on the time that the activity takes to complete, but instead on how much of the resource is consumed during the operation. Both consumable and non-consumable resources include fields for **Currency** (i.e. the unit of currency to be used in reporting the calculated costs) and **Collect Cost Statistics** check box which tells SIMPROCESS to calculate the costs for this resource during the simulation run.

### Step 8: Define Real-Time Plots

Real-Time Plots allows live simulation charts to be seen during a simulation. They can be defined for Entities, Resources, Activities, and Connectors. They are good tools for verification and validation. Trace and Histogram plots are available. These plots can be displayed while the simulation is running, after the simulation has ended, and anytime during the actual simulation run.

To define a Real-Time Plot, click on Report pull-down menu and select Real-Time Plots. From the Define Real-Time Plots window, one can select charts for any resource, entity, or activity of interest to view their real-time behavior during the simulation.
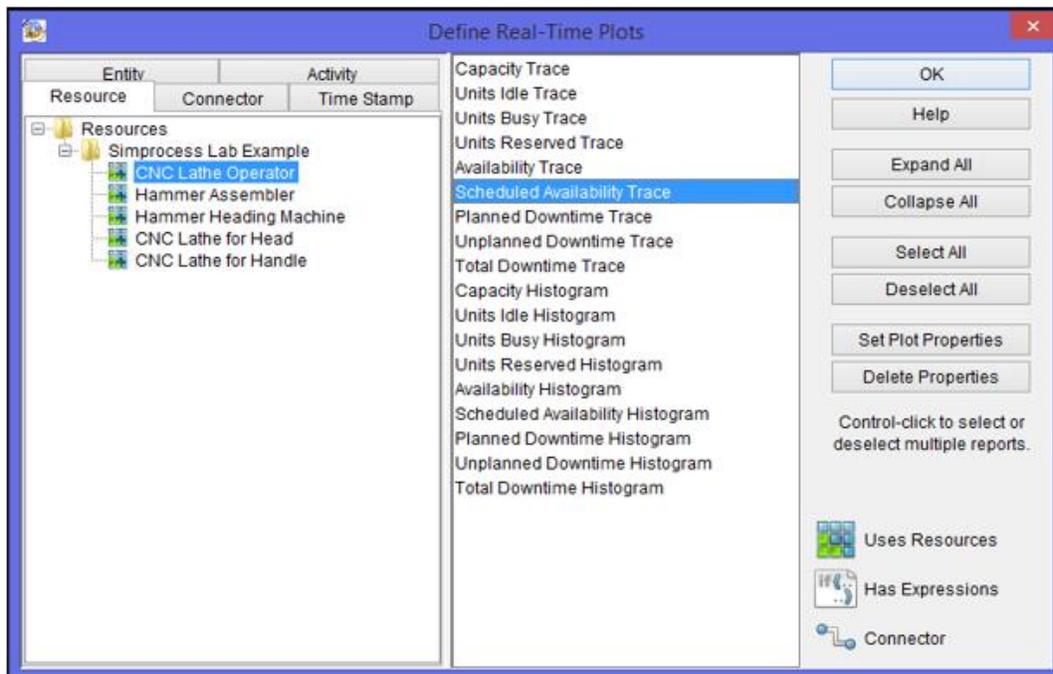


Figure 13: Defining Real-Time Plot for CNC Operator

17

In this case study, the subject of choice is the CNC operators (resources) shown in Figure 13. Selecting this particular resource and the types of charts needed will result in different types of charts like the ones shown in Figure 14. The programmer or manager will then determine whether these characteristics are the results that have been planned for the system. Notice that many other types of charts can be selected for resources, entities, connectors etc. These real-time plots can also be customized as needed.
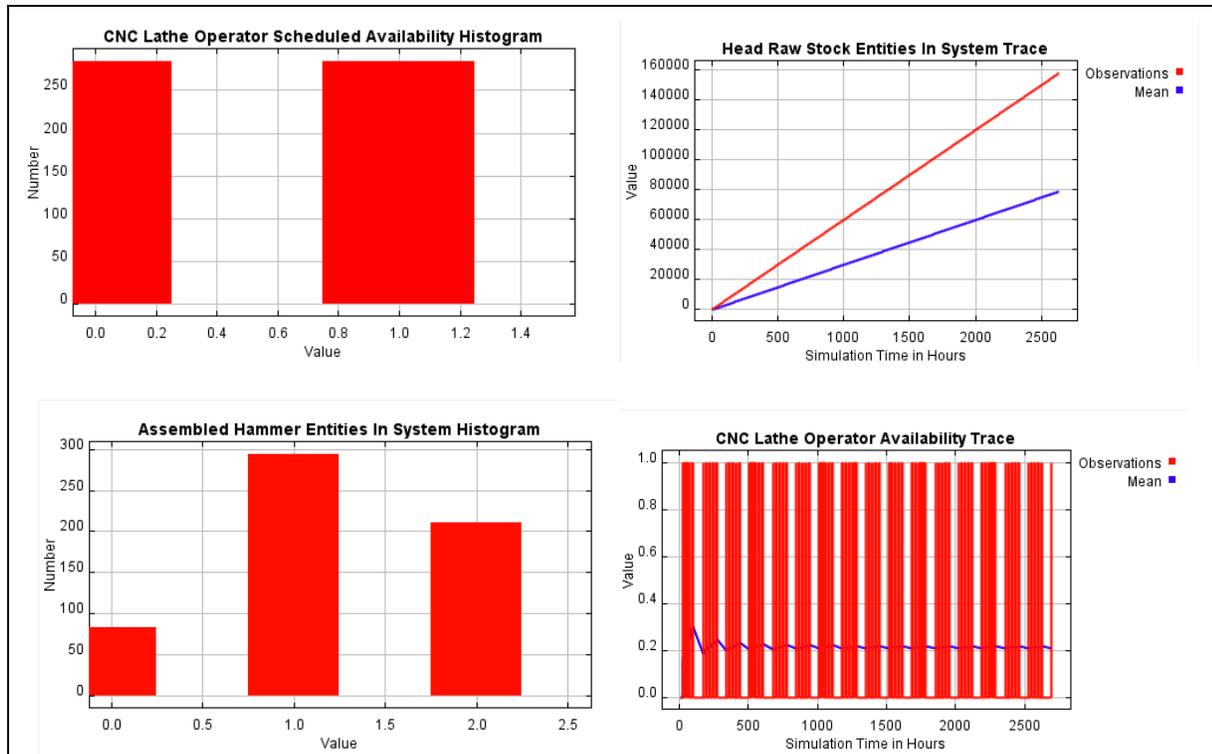


Figure 14: Real-Time Plots of CNC Operator and Some Entities

**Step 9: Define Run Settings**
Before the simulation is run, it is necessary to define its run settings so that it will generate the required results. The Run Settings dialog, found under the Simulate pull-down menu, has the following categories: simulation start and end values (or date and time), number of replications, reset the random number stream, warmup length, and remote access inputs.

