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Systems Simulation Using ProModel: An online teaching method

Gustavo Sioni Bosoli
Eastern Illinois University

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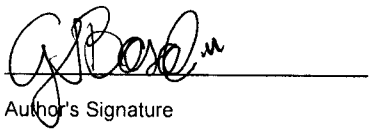

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Systems Simulation Using ProModel: An online teaching method

(TITLE)

BY

Gustavo Sioni Bosoli

THESIS

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ABSTRACT

This study was designed with the purpose to create an online method to deploy the concepts and practical knowledge necessary for the course System Simulation (TEC 5523) offered by Eastern Illinois University. The course is currently offered on a hybrid format, with part of it being ministered in the classroom and the remaining on the online environment. This research focused on creating a set of multimedia and step-by-step lessons aimed to substitute the part of the course that demands the students to be present in the classroom. These lessons were developed based on exercises from the textbook currently used for this class, and were selected in order to guarantee that the key concepts of this course were transmitted to the students. The lessons that resulted from this research were then tested and evaluated by a few students that did not have previous contact with the systems simulation topic. These students were enrolled in the Masters of Science program at Easter Illinois University. The results of this evaluation show that the multimedia lessons and step-by-step guides that resulted from this research are successful in guiding the students in the execution of the lessons that were selected as part of the material.

This thesis is dedicated to my parents, Jose Mario Bosoli and Elisabete Sioni Bosoli,

to my sister Fernanda Sioni Bosoli,

and to Jaclyn Bartz.

Whose constant support, encouragement, and patience have been fundamental for my success.

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Systems Simulation Using ProModel: An online teaching method

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by

Gustavo Sioni Bosoli

A thesis submitted to Dr. Rendong Bai, Dr. Rigoberto Chinchilla, and Dr. Wutthigrai Boonsuk of the Eastern Illinois University

Thesis Coordinator: Dr. Rigoberto Chinchilla

School of Technology

Eastern Illinois University

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CHAPTER ONE

Introduction

Traditional teaching methods generally follow the same protocol: the ones interested in learning and the instructor meet together at the same location and at the same time expecting a successful learning outcome. This conventional model of teaching can be considered fairly successful, once it has held its place for generations of instructors and learners. (Latchman & Latchman, 2000). But the basics of the teaching-learning processes are changing, once even more electronic tools and support become available and, in some cases, are even demanded by the students. (Andreas & Sieber, 2009)

It is possible to notice that a paradigm shift has been in course, students are starting to understand that the learning process can take forms other than the traditional face-to-face knowledge transfer. Nowadays, teachers and students comprehend that the educational process is more about developing a learning environment that is successful in transmitting the desired knowledge, independently of how instructor-centric that environment is. The name of this new spectrum of learning methods is "e-learning" which in the opinion of many enable students to learn faster, and more efficiently. (Rajendran, Veilumuthu, & J, 2010)

The variety of electronic support available in different learning environments spread from electronic presentations (supplied as a complimentary material for face-to-face classes) to completely online scenarios, where those interested in learning and the instructor will never be physically present in the same learning environment. At the present moment, there are several systems that support the electronic learning

environment, some examples being Blackboard®, WebCT®, Moodle®, and Desire2Learn® (D2L). These learning environments provide tools for communication between classmates and professors (i.e. forums and email), for progress evaluation (i.e. online tests), and other advanced features for content distribution. (Andreas & Sieber, 2009)

While studies have shown that a wide range of academic subjects can benefit from the use of online multimedia lessons, almost nothing has been done to teach the principles of systems simulation in such fashion. The development of a training material that focuses on teaching these concepts and tools represents more than just another instrument to teach the systems simulation subject; it also creates a possibility for members of a company or students to learn subjects that can largely benefit the productivity and efficiency in their workplaces in a manner that will have a much smaller impact on their current work schedule, once they are able to learn at their own pace and make use of lower workload periods to do so.

When making the decision of converting a customary face-to-face course to an online-based methodology, there are a few factors that should be carefully analyzed. As the transition can be somehow easier for the theoretical parts (mostly a matter of converting the material into a digital format), it could be a more complicated process for the hands-on part of this course, like a lesson that would focus on how to execute practical system simulation exercises using ProModel. The main cause behind this fact is mostly due to the way that the exercises and examples are presented by textbooks which usually lack of step-by-step fool-proof and/or comprehensive instructions, which typically confuse students and constantly requires the intervention of an instructor to help them to fill the gaps and/or to conduct live demonstrations of the exercise in place.