The simulation start and end values (or Run Time) will be emphasized in this case example. SIMPROCESS executes models in simulation time, not in real time. In this way, models can represent the operation of a system over a long period of time so that model results can be obtained very quickly. The simulation clock jumps from the time of one event to the time of the next event. This case study used a time

18

value of one year. Therefore, the Run period is set to between January 1, 2014 and January 1, 2015. This is indicated as 01/01/2014 and 01/01/2015 on Figure 15.
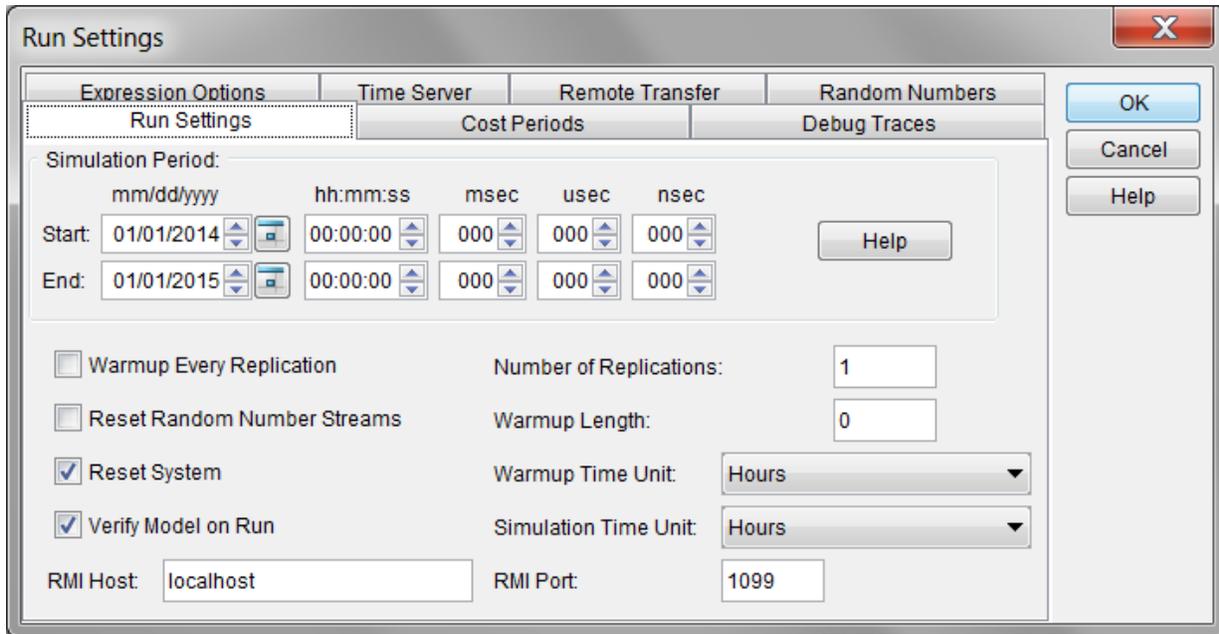


Figure 15: Simulation Run Settings Window

It is also good to perform the animation settings while at this juncture. Animation setting is also found under the Simulate pull-down menu. Animation is a powerful tool for generating instant client feedback, which helps to correct errors, set proper objectives, and maintain the project schedule. Animation also helps debug a model or assist in a presentation, and is very helpful in verification and validation. However, turning the animation off when running a model will greatly reduce the execution time.

**Step 10: Run Model and Analyze Results**
The simulation is run by selecting Run from the Simulate pull-down menu or by clicking the Run icon on top of the window. The simulation will run as designed and set. If the entities, clock and counters are set to operate, then they will be seen moving and counting on the screen (see Figure 16).

During a simulation run, SIMPROCESS collects statistics for all Entities, Resources, Activities, Attributes, and Connectors in the model that have been designated for statistics collection. These statistics are displayed in the Standard Report when the simulation is complete or it can be viewed with View Simulation Results. The reporting of the data collected during a simulation run can also be customized.
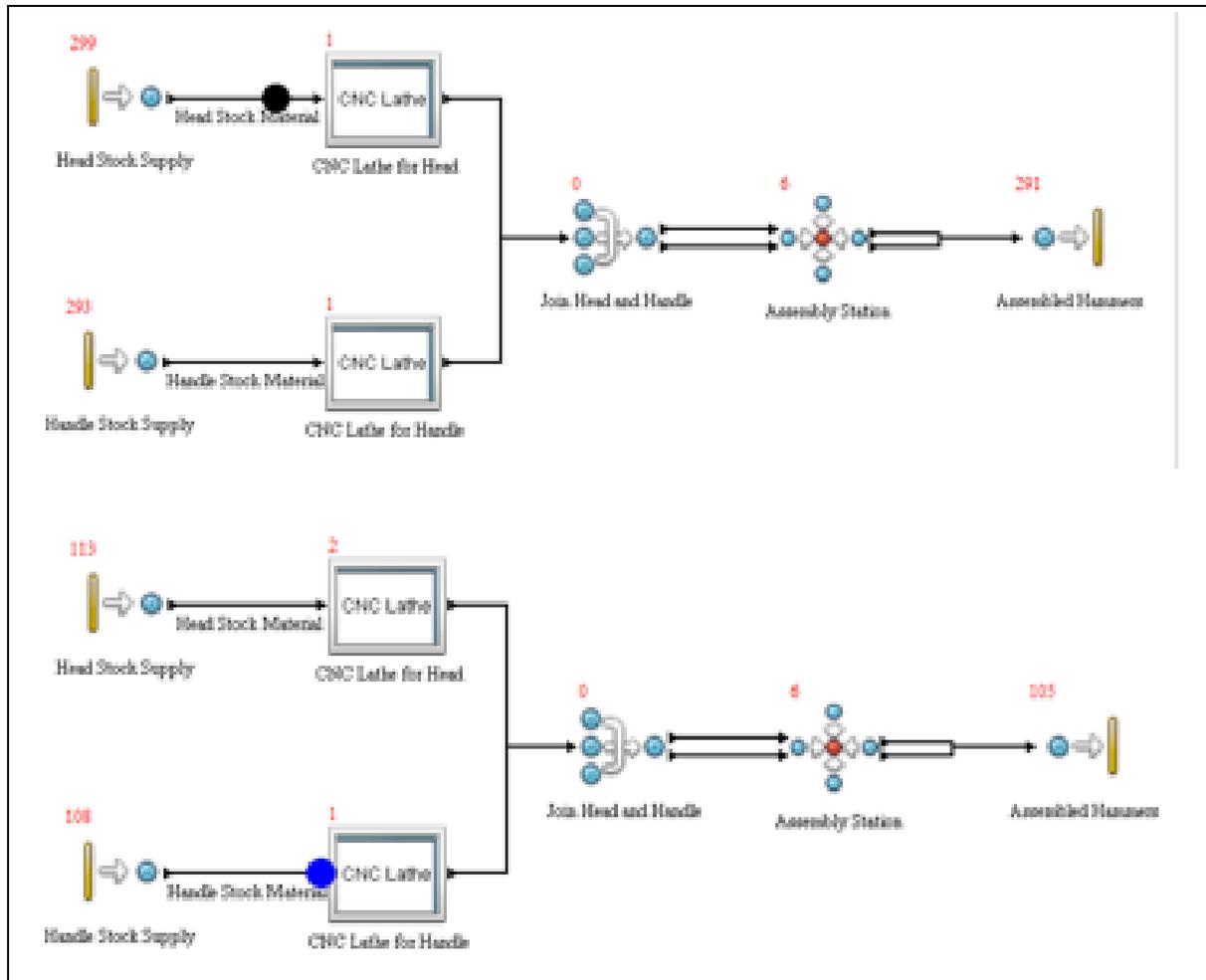
Figure 16: Moving Entities in the System During Simulation Run