An institution that desires to offer a Systems Simulation course using ProModel in an online fashion should be able to create educational materials that are easy-to-follow and fail-safe video and text instructions to guide students on the process of learning the concepts and how to execute key laboratory exercises. The online course should also offer a smooth learning experience, and should be available from any physical location with internet connectivity at any time, and demand the least amount as possible of the instructor participation.

One of the courses offered by the School of Technology at Eastern Illinois University (EIU) Master of Science Program is the "Systems Simulation" course (TEC 5523), where the students are introduced to concepts of Systems Simulation, statistics, required to execute laboratory exercises and design simulation projects with ProModel® Simulation Software. The "System Simulation" course was originally offered on a weekly face-to-face basis, currently is offered as a hybrid course where the students would meet for some Saturdays during the semester and online in between face-to-face meetings.

The course, as it is right now, requires students to rely on the theoretical information that is presented in class to execute the practical laboratory exercises on their own. This typically represents a barrier to the learning process of those students who are less familiar with systems simulation concepts, statistics, and basic programming logic. A shift to an e-learning course is possible due the existence of screen recording technologies, such as Camtasia Studio®, that would allow the execution of some laboratory exercises and lectures to be recorded and provided to the students using the D2L portal, that is already available to faculty and students at EIU. This could mitigate in

great percentage the difficulties faced by some students, once the laboratory exercises can be seen executed in a video lesson, and also to get additional information on a text guide provided with the course's material.

Statement of the problem

The current setup of the Systems Simulation course at Eastern Illinois University requires learners to be present in the classroom at scheduled meetings to participate in the lectures, execute a few exercises, turn in their homework, and also to get constant help from the instructor in case they face difficulties with some parts of their assignments. While it is possible to have the ProModel simulation Student Edition software installed in the students' personal computers for free, the way the lessons are presented in the textbook and current materials, typically requires them to be present in class in order to obtain the necessary instruction on how to operate the software and execute their laboratory exercises.

The main difficulties faced for the students of this course are:

- The meetings are few during the semester, what can cause the student to have to wait for a long period to have help from the instructor or to rely on e-mail or D2L which not always is the best method to assist them in their simulation projects.
- Since there are only a few meetings for the course, not all key laboratory exercises can be executed in class, representing a big learning barrier to some students.

Hypothesis

It is possible to develop an online class to teach the concepts and practical knowledge of Systems Simulation (TEC 5523) using ProModel without losing the

efficiency and effectiveness of the face-to-face method. Indeed is possible even to improve the class as it is by using well prepared written and audiovisual materials. The instructor, instead of an agent who constantly is guiding the students in their simulation exercises, becomes more like a consultant and more advanced and special projects can be developed in class. EIU has the necessary resources to make the shift from the traditional face-to-face methodology to an online oriented course: software for the edition of video lessons, and a portal that can be used to distribute the multimedia material, test the students' learning process, and to make a more efficient bridge between students and instructor.

Statement of Purpose

The goal of this study is to research and develop a methodology to teach the concepts and practical applications behind the Systems Simulation technology in an online fashion. The lessons have to be planned in a way that will give the students the opportunity to learn with more independence of the instructor and with more flexibility in their time and schedule.

The goal of this thesis is to create educational materials that allow students to follow the lessons using their personal computer, and with the required systems simulation software, be able to execute the practical exercises just by following the online multimedia lessons and the companion step-by-step written instructions. This will allow the students to complete the assignments at their own time, re-watch the lessons if they have any doubts, reduce the amount of times that the student has to be present at the University and/or contact the instructor, and also make the knowledge available for learners trying to take distance education classes.

Significance of the Study

The results of this study will provide a complete and fail-proof set of lessons that can be used to turn the traditional face-to-face method of teaching Systems Simulation into a more dynamic online learning environment, so students can complete the course at any geographical location as long as they have access to a computer with Internet connection. The material will provide the students with multimedia lessons, and easy to follow and fail-proof written guides that will make the learning process more smooth, available to students geographically located far from our campus, and significantly reduce the need of interaction with the instructor for trivial questions but increase the interaction with the instructor for more significant projects or research.