To view a standard report after the simulation, click at Report pull-down menu and select Standard Report. Then select the format you want it to be displayed, i.e. whether in spreadsheet or text format. When you click at Display Report, the result of the simulation run will be displayed. Many useful statistics such as entity counts, cycle times, percent utilization, and averages of Activities, Entities, Resources, Connectors, and so forth are generated. Multiple charts can also be created based on the selected options. Appendix B shows the full report generated from the case study used in this example.

### SIMPROCESS Standard Report Analysis of Case Example

There are typically 17 areas in the standard report generated after a SIMPROCESS simulation run. They are listed here in Table 1 with brief interpretations. The full report with detailed results is in Appendix B.

Table 1: Explanation of Standard Report

_____

| Item or Activity | Meaning |
|---|---|
| Entity: Total Count - Observation Based | Shows how many entities went through the systems for the time period and were actually counted during simulation. |
| Entity: Count By State - Time Weighted | Average and maximum time weighted values of the numbers of entities in the system, counted as: total in system, processing, wait for resources, hold for conditions, and traveling. |
| Entity: Cycle Time (in Hours) By State – Observation Based | Average and maximum cycle times of the observed entities. Shows these data for total in system, processing, wait for resources, hold for conditions, and traveling. |
| Resource: Number of Units By State – TimeWeighted | Shows the number (capacity) of resources and their average and maximum status in idle, busy, planned downtime, unplanned downtime, and reserved. |
| Resource: Percent Utilization By State | Shows resource percent utilization in idle, busy, planned, unplanned, and reserved status. |
| Resource: Percent Utilization By State When Available | Shows percent utilization of resources when they are available, in Idle, Busy, and Reserved state. |
| Resource: Units Busy By Activity – TimeWeighted | Shows how busy (by activity) the resources are by listing their average and maximum capacities. |
| Activity: Total Entity Count at Selected Activity - Observation Based | Shows total entity counts for selected activity stations, as total accepted, total |

remaining in the activity, total that exited the activity, and total not process.

Activity: Entity Count By State at Selected Activity - Time Weighted

Shows the average and maximum entity count by state at selected activity by the following categories: total in activity, processing, wait for resources, and hold for conditions.

Activity: Entity Cycle Time (in Hours) By State at Selected Activity - Observation Based

Shows the defined, average and maximum entity cycle times (in hours) and the number of observed entities by state at selected activities in the following areas: total in process, processing, wait for resources, and hold for conditions

Connector: Total Entity Count at Selected Connector - Observation Based

Shows the total entity count at selected connectors by showing the total accepted by each connector, number still in connector, and total that exited each connector.

Connector: Entity Count at Selected Connector - Time Weighted

Shows the total entity count at any one time at selected connectors for various types of entities in the system. Shows average and maximum values.

Connector: Entity Cycle Time (in Hours) at Selected Connector - Observation Based

Shows average and maximum entity cycle times (in hours) at selected connectors. Also shows number of entities observed.

Time Stamps (in Hours)

Shows the time period for the run, the average, standard deviation, minimum, and maximum entities in system at any time, and the observed counts during the period.

Resource By Activity - Cost Of Processing
(USD)

Shows the variable costs and absorption costs of processing by different resources used in the system. Costs are listed individually for each resource and their relative activities.

Resource By Entity - Cost Of Processing
(USD)

Shows the variable costs and absorption costs (or cost of processing) of all the resources listed individually for each resource in the system.

Activity By Entity - Cost Of Processing (USD)

Shows the variable costs and absorption costs (or cost of processing) each group of entities.

_____

**References**

AcqNotes (2015). Modeling & Simulation: Simulation Modeling Steps. Retrieved from http://acqnotes.com/acqnote/tasks/simulation-modeling-steps, accessed on October 14, 2015).

CACI (2015). Process Mapping and Simulation. Located at: http://simprocess.com/about-simprocess/why-simulation/process-mapping-and-simulation/. Accessed October 14, 2015.

Obi, S. C. (2013). Introduction to Manufacturing Systems. Bloomington, Ind: AuthorHouse.

Webster's Dictionary (2015). Merriam-Webster: Dictionary and Thesaurus located at:  http://www.merriam-webster.com/

WikiHow to do anything (2015). How to Conduct a Simulation Analysis. Retrieved from http://www.wikihow.com/Conduct-a-Simulation-Analysis on October 14, 2015)

**Appendix A**
**SIMPROCESS Tool Pallet Descriptions**

**Processes and Activities:** A key distinguishing feature of SIMPROCESS is its hierarchical process modeling capability. This allows decomposition of a process into as many levels of detail as required. The Process construct creates the hierarchy. A process may have several sub-processes and activities. For example, an inspection process that consists of a BRANCH activity and two DELAY activities can be defined as a hierarchical process template.

**Resources:** Resources are the second most important modeling construct of SIMPROCESS. In the real world, the performance of a business process is usually constrained by the limited availability of resources or by resource interdependencies. SIMPROCESS defines the costs, capacity, usage, and interdependencies associated with resources. It automatically keeps track of the resource's utilization and costs. Schedules and Downtimes can be modeled to mimic the dynamic behavior of resources.

**Entities:** The third building block of a SIMPROCESS model is the Entities (or flow objects) that flow through the process model. Entities can be used to represent physical things (orders, paperwork), or logical things (signals, flags). Entities may be assigned attributes to define such characteristics as order size and customer type. Entities are created using the GENERATE activity and disposed using the DISPOSE activity.

**Connectors:** Connectors are the links between processes or activities. They are used for defining the flow of entities. Connectors are objects in their own right with characteristics, and they can have duration to represent travel time.

**Pads:** Pads are the objects used for linking connectors between processes or activities. A process may have multiple pads for input or output. Pads have three sizes: small (default), medium, and large. The default pad size can be set in the Preferences.

**Activity Modeling Constructs**
Activity modeling constructs are the objects at the lowest level of the SIMPROCESS hierarchy and they are used for modeling the behavior of a process. Activities are non-decomposable. The SIMPROCESS Model Toolbar contains 19 built-in activity blocks; however, re-usable activity templates can be created and added to the Library Toolbar. Below is a basic overview of the SIMPROCESS activity modeling constructs.

**Generate:** A GENERATE activity generates the arrival of entities into the model. Arrivals may be random, deterministic or conditional. An example of a GENERATE activity is the arrival of patients in a clinic. A GENERATE activity may have values for arrival time, quantity, frequency and occurrences.

**Dispose:** A DISPOSE activity disposes of the entities when they are finished with processing. A DISPOSE activity can be used for collecting customized statistics for throughput or throughput time.

**Delay:** A DELAY activity defines value added or non-value added activity times. It is one of the most commonly used activities in SIMPROCESS. A DELAY activity with resource constraints provides queue statistics that can be used for analyzing wait times.

**Assemble:** An ASSEMBLE activity assembles multiple entities coming from multiple sources to create a single entity. For example, the development of a business proposal may contain three documents that are merged using an assembly activity.
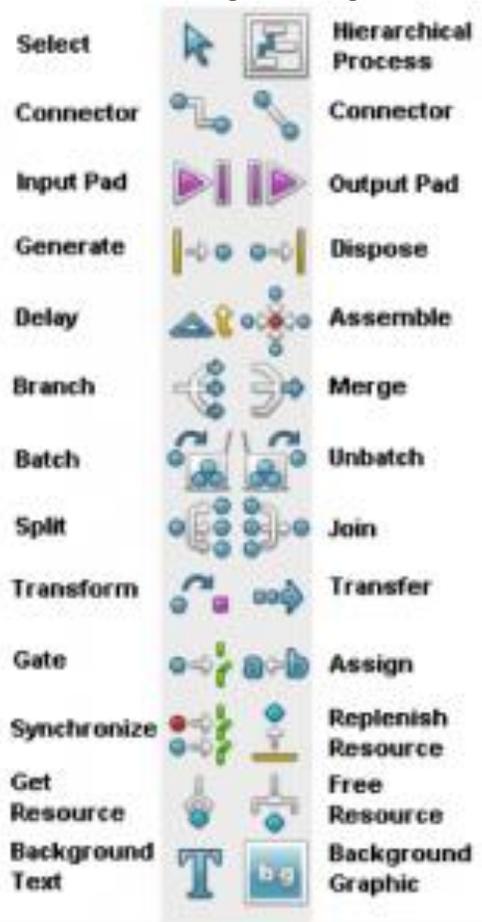


**Branch:** A BRANCH activity allows for defining alternative routings for flow objects. Branching may be based on a probability or a condition. For example, the outcome of an inspection process may be modeled using probabilistic branching.

**Merge:** A MERGE activity provides a mechanism for merging a number of connectors into a single connector.

**Batch:** A BATCH activity combines a given quantity of entities into a single batch. An example of a batching activity is the accumulation of mail for delivery.

**Unbatch:** An UNBATCH activity splits a previously batched entity into individual entities. For example, unloading of a truck that results in multiple loads may be modeled with an unbatch activity.

**Split:** A SPLIT activity takes an incoming entity and creates clones of that entity as well as providing an output of the original entity. For example, clones of a purchase order may be created with a SPLIT activity and sent to accounts payable and shipping.

**Join:** A JOIN activity takes the clones and original entity that were split up, and matches them to produce the original one. For example, a JOIN activity may be used for matching the paperwork with the shipment.

**Transform:** A TRANSFORM activity converts an incoming entity into another entity. For example, a prospective buyer is transformed into a customer when an order is placed. This activity can be modeled using the transform construct.

**Transfer:** A TRANSFER activity routes entities from one portion of a model to another without using a connector or routes entities to another model.

**Clone:** A CLONE activity makes multiple copies of the original entity. Note that this activity is not on the Model Toolbar. It is only on the **Create** menu in order to support pre-SIMPROCESS version 4 models.

**Gate:** A GATE activity holds entities in a queue, until a signal is received. For example, a GATE activity would be used to model orders held in inventory until a signal is received from the distributor to fulfill the demand.

**Assign:** An ASSIGN activity provides a mechanism for defining or changing attributes values.

**Synchronize:** A SYNCHRONIZE activity takes inputs that arrive at different times and outputs them in a synchronized fashion. For example, passengers and their baggage must be synchronized at a terminal.

**Replenish Resource:** This activity allows for replenishment of consumable resources.

**Get Resource:** This activity provides a mechanism for capturing resources that may be used for a number of downstream activities.

**Free Resource:** This activity provides a mechanism for releasing resources that were captured by a GET RESOURCE activity.

## Advanced Modeling Functions

Advanced modeling functions are very important for realistically modeling the complex behavior of business processes. These functions of SIMPROCESS differentiate it from other BPR tools that are based only on simplistic modeling functions. The advanced modeling functions combined with programming capabilities provide the power and flexibility to accurately analyze the dynamic behavior of real-world business problems.

**User Defined Attributes:** Entity Types, Entity Instances, Resources, Activities and Processes, and the Model itself can have user defined attributes. User defined attributes can be used as tags attached to entities that travel through the model. Attributes can be used for conditional branching, sequencing, or decision making in expressions or logic. For example, order quantity may depend on which customer the order came from. Furthermore, order processing time may depend on the size of each order. By defining an attribute named "OrderQuantity" and writing an expression that multiplies "OrderQuantity" by "ProcessTimePerOrder," the order processing delay can be accurately modeled.

**System Attributes:** These attributes keep track of the states of model elements so that expressions can be written to deal with complex business situations. For example, the number of customers waiting for a service representative is a system attribute that changes over time. In a typical service process, the number of servers would be increased if the customers in line reach a certain number.

**User-defined Expressions:** When modeling real-world business processes, there will inevitably be situations which will require modeling functionality that is not built-into a BPR tool. SIMPROCESS provides the capability to write user-defined expressions and use them for modeling or customizing the performance measures. For example, service level may be an important performance measure for a business that is trying to fulfill orders within a 12 hour window from the time orders are placed. Using system attributes, user-defined attributes and user-defined expressions, the cycle time for each order can be compared with the 12 hour target and the service level of the process calculated.

**Built-in Programming Environment:** Although the built-in functionality and the ability to customize models with attributes, expressions, and distributions offer plenty of power for modeling most business processes, there may be situations where added flexibility is needed that can only be achieved by a programming environment. For these complex business process applications, SIMPROCESS has a built-in programming environment.

**Built-in & User-defined Distributions:** SIMPROCESS comes with 26 standard probability distributions and allows the creation of empirical distributions based on raw data. Eleven of the distributions also have Apache Commons Math implementations. One of the powerful features of SIMPROCESS is its data analysis (curve fitting) functionality using ModelFit. ModelFit accepts a number of data points and then provides the distribution that best represents the data set. This can be done on-demand or automatically at the beginning of a simulation.

**Reusable Modeling Templates:** One of the most powerful features of SIMPROCESS is modeling templates can be created that can be stored in a library and used over and over. For example, an inspection process template using three SIMPROCESS activity blocks such as DELAY (inspection activity), BRANCH (probabilistic outcome of inspection), and DELAY (rework activity) can be created. A favorite inspection graphic can then be attached to the template and the inspection template saved in a library. When needing to model an inspection process, simply click on the inspection graphic, drop it in the model diagram, and double-click on it to customize its parameters.