Objectives

This study aims to accomplish the following goals:

1. To develop a set of lessons that will make possible to teach the concepts and practices behind the Systems Simulation subject in an online fashion.
2. To use a teaching methodology that will assist the students to develop their knowledge and ability to work with the system simulation software ProModel.
3. To design a learning material that is at the same time easy to follow, fail-proof, and also provide students with knowledge equal or superior to the one offered on the classroom.
4. To eliminate the need of regular face-to-face meetings for TEC 5523 by making the TEC 5313 course knowledge completely available online, so students can learn at their own pace and independently of their physical location.

Delimitations of the Study

This research will mainly focus on the materials used in TEC 5523 and is aimed to complement properly the PROMODEL textbook "Simulation Using ProModel", third edition, by Harrel, Ghosh, and Bowden, and published by McGraw Hill. The developed teaching materials will not provide solutions for all the laboratory exercises contained in the textbook; instead it will focus on exercises that are considered key for the development of the Systems Simulation concepts and knowledge. These exercises will be selected with the aid of the present course professor, Dr. Rigoberto Chinchilla. Selected exercises will be those that are considered essential and key for introducing new functions of ProModel® software, and complementary ones that will help the students to get a better understanding of these functions. The outcomes of this research are most likely to eliminate the need for regular classroom meetings, but will not eliminate the need for a dedicated instructor, once students will probably still have questions and face uncertainties about their assignments, their projects and their exams and quizzes.

CHAPTER TWO

Literature Review

The benefits of using an online method to teach Systems Simulation using ProModel in the Eastern Illinois University was discussed in the previous chapter. This current chapter will offer extra theoretical knowledge in order to justify the substitution of the current face-to-face method currently applied at EIU to an online delivery method.

Systems Simulation

Nowadays most markets are extremely competitive and globalized, which has been forcing companies to constantly bring their productivity to new levels in order to maintain or increase their market share. Businesses of the 21st century are faced with challenges to elevate their responsiveness to present market requirements, mostly because customers expect shorter delivery periods, higher agility and quality, and lower costs. (Flip, Mebrahtu, Marascu-Klein, & Deaky, 2012)

Simulation has been used as a support tool for decision making on analysis, modeling, and designing of systems. Therefore, when it is inconvenient to make parameters measurements on the actual system, the process of simulate this system would provide the means to understand the behavior of it over a period of time and under different circumstances. (Cho, 2005)

During the last decade, computer aided simulation software combined with statistical analysis techniques, have evolved to provide decision makers with powerful tools to complete certain tasks. Systems simulation makes use of models to develop conclusions about the comportment of the elements being analyzed in a real-world situation. Also, the use of this technique has increased over the past years mostly due to

the rise of computational power and the evolution of the programming languages. (McHaney, 2009)

To make use of simulation techniques, it is very important that the user understands what a model is, and exactly what it characterizes. A model is a representation of the configuration and functioning of a selected system, it has to be similar to this system, but at the same time it has to be simpler in order to make the modeling process viable. The model designer must always consider the tradeoff between simplicity and realism. Usually, a model used for simulation analysis is composed mostly of mathematical functions, and is built with the aid of specific simulation software. (Maria, 1997)

Once a model is constructed, the actual simulation process takes place. The simulation part consists of the operation of the model; in this phase, the model can be tested under different setups and also be reconfigured, which would be prohibitive to do on the system it represents, because it is too costly or impractical to do so. The main goal of simulation is to understand the behavior of the actual system under different configurations covering extended period of times, based on the conclusions provided by the study of the model representing it. Simulation is a tool used before a system is built or transformed, in order to avoid under or over-utilization of resources, to make sure that it will meet the requirements, to identify possible bottlenecks, and to maximize the system's performance. (Maria, 1997)

Required skills to work with systems simulation

It is very common for software vendors to advertise their system simulation solutions as options that do not require any prior knowledge of programming, or

statistics. But the fact is that this knowledge is very useful, if not essential to the successful execution of a systems simulation project.

Companies interested in pursuing the development of a systems simulation projects usually spend a great amount of energy and precious time evaluating different options and solutions on simulation tools, but most important is to identify the ideal person that will make use of simulation software, as part or their work. To select and train a person that will make use of system simulation tools can be a long and costly process. (Rohrer & Banks, 1998)

According to Rohrer & Banks (1998), among the knowledge areas that are necessary for a simulation analyst are: data collection, conceptual model development, model construction, and results analysis.