**Event Logs:** Event Logs are built-in features for tracking custom cycle time measures. There are two types, Time Stamps and Recorders. Time Stamps are used to measure time between any two events. A Time Stamp can be thought of as a label or key that contains the current simulation time. This key is added to an Entity by an Event Log when it either enters or leaves a Process or Activity. Pairs of keys (start key and stop key) are specified and Entity cycle times are computed between them. Recorder event logs can be used for monitoring statistics such as arrival and departure rates. They write the arrival or departure time of an Entity at a Process/Activity into a file in the model's directory.

**Custom Reports:** Custom reports are user-defined reports. They are defined for specific purposes and can contain statistical and non-statistical information. Custom reports are typically defined and viewed once all modeling, simulation, and analysis is complete. Multiple custom reports can be defined for a single model. Each report displays in a report viewer. From that viewer reports can be printed or saved in various file formats (for example pdf, rtf, and docx). (Link to custom report pdf)

**Simulation Results Analysis and Export:** Simulations can produce much data. SIMPROCESS allows you to view simulation results in reports, .xls or .csv files, or graphically. You can also export specific results to databases and spreadsheets.
- Standard Report
- .xls Report

**Real-Time Plots:** Real-time plots of key metrics can be displayed during or after a simulation. SIMPROCESS offers real-time plots of standard metrics plus custom real-time plots can be defined. A real-time plot can trace a value over time or display a histogram of a value. Custom real-time plots can handle multiple values.

**Scenarios:** Scenarios are used to save simulation results for comparison purposes and are specific to a model. Thus, Scenario results from different models cannot be compared directly in SIMPROCESS. A Scenario is defined, and then the model is run with the Scenario selected. When the simulation completes the results from the Scenario are saved into an external file (Scenarios.xml) for later use. Scenario Reports can be created to compare results from different Scenarios or within the same Scenario.
  - o Purchasing Baseline Report
  - o Purchasing Hybrid Report

**Experiment Manager:** The experiment manager runs models automatically. SIMPROCESS loads the model, runs the replications, and (optionally) places the results in the database. Multiple models can be setup for simulation, and initial conditions can be varied for each model run. In addition, a text file of the results from each run can be automatically created.

**OptQuest:** OptQuest® for SIMPROCESS is an optimization tool created by OptTek. Since OptQuest is an optimization tool, it attempts to minimize or maximize the value of a performance measure based on limits (constraints, upper bounds, and lower bounds). OptQuest automatically runs SIMPROCESS models varying the values for the model parameters searching for optimum results within the specified limits.

**Dashboards:** SIMPROCESS Dashboards are collections of dynamic graphs that can be displayed locally or remotely by a Dashboard Server. The graphs contained by Dashboards can be of the same type or of differing types. Dashboards are defined independent of SIMPROCESS models. Thus, a Dashboard can be used with multiple models, or multiple models may use a single Dashboard. To use a Dashboard with a model, the Dashboard must be assigned to a model. The Assign process links the Dashboard to the model, indicates the location of the Dashboard Server for display (host or IP address and port), and sets the values that will be displayed on the graphs defined for that Dashboard.

**TimeServer:** SIMPROCESS models have the ability to let an outside agent manage the advancement of simulation time. That agent is the SIMPROCESS TimeServer. The TimeServer is a separate application that manages simulation time for multiple participants.
  - o SIMPROCESS TimeServer.pdf

**Dispatcher:** The Dispatcher is a program that controls the operation of one or more instances of SIMPROCESS or OptQuest® for SIMPROCESS when requests arrive from the DispatcherService. The DispatcherService is a Web service that can be deployed in a Web Container (an application supporting the Java Servlet Specification) or Application Server. It is the gateway through which a client application obtains SIMPROCESS or OptQuest® for SIMPROCESS services.

**Java:** User-written or third party Java code can be executed during simulations to extend the capability of SIMPROCESS.


**Other Explanations**

**Process Mapping -** Process Mapping is becoming more popular due to software tools and it is used in SIMPROCESS. The process modeling is used for defining what happens in business, what are the responsibilities, what should be done to achieve success, increase revenues and decrease costs. Process mapping, ABC and event-driven simulation are integrated into a single tool. SIMPROCESS integrates process mapping, discrete simulation, and Activity-Based Costing into one modeling tool.

**Discrete Simulation -** Discrete simulations model the operation of a system as a discrete sequence of events in time.

**Activity-Based Costing** (ABC) - Costing objects (services, projects or products) need some activities that use resources which could be simulated in SIMPROCESS.
The building blocks of SIMPROCESS are activities, entities, resources, connectors and pads.

**Activities / Processes** - SIMPROCESS is based on a concept of hierarchical process modeling.
Activities are time-consuming elements of a system whose starting and ending coincide with event occurrences.

**Entities** - dynamic objects such as customers, orders, invoices, workers or material. Entities depend on type of model.
Entities are objects in the dynamic system whose motion within the system may result in the occurrence of events.

**Resources** - objects used for modeling capacity of material, workers or any other kind of needed resource.
Resources are limited commodities that are used, consumed, or replenished by the entities.

**Connectors** - are linking activities and processes.

**Pads** - are activities and processes that are subjects to be linked by connectors.

```
SIMPROCESS Standard Report for Simprocess Lab Example    StdRpt2015-12-04_15-22-51
Simulation Initiated at Fri Dec 04 12:40:23 2015
Simulation Concluded at Fri Dec 04 15:21:55 2015
Simulation Run Duration 02:41:31.727

Model Start Date/Time   : 12/01/2014 08:00:00:000:000:000
Model End Date/Time     : 01/01/2016 17:00:00:000:000:000
Actual Start Date/Time  : 12/01/2014 08:00:00:000:000:000
Actual End Date/Time    : 02/28/2015 20:10:59:999:999:071
Actual Run Duration     : 89 days 12:10:59:999:999:071
```

Entity : Total Count - Observation Based : Replication 1

| Entity Names | Total Generated | Remaining In System | Total Processed |
|---|---|---|---|
| Assembled Hammer | 294 | 0 | 294 |
| Finished Head | 299 | 5 | 294 |
| Handle Raw Stock | 128886 | 128592 | 294 |
| Head Raw Stock | 128892 | 128592 | 299 |
| Machined Handle | 294 | 0 | 294 |

Entity : Count By State - Time Weighted : Replication 1

| Entity Names | Traveling Average | Maximum | Total In System Average | Maximum | Processing Average | Maximum | Wait For Resources Average | Maximum | Hold For Conditions Average | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| Assembled Hammer | 0.000 | 1 | 0.002 | 2 | 0.002 | 1 | 0.000 | 1 | 0.000 | 0 |
| Finished Head | 0.000 | 1 | 5.001 | 6 | 0.000 | 0 | 0.000 | 0 | 5.001 | 6 |
| Handle Raw Stock | 0.000 | 1 | 64147.349 | 128592 | 0.111 | 2 | 64147.238 | 128592 | 0.000 | 0 |
| Head Raw Stock | 0.000 | 1 | 64147.348 | 128593 | 0.111 | 2 | 64147.237 | 128592 | 0.000 | 0 |
| Machined Handle | 0.000 | 1 | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 | 0.000 | 1 |