The data collection phase of a simulation project concerns the gathering of information that is necessary for the system to be modeled; this can be a very tedious phase of the process, but at the same time it is fundamental for its success. The conceptual model development refers to the "translation" of the real-world system into a logic-flow diagram that successfully represents the essential features of the original system, thus providing results that can be useful for future analysis. (Rohrer & Banks, 1998)

The model construction part represents the transformation of the conceptual model into a computational model; the model builder must be familiar with a simulation tool in order to succeed in this phase of the process, once he will have to make use of the programming structure of the selected software in order to construct the simulation model. Finally, the simulation analyst should be able to investigate the results provided

by the model, to judge if the model accordingly represents the real system, understand how the model's performance indicators translate to real life situations and then propose solutions to the problem. (Rohrer & Banks, 1998)

It is important to notice that the knowledge areas that are necessary for a simulation analyst are currently present on the face-to-face Systems Simulation course offered by Eastern Illinois University, and that the new online teaching method will contribute to the distribution of this knowledge to a wider array of students. Some of the materials provided with the new methodology are likely to make the learning process smoother.

ProModel®

ProModel® is a powerful and easy-to-use simulation software commercially available to customers around the world. One of its main advantages is the fact that it was designed with the goal of improving the efficiency of the simulation of discrete-event scenarios. ProModel also has elements that can be used to develop the simulation of continuous events (such as the inflow and outflow of fluids in a tank). (Harrel, Ghosh, & Bowden, 2012)

A model is constructed in ProModel® by using simple graphic tools, data input using dialog boxes, and tables where specific information can be entered. A model built in ProModel® will always be composed of items that fit in one of the following categories:

- Entities: the items that are processed in the different locations of the model.
- Locations: the places in the model where the entities are processed.
- Resources: the elements that are responsible for transporting the entities or to

process them in the model), and paths (the tracks that are designed for the entities and resources to move on). (Harrel, Ghosh, & Bowden, 2012)

The models built using ProModel® can be very detailed and at the same time easy to develop. (Banks, Carson II, Nelson, & Nicol, 2005). Dialogs are linked with all the modeling entries that are in turn used to program the operational behavior of the system. (Harrel, Ghosh, & Bowden, 2012)

The great majority of the simulation elements in ProModel® are represented by a graphic component, for example, a gear image can be selected to represent a new entity on the model. When a new entity is created, it is possible to define characteristics such as speed, name, color, dimensions, and others; these characteristics will be used for the software as input data and can affect the output of the model. The advantage of this graphical approach on modeling is that it makes the process more visual and intuitive for the model builder, but there is also the option of creating a model without making use of any graphical elements. It is possible to import CAD drawings to be used as the model's layout background, or to represent entities, locations, or resources. (Harrel, Ghosh, & Bowden, 2012). Figure 1 shows an example of ProModel's interface elements.

When a model is run using ProModel®, the input data of the model is converted into a simulation database. During the execution, an animation is displayed concurrently with the system's simulation execution. The animation is composed of different types of graphics: static or dynamic. (Harrel, Ghosh, & Bowden, 2012). Dynamic graphics are the ones that move around or suffer some sort of transformation during the simulation, such as resources carrying entities or moving from one machine to another; static graphics

refer to those that remain the same during the whole process, for example, an image representing a wall or a factory layout.

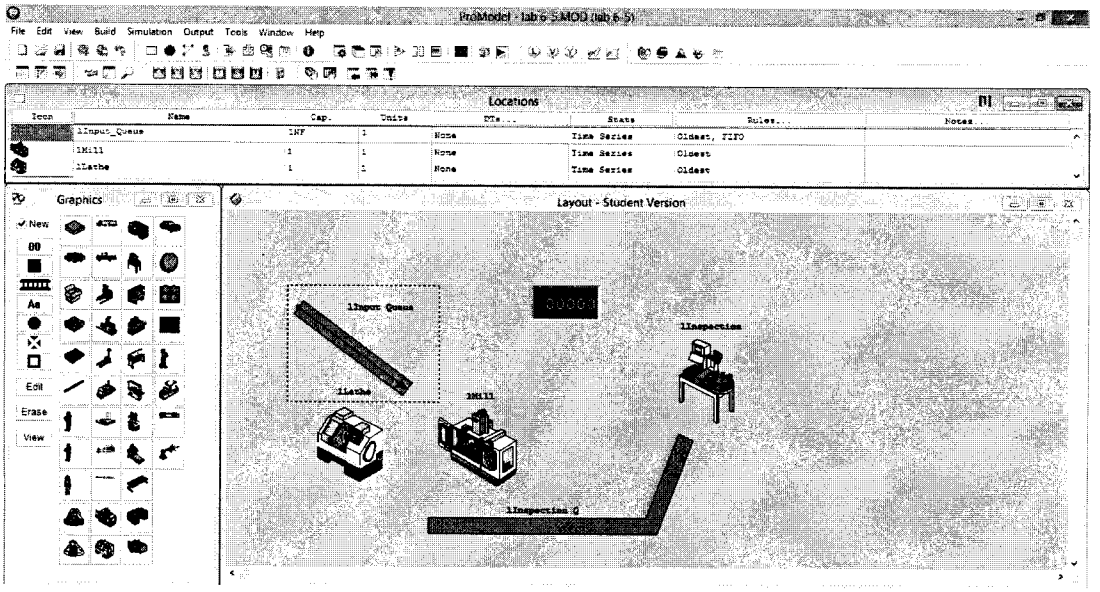

Figure 1 - ProModel user interface

After the simulated system has been executed, it is possible to observe key performance indicators results on ProModel's® Output Viewer module. The results of the simulation can be presented in a variety of forms, such as histograms, pie charts, line plots, reports, tables and others. Some analysis tools are already included and can be easily accessed on the Output Viewer, such as confidence interval, mean, standard deviation, variation, mode, minimum and maximum values. (Harrel, Ghosh, & Bowden, 2012). Histograms can be easily customized by selecting the number and width of its intervals, which is one of the best tools to understand the distribution of some performance indicators. Another benefit of using the Output Viewer is the fact that it makes possible to summarize the results from different replications and scenarios for easier comparison between them. Figure 2 shows the Output Viewer for the results of a demonstration model included in the ProModel® Student Version 8.6.

Figure 2 - ProModel Output Viewer module

Distance Education

Distance education can be defined as a learning methodology that makes use of different technologies to provide education and other services to learners located in different physical locations. Distance education also focuses on aiding adults with their professional needs, and in offering different levels of education rather than only degree level certifications. (Meyer, 2009). Distance education can be sub-divided into three different categories: correspondence, where print based courses are distributed by mail; the extended classroom, which makes use of live video feeds to provide a view of the actual classroom to students located out of the classroom boundaries; and web-based, which makes use of online technologies exclusively. (Hanna, 1998)

A central part of distance education is the medium used for communication. Recent developments in technology have allowed a shift from mail based courses to completely online knowledge delivery methods. At the present time, a few universities still offer correspondence courses, but most of the current distance education programs now consist of virtual classrooms, "made possible through the Internet, compressed video, satellite links, and microwave transmission." (Bryant, Kahle, & Schafer, 2005). Table 1 lists the different format modes used to make distance education possible.

Table 1 - The Technologies of Distance Education

Format	Transmission Mode	Learner Autonomy Regarding Pace	Characterized By
Correspondence Study	Asynchronous	High	Learner and instructor communicate via mail or email
Commercial TV (e.g., PBS)	Asynchronous	High	Learner must watch the program but can record it and watch at his convenience. No live interaction
Interactive TV	Synchronous	Low	Cameras at both instructor and learner location, they interact live.
Virtual Classroom	Synchronous	Low	Cameras are at the instructor's location.
Web-Enabled Classroom	Synchronous and Asynchronous	Medium	Course management tools such as WebCT and Blackboard.

Web-Based Classroom (online)	Synchronous and Asynchronous	Low	Software-driven, synchronous environment; learner does not control pace.

Note. Adapted from *Issues in Accounting Education*, p. 259, by Bryant, S. M., Kahle, J. B., & Schafer, B. A, 2005.