Entity : Cycle Time (in Hours) By State - Observation Based : Replication 1

| Entity Names | #Observed | Total In System Average | Maximum | Processing Average | Maximum | Wait For Resources Average | Maximum | Hold For Average | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Assembled Hammer | 294 | 0.017 | 0.017 | 0.017 | 0.017 | 0.000 | 0.000 | 0.000 | 0.000 |

Page 1

StdRpt2015-12-04_15-22-51

```
                0.000        0.000        0.000        0.000        0.008
 Finished Head  0.008        0.008        0.008        0.008        0.008
                0.000        0.000        0.000        0.000        0.000
 Handle Raw Stock 294        0.025        0.025        0.008
                0.000        0.000        0.000        0.000
 Head Raw Stock  299         0.017        0.017        0.017        0.000
                0.000        0.000        0.000        0.000
 Machined Handle 294         0.000        0.000        0.000        0.000
                0.000        0.000        0.000        0.000
```

Resource : Number of Units By State – Timeweighted : Replication 1

| | --Planned Downtime-- | | --Unplanned Downtime-- Defined Capacity | | ------Reserved------ Capacity Average | | -------Idle-------- | | -------Busy-------- | |
|---|---|---|---|---|---|---|---|---|---|---|
| Resource Names | Average | Maximum | Average | Maximum | Average | Maximum | Average | Maximum | Average | Maximum |
| CNC Lathe Operator | 0.780 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.220 | 1.000 |
| CNC Lathe for Hand | 0.998 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 1.000 | 0.001 | 1.000 |
| CNC Lathe for Head | 0.998 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 1.000 | 0.001 | 1.000 |
| Hammer Assembler | 0.996 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 1.000 | 0.002 | 1.000 |
| Hammer Heading Mac | 0.998 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.002 | 1.000 |

Resource : Percent Utilization By State : Replication 1

| Resource Names | Idle | Busy | Planned | Unplanned | Reserved |
|---|---|---|---|---|---|
| CNC Lathe Operator | 0.002% | 22.038% | 77.960% | 0.000% | 0.000% |
| CNC Lathe for Hand | 0.119% | 0.114% | 99.767% | 0.000% | 0.000% |
| CNC Lathe for Head | 0.116% | 0.116% | 99.767% | 0.000% | 0.000% |
| Hammer Assembler | 0.191% | 0.228% | 99.581% | 0.000% | 0.000% |
| Hammer Heading Mac | 0.005% | 0.228% | 99.767% | 0.000% | 0.000% |

Resource : Percent Utilization By State When Available: Replication 1

| Resource Names | Idle | Busy | Reserved |
|---|---|---|---|
| CNC Lathe Operator | 0.009% | 99.991% | 0.000% |
| CNC Lathe for Hand | 51.000% | 49.000% | 0.000% |
| CNC Lathe for Head | 50.000% | 50.000% | 0.000% |
| Hammer Assembler | 45.556% | 54.444% | 0.000% |
| Hammer Heading Mac | 2.163% | 97.837% | 0.000% |

StdRpt2015-12-04_15-22-51

Resource : Units Busy By Activity - Timeweighted : Replication 1

| Resource Names | Activity Names | Average | Maximum |
|---|---|---|---|
| CNC Lathe Operator | Delay282 | 0.110 | 1.000 |
| CNC Lathe Operator | CNC Lathe Operator | 0.110 | 1.000 |
| CNC Lathe for Hand | Load/Unload Time | 0.001 | 1.000 |
| CNC Lathe for Hand | Machined/Transform | 0.000 | 1.000 |
| CNC Lathe for Head | CNC Machining Time | 0.001 | 1.000 |
| CNC Lathe for Head | Machined/Transform | 0.000 | 1.000 |
| Hammer Assembler | Assembly Station | 0.002 | 1.000 |
| Hammer Heading Mac | Assembly Station | 0.002 | 1.000 |

Activity : Total Entity Count at Selected Activity - Observation Based : Replication 1

| Activity Names | Entity Names | Total Accepted | Remaining In Act. | Total Exited | Total Not Processed |
|---|---|---|---|---|---|
| Handle Stock Suppl | | 0 | 0 | 128886 | 0 |
| Handle Stock Suppl | Handle Raw Stock | 0 | 0 | 128886 | 0 |
| CNC Lathe for Hand | | 128886 | 128592 | 294 | 0 |
| CNC Lathe for Hand | Handle Raw Stock | 128886 | 128592 | 0 | 0 |
| Machined/Transform | Machined Handle | 0 | 0 | 294 | 0 |
| Machined/Transform | | 294 | 0 | 294 | 0 |
| Machined/Transform | Handle Raw Stock | 294 | 0 | 0 | 0 |
| Load/Unload Time | Machined Handle | 0 | 28109 | 294 | 0 |
| Load/Unload Time | | 28403 | 28109 | 294 | 0 |
| Delay282 | Handle Raw Stock | 28403 | 100483 | 28403 | 0 |
| Delay282 | | 128886 | 100483 | 28403 | 0 |
| Assembly Station | Handle Raw Stock | 128886 | | 294 | 0 |
| Assembly Station | | 593 | 5 | 0 | 0 |
| Assembly Station | Finished Head | 299 | 5 | 0 | 0 |
| Assembly Station | Machined Handle | 294 | 0 | 294 | 0 |
| Head Stock Supply | Assembled Hammer | 0 | 0 | 294 | 0 |
| Head Stock Supply | | 0 | 0 | 128891 | 0 |
| Join Head and Hand | Head Raw Stock | 0 | 0 | 128891 | 0 |
| Join Head and Hand | | 593 | 0 | 593 | 0 |
| Join Head and Hand | Finished Head | 299 | 0 | 299 | 0 |
| Join Head and Hand | Machined Handle | 294 | 0 | 294 | 0 |
| Assembled Hammers | | 294 | 0 | 0 | 0 |
| Assembled Hammers | Assembled Hammer | 294 | 0 | 299 | 0 |
| CNC Lathe for Head | Head Raw Stock | 128891 | 128592 | 299 | 0 |
| CNC Lathe for Head | | 128891 | 128592 | 0 | 0 |
| CNC Lathe for Head | Finished Head | 0 | 0 | 299 | 0 |
| Machined/Transform | | 300 | 1 | 299 | 0 |
| Machined/Transform | Head Raw Stock | 300 | 1 | 0 | 0 |
| Machined/Transform | Finished Head | 0 | 0 | 299 | 0 |
| CNC Lathe Operator | | 128891 | 100483 | 28408 | 0 |

34

```
                                StdRpt2015-12-04_15-22-51
CNC Lathe Operator  Head Raw Stock   128891   100483   28408   0
CNC Machining Time  Head Raw Stock    28408    28108     300   0
CNC Machining Time  Head Raw Stock    28408    28108     300   0
```