Distance education has become a reality to many students in the present higher level education scenario in the United States of America. This education method has benefits that set it apart from traditional face-to-face methods such as: it allows the access of courses for larger audiences, it meets the requirements of students that are unable to encounter in the same location, it makes it possible for students with different cultures and backgrounds to interact, and also it can benefit from professors and speakers that are not located in the same country. (Abarashi, 2011)

Distance education can offer a modern channel to deliver knowledge, thus expanding the customary educational system. Research shows that students included in the current educational scenario are more expected to make use of new technologies and tools to increase their comprehension of a subject. (Khan, 2003)

One of the important components of most scientific-oriented courses is the presence of laboratory practices, which can be complicated to reproduce in an online learning system. Since the advent of distance education courses, the knowledge transference of technical subjects has been characterized as a complicating factor for educational institutes. The requirement for laboratory training is particularly significant in technology, science and engineering related courses. (Lahoud & Krichen, 2010)

When speaking about the requirement of laboratory skills in a distance-based course, two main options are available. The first option demands that the student visits the campus in a pre-determined schedule to execute his laboratory exercises, and the second one is the development and delivery of online laboratory lessons. These lessons can be created using a different array of techniques that "vary from online interaction experiments, to computer simulations, to video-based" lessons. (Abdel-Salam, Kauffman, & Crossman, 2006)

An experiment that assessed the efficiency of video-based laboratory lessons versus its hands on the counterpart was performed at Old Dominion University, located in Virginia. The study was conducted using two groups of students, one that was present on hands-on lessons, and another that participated on the online video-based lessons. The research concluded that the second group performed as well or better than the first group, in laboratory writing performance, technical comprehension, and final examination scores. (Abdel-Salam, Kauffman, & Crossman, 2006). This experiment shows that, if well designed, online video lessons can be used as an efficient substitute to hands-on laboratory classes, not presenting any evident negative consequences.

Evolution of distance learning

The distance learning history in America has an important year in its timeline: 1874, the year when the first correspondence based course in this country was created by the University of Illinois. Between 1920 and 1940, education found its way on the radio and television formats, which led the way for the development of fundamental techniques in the distance education field. (Abarashi, 2011)

Programs that used radio and television as part of their distance training were the target of millions seeking learning opportunities. With the advent of long-distance telephone communication on the beginning of the twentieth century, the diffusion of distance learning courses was even more prominent. But was the expansion of computer networks in the nineties, the great responsible for connecting millions of people, and by making possible to learn on any location of the world simply by using a computer with Internet connection. (Abarashi, 2011)

Educational technology has mostly focused on the use of computers to aid in the classroom learning process. Businesses are starting to understand the advantages of combining microcomputers and telecommunications to change the nature of their tasks. In another hand, people in charge of educational institutions are analyzing how the traditional distance learning methods could be turned into more effective and advanced teaching methods by the use of innovative multimedia tools. (Dede, 1990)

Distance education and Internet

Distance education has become more common with the advent of the Internet, mostly because in the online environment it is not subject of space and time limitations. Data retrieved from the *Distance Education at Degree-Granting Postsecondary Institutions: 2006-07* show that between 2006 and 2007, over 60% of institutions that offered degree-granting programs made their courses available online, or in a hybrid format. The same report also indicated that approximately twelve million enrollments on distance education courses happened during the same period. (Parsad & Lewis, 2008)

Different methods can be used to deliver distance education courses, but the use of asynchronous web-based videos was indicated as the most popular of the available

approaches. The use of the asynchronous method for the distribution of online courses does not need real-time interaction between students and instructor, which is in turn sustained by the use of emails, discussion forums, wikis, or multimedia lessons. (Huang & Ling, 2012). Studies have shown that the use of the asynchronous system is very efficient on facilitating the learning process. It has been proven that this methodology promotes critical thinking, once students have a longer period to process the information transmitted and their ideas. (Benbunan-Fitch & Hiltz, 1999)

One of the main factors that drive the demand for the offering of online courses is the fact that over half of the students in the United States are coming back to the academy after they start working (and frequently have family). This makes online courses the most desired option for this public, because they would still be able to work and dedicate time to their household and familiar activities. (Hiltz & Turoff, 2005)

Given the facts presented on the previous paragraphs, it is evident that an online course that makes use of the asynchronous method could contribute positively to the learning process of future students of the systems simulation course discussed on this study. The suggested course would make use of textbook readings, audiovisual recordings, and written instructions to transmit the concepts of the System Simulation course (currently offered by Eastern Illinois University), including the theoretical knowledge and operation of the software ProModel®.

Screen capturing

Screen capture tools consist of software that allows the instructor to record actions executed in a computer screen and then make these videos available for his students. For the specific scenario analyzed by this thesis, the course tutor could record his actions

when constructing a simulation model, and then provide the video files to his students. This process has as its goal to provide the learners with an experience similar as the one that would be presented in a classroom setting.

The use of screen capture software brings a few advantages for the learning process. It is possible to make annotations on the images, highlight specific parts of the screen, add captions, and add narrations. Videos created using screen capturing techniques provide students with a reference material that can easily substitute in-class instruction. (Drumheller & Lawler, 2011)

Many options of screen capture tools are available in the commercial and open source modalities; both of them offer the same basic features, but the first usually have a more sophisticated video edition environment, which would greatly contribute to the creation of more elaborate lessons. One of the highest-rated tools in this category is Camtasia Studio®, from Tech-Smith.

Camtasia Studio® offers a very complete and intuitive set of production and edition tools, such as smart zoom, captioning, highlighting, underlining, insertion of shapes, narration, and it also allows the instructor to create quizzes at the end of each video to assess the student's knowledge absorption. Once the recording and edition phases are completed, the software also possibilities the creation of video in different formats and with different compression settings, which is a needed feature for the distribution of the lessons in an online environment. (Mark, 2004)

Success cases on using online classes

It is possible to identify many institutions that are successful on the business of providing students with online delivered courses; some of them are colleges that provide

complete degree-earning courses and others specialize in providing content focused on teaching specific subjects, such as the practical uses of software.

The University of Phoenix and DeVry University are two relevant represents of colleges that provide degree-earning programs based on online courses. Both of them offer courses for Associates, Bachelors, and Master's degree; while their online courses catalog do not contain as many options as other universities that offer traditional face-to-face methods, they offer courses in diverse areas of knowledge.

One of the most successful representatives of institutions that make use of online lessons to teach specific subjects is Lynda.com. This company makes use of video lessons to teach knowledge in specific areas such as video edition, advanced functions of MS Excel®, or photography techniques.

These examples show that it is possible to make use of video capturing tools to provide online lessons with high quality, and that will help the students to achieve their goals of learning the concepts involved in the Systems Simulation course offered by Eastern Illinois University, as well as to operate the ProModel® software.

CHAPTER THREE

Methodology

This research will be conducted by analyzing different options of distributing the learning material in an online fashion, and then selecting the one that is more suitable for distributing the System Simulation concepts to the EIU students. Once the new technique is selected, the present face-to-face methodology used for the class will be converted to the new online standard modality.

The online methodology will include step-by-step videos and written instructions to guide the students on how to build simulation models using ProModel®. The laboratory exercises will be aimed to introduce new system simulation concepts to the students, and will be selected from the exercises contained in the textbook "Simulation Using ProModel".

The step-by-step instructions will be created to guide the students in the process of developing simulation models based on the laboratory exercises selected from the textbook. Once the instructions are finished, the model construction process will be recorded in a video format using Tech-Smith's Camtasia Studio®. This software allows the recording of a computer's screen in real time, and also allows the addition of voice narration, captions, and other graphical elements supporting the learning process.

This chapter will introduce the methodology to be applied in order to offer the course TEC 5523 as an online class. Some of the material contained in this chapter can also be used as a foundation for teaching other courses for the Masters in Technology Program at Eastern Illinois University on an online-based distribution environment.

Overview of current course

The TEC 5523 Systems Simulation course currently offered at Eastern Illinois University has evolved from a pure face-to-face class to a hybrid format, where the students were required to be present in a few physical meetings during the semester and then complete part of the work from home based on instructions transmitted in class and contained in the course's textbook.

Due to the hybrid nature of the class model, the last Syllabus for TEC 5523 (APPENDIX A) already requested that students interested in taking this course must be able to work independently, self-guided, and do not postpone the completion of exercises and projects to the few days before the deadline.

The first part of the course schedule requires the students to read a few chapters of the book, to download ProModel®, and to execute a tutorial lesson following a written instruction set. While the reading part could easily be executed, students that never had contact with the simulation software could face some difficulties on executing the tutorial lesson.

The schedule described on the syllabus shows that students would have to be present on a few lectures during the semester, which would provide them with basic statistics skills and knowledge on the development of basic simulation models that would in turn be used to complete the online part of this course. During the period between physical meetings, the students are required to execute laboratory exercises on their personal computers by following the directions provided on the textbook, to execute a few projects that are determined by the professor of this course, and to complete tests to assess their learning progress.