Activity : Entity Count By State at Selected Activity - Time Weighted : Replication 1

| Activity Names | Entity Names | Hold For Conditions Average | Maximum | Total In Activity Average | Maximum | Processing Average | Maximum | Wait For Resources Average | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Handle Stock Suppl | Handle Raw Stock | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| CNC Lathe for Hand | Handle Raw Stock | 0.000 | 0 | 64147.349 | 128592 | 0.000 | 0 | 0.000 | 0 |
| CNC Lathe for Hand | Machined Handle | 0.000 | 0 | 64147.349 | 128592 | 0.000 | 0 | 0.000 | 0 |
| Machined/Transform | Handle Raw Stock | 0.000 | 0 | 0.000 | 1 | 0.000 | 1 | 0.000 | 1 |
| Machined/Transform | Machined Handle | 0.000 | 0 | 0.000 | 1 | 0.000 | 1 | 0.000 | 1 |
| Machined/Transform | Handle Raw Stock | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| Load/Unload Time | | 0.000 | 0 | 14164.005 | 28109 | 0.001 | 1 | 14164.004 | 28109 |
| Load/Unload Time | | 0.000 | 0 | 14164.005 | 28109 | 0.001 | 1 | 14164.004 | 28109 |
| Delay282 | | 0.000 | 0 | 49983.344 | 100483 | 0.110 | 1 | 49983.233 | 100483 |
| Delay282 | | 0.000 | 0 | 49983.344 | 100483 | 0.110 | 1 | 49983.233 | 100483 |
| Assembly Station | | 5.003 | 7 | 5.003 | 8 | 0.002 | 1 | 0.000 | 1 |
| Assembly Station | Finished Head | 5.001 | 6 | 5.001 | 6 | 0.000 | 0 | 0.000 | 0 |
| Assembly Station | Machined Handle | 0.000 | 1 | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |
| Assembly Station | Assembled Hammer | 0.000 | 0 | 0.002 | 2 | 0.002 | 1 | 0.000 | 1 |
| Head Stock Supply | | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| Head Stock Supply | Head Raw Stock | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| Join Head and Hand | | 0.000 | 0 | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |

StdRpt2015-12-04_15-22-51

| Process/Conditions | | Entity | Average | Maximum | #Observed | | Average | #Observed |
|---|---|---|---|---|---|---|---|---|
| 0.000 | Join Head and Hand 1 | Finished Head | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | Join Head and Hand 1 | Machined Handle | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | Assembled Hammers 0 | Assembled Hammer | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | CNC Lathe for Head 0 | Head Raw Stock | 64147.348 | 128592 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | CNC Lathe for Head 0 | | 64147.348 | 128592 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | CNC Lathe for Head 0 | Finished Head | 0.000 | 1 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | Machined/Transform 0 | | 0.998 | 1 | 0.000 | 1 | 0.998 | 1 |
| 0.000 | Machined/Transform 0 | Head Raw Stock | 0.998 | 1 | 0.000 | 1 | 0.998 | 1 |
| 0.000 | Machined/Transform 0 | Finished Head | 0.000 | 0 | 0.000 | 0 | 0.000 | 0 |
| 0.000 | CNC Lathe Operator 0 | | 49983.049 | 100483 | 0.110 | 1 | 49982.939 | 100483 |
| 0.000 | CNC Lathe Operator 0 | Head Raw Stock | 49983.049 | 100483 | 0.110 | 1 | 49982.939 | 100483 |
| 0.000 | CNC Machining Time 0 | | 14163.302 | 28108 | 0.001 | 1 | 14163.300 | 28108 |
| 0.000 | CNC Machining Time 0 | Head Raw Stock | 14163.302 | 28108 | 0.001 | 1 | 14163.300 | 28108 |

Activity : Entity Cycle Time (in Hours) By State at Selected Activity - Observation Based : Replication 1

| Process------- | --------Processing---------- | ------Wait For Resources------- | -----Hold For |
|---|---|---|---|
| Conditions----- | | | ------Total In |

| Activity Names | Entity Names | Defined Duration | | Duration Time Unit | |
|---|---|---|---|---|---|
| #Observed Average | Maximum | #Observed Average | Maximum | Average Maximum | Average #Observed | Maximum #Observed |
| Handle Stock Suppl 0 0.000 | Handle Raw Stock | 0.000 | 0 | 0.000 | 0.000 | 0.000 | 0 |
| Handle Stock Suppl 0 0.000 | Handle Raw Stock | 0.000 | 0 | 0.000 | 0.000 | 0.000 | 0 |
| CNC Lathe for Hand 588 0.000 | Handle Raw Stock | 0.000 | 0 | 0.013 | 0.000 | 0.025 | 0 |
| CNC Lathe for Hand 294 0.000 | Machined Handle | 0.000 | 0 | 0.025 | 0.000 | 0.025 | 0 |
| CNC Lathe for Hand 294 0.000 | Machined Handle | 0.000 | 0 | 0.000 | 0.000 | 0.000 | 0 |

```
Machined/Transform
   294      0.000                                    0    0.000   0.000   Minutes   0.000   0.000   0.000        0
Machined/Transform
   294      0.000   Handle Raw Stock     0.000       0    0.000   0.000       294   0.000   0.000   0.000        0
Machined/Transform
     0      0.000   Machined Handle      0.000       0    0.000   0.000       294   0.000   0.000   0.000        0
Load/Unload Time
   294      0.008                                  294.5  0.000   0.000   Minutes   0.000   0.008   0.008        0
Load/Unload Time
   294      0.008   Handle Raw Stock     0.008     294    0.000   0.000       294   0.000   0.008   0.008        0
Load/Unload Time
   294      0.008                                  294.5  0.000   0.000       294   0.000   0.000   0.000        0
Delay282
 28403      0.008                                  294.5  817.943 1647.550 Minutes  0.000   817.951 1647.558      0
Delay282
 28403      0.008   Handle Raw Stock     0.008   28403   817.943 1647.550   28403   0.000   817.951 1647.558      0
Assembly Station
   882      0.017                                    1    0.000   0.000   Minutes   0.004   0.008   0.017        0
Assembly Station
   294      0.017   Finished Head        0.000     294    0.000   0.000       294   0.008   0.008   0.008      588
Assembly Station
   294      0.000   Machined Handle      0.000       0    0.000   0.000   Minutes   0.008   0.000   0.000      294
Assembly Station
   294      0.017   Assembled Hammer     0.017       0    0.000   0.000   Minutes   0.000   0.000   0.000      294
Head Stock Supply
     0      0.000                                  294    0.000   0.000       294   0.000   0.017   0.017        0
Head Stock Supply
     0      0.000   Head Raw Stock       0.000       0    0.000   0.000         0   0.000   0.000   0.000        0
Join Head and Hand
   593      0.000                                    0    0.000   0.000   Minutes   0.000   0.000   0.000        0
Join Head and Hand
     0      0.000   Finished Head        0.000       0    0.000   0.000   Minutes   0.000   0.000   0.000      593
Join Head and Hand
   294      0.000   Machined Handle      0.000       0    0.000   0.000   Minutes   0.000   0.000   0.000      299
Assembled Hammers
   294      0.000                                    0    0.000   0.000       294   0.000   0.000   0.000      294
Assembled Hammers
     0      0.000   Assembled Hammer     0.000       0    0.000   0.000         0   0.000   0.000   0.000        0
CNC Lathe for Head
   598      0.000                                    0    0.000   0.000         0   0.000   0.008   0.017        0
CNC Lathe for Head
   299      0.000   Head Raw Stock       0.000       0    0.000   0.000         0   0.000   0.000   0.017        0
CNC Lathe for Head
   299      0.000   Finished Head        0.000       0    0.000   0.000         0   0.017   0.000   0.000        0
Machined/Transform
   299      0.000                                    0    0.000   0.000   Minutes   0.000   0.000   0.000        0
Machined/Transform
   299      0.000   Head Raw Stock       0.000       0    0.000   0.000       299   0.000   0.000   0.000        0
Machined/Transform
     0      0.000   Finished Head        0.000       0    0.000   0.000   Minutes   0.000   0.000   0.000        0
```

StdRpt2015-12-04_15-22-51

CNC Lathe Operator
28408   0.008                          28408   817.777   0.000   817.785   1647.550   0   Minutes
CNC Lathe Operator   Head Raw Stock   0.008   28408   817.777   0.000   817.785   1647.550   0   Minutes
CNC Machining Time
300   0.008                            300   0.000   0.000   0.008   0.008   0   Minutes
CNC Machining Time   Head Raw Stock   0.008   300   0.000   0.000   0.008   0.008   0   Minutes

## Connector : Total Entity Count at Selected Connector – Observation Based : Replication 1

| Connector Names | Entity Names | Total Accepted | Remaining In Conn. | Total Exited |
| --- | --- | --- | --- | --- |
| Conn230 | | 0 | 0 | 0 |
| Conn229 | | 294 | 0 | 294 |
| Conn229 | | 294 | 0 | 294 |
| Handle Stock Mater | Assembled Hammer | 128886 | 0 | 128886 |
| Handle Stock Mater | Handle Raw Stock | 128886 | 0 | 128886 |
| Head Stock Materia | | 128891 | 0 | 128891 |
| Head Stock Materia | Head Raw Stock | 128891 | 0 | 128891 |

## Connector : Entity Count at Selected Connector – Time Weighted : Replication 1

| Connector Names | Entity Names | Total In Connector-- Average | Maximum |
| --- | --- | --- | --- |
| Conn230 | | 0.000 | 0 |
| Conn229 | | 0.000 | 1 |
| Conn229 | | 0.000 | 1 |
| Handle Stock Mater | Assembled Hammer | 0.000 | 1 |
| Handle Stock Mater | Handle Raw Stock | 0.000 | 1 |
| Head Stock Materia | | 0.000 | 1 |
| Head Stock Materia | Head Raw Stock | 0.000 | 1 |

## Connector : Entity Cycle Time (in Hours) at Selected Connector – Observation Based : Replication 1

| Connector Names | Entity Names | Total In Process-- Average | Maximum | #Observed |
| --- | --- | --- | --- | --- |
| Conn230 | | 0.000 | 0.000 | 0 |
| Conn229 | | 0.000 | 0.000 | 294 |
| Conn229 | | 0.000 | 0.000 | 294 |
| Handle Stock Mater | Assembled Hammer | 0.000 | 0.000 | 128886 |
| Handle Stock Mater | Handle Raw Stock | 0.000 | 0.000 | 128886 |
| Head Stock Materia | | 0.000 | 0.000 | 128891 |
| Head Stock Materia | Head Raw Stock | 0.000 | 0.000 | 128891 |

Time Stamps (in Hours) : Replication 1

| Stamp Keys | Average | Std. Dev. | Minimum | Maximum | #Observed |
|---|---|---|---|---|---|
| 12/1/2014 To 1/1/2 | 1069.955 | 622.934 | 0.000 | 2148.167 | 573551 |

Resource By Activity - Cost Of Processing (USD) : Replication 1

| Period Names | Resource Names | Activity Names | Variable Cost | Absorption Cost |
|---|---|---|---|---|
| Quarter1 | CNC Lathe for Hand | Machined/Transform | 176.40 | 176.40 |
| Quarter1 | CNC Lathe for Hand | Load/Unload Time | 180.89 | 4110.77 |
| Quarter1 | Hammer Heading Mac | Assembly Station | 155.97 | 4081.37 |
| Quarter1 | CNC Lathe Operator | CNC Lathe Operator | 6085.88 | 10865.82 |
| Quarter1 | CNC Lathe Operator | Delay282 | 6084.81 | 10863.91 |
| Quarter1 | CNC Lathe for Head | CNC Machining Time | 154.58 | 4084.37 |
| Quarter1 | CNC Lathe for Head | Machined/Transform | 149.50 | 149.50 |
| Quarter1 | Hammer Assembler | Assembly Station | 113.37 | 11123.30 |
| Total | | | 13101.41 | 45455.44 |

Resource By Entity - Cost Of Processing (USD) : Replication 1

| Period Names | Resource Names | Entity Names | Variable Cost | Absorption Cost |
|---|---|---|---|---|
| Quarter1 | CNC Lathe for Hand | Handle Raw Stock | 357.29 | 4287.17 |
| Quarter1 | Hammer Heading Mac | Assembled Hammer | 155.97 | 4081.37 |
| Quarter1 | CNC Lathe Operator | Head Raw Stock | 6085.88 | 10865.82 |
| Quarter1 | CNC Lathe Operator | Handle Raw Stock | 6084.81 | 10863.91 |
| Quarter1 | CNC Lathe for Head | Head Raw Stock | 304.08 | 4233.87 |
| Quarter1 | Hammer Assembler | Assembled Hammer | 113.37 | 11123.30 |
| Total | | | 13101.41 | 45455.44 |

Activity By Entity - Cost Of Processing (USD) : Replication 1

| Period Names | Activity Names | Entity Names | Variable Cost | Absorption Cost |
|---|---|---|---|---|
| Quarter1 | Assembly Station | Assembled Hammer | 269.35 | 15204.67 |
| Quarter1 | Delay282 | Handle Raw Stock | 6084.81 | 10863.91 |
| Quarter1 | CNC Lathe Operator | Head Raw Stock | 6085.88 | 10865.82 |
| Quarter1 | Load/Unload Time | Handle Raw Stock | 180.89 | 4110.77 |
| Quarter1 | CNC Machining Time | Head Raw Stock | 154.58 | 4084.37 |
| Quarter1 | Machined/Transform | Head Raw Stock | 149.50 | 149.50 |
| Quarter1 | Machined/Transform | Handle Raw Stock | 176.40 | 176.40 |
| Total | | | 13101.41 | 45455.44 |