The laboratory exercises that students execute on their own include:

- Tutorial: This laboratory provides the students with a first contact with ProModel's® functions, and guides them on the creation and analysis of their first simulation model.
- Fitting Distributions: This is a custom laboratory developed by the course professor, which focuses on teaching the students how to collect data and convert them to statistical distributions, that are used as input for the simulation models built during the course.
- Laboratory 2: The exercises from this section are contained in the textbook. They are focused on the development of basic simulation models, and on how to make small alterations in simulation logic after the models are finished.
- Laboratory 3: This laboratory section of the textbook focus on introducing the students to the Output Viewer module from ProModel®. This module is responsible for displaying the compilation of simulation results after a model is executed.
- Laboratory 4: This laboratory section focuses on basic system simulation concepts and on new tools from the simulation software that are used in this class.

The laboratory directions contained in the textbook are very general not a step-by-step set of instructions to get the students familiarized with the software. The fact that the book instructions are not specific and detailed, could cause misinterpretations and result on models that are different from the ones that were intended by the book authors. Students with a poor background in System Simulation could face difficulties that would not allow them to build fully working models.

It is evident that the presence of step-by-step written instructions paired with video guidelines will greatly improve the student's ability to execute the laboratories, and will help them to create models as they were intended by the textbook authors. The learning process will also be smoother, once the students follow the instructions and watch the videos at their own pace in order to absorb its contents and master ProModel's® functions.

Basic requirements for Online Classes

The basic requirements needed to create a dynamic online environment that will allow students to succeed on learning the concepts and applications of systems simulation are:

1. Online lessons should be designed to be easy to follow and as clear as possible, so the students can focus on learning the concepts being transmitted.
2. The lessons should be dynamic and engaging in order to make sure that students do not lose their focus on the activity.
3. The lessons should stimulate the students' rational aptitudes, in order to make them able to apply the gained knowledge in real life situations.
4. The lessons should be frustration free, fail-proof, and follow a step-by-step approach that would make the students capable of completing their practical tasks with a minimum amount of help from a dedicated instructor.
5. The online lessons should be crafted to meet university quality levels, in a way that the practical lessons are developed to offer a learning value equal or superior to the one provided by face-to-face classes.

6. The online lessons should be able to give the students an experience as close as possible to the one that would be provided in a traditional classroom.

The Online Class materials

The online class materials will be designed to cover the same subjects as the ones covered by the actual hybrid method: students will be required to read the textbook chapters, execute laboratory exercises, develop projects, and be evaluated on tests.

Since the TEC 5523 "Systems Simulation" course has been ministered in the form of hybrid course (where the students would have the opportunity to have their questions relative to the class subject answered by the instructor, and also where they would receive the necessary instructions to execute the next group of laboratory assignments and projects) a great part of its content was already made available online to students, with the exception of the practical lessons responsible for teaching the functions and applications of ProModel®.

In the practical lessons ministered during the physical meetings, the instructor would select a few key exercises that were responsible for introducing new functions of ProModel®, and guide the students on how to solve them using a step-by-step method. The students would follow the explanation, take notes, and build simulation models on their personal computers. In order for this hybrid class to be offered completely in an online environment, this part of this course would have to be converted to a digital version that could be delivered to students using the Desire 2 Learn® portal.

In order to offer the practical laboratory lessons digitally, the process of model construction and analysis will be described using a complete set of step-by-step written and audiovisual instructions that will have as a goal to guide the students on the complete

execution of selected exercises. This methodology would offer some improvements over the way in which this process is currently executed: the students would be able to watch the audiovisual instructions as many times as necessary and they would be able to follow the detailed written instructions to build the model. The main disadvantage of this deployment method is that if the students have a question, they will have to send a message to the professor and wait for a response, rather than getting it instantly as it would happen in a physical meeting. Even though this may sound like a big barrier for this methodology, if the students follow the class schedule, they will have enough time to get a response from the professor before the exercises are due, the intended lessons are aimed to diminish these barriers.

The step-by-step instruction guide

The lessons will follow certain exercises contained in the textbook "Simulation Using ProModel" third edition by Harrell, Ghosh, and Bowden, published by McGraw-Hill in New York in 2012. A total of twelve step-by-step guides covering a equal number of practices will be written with the goal to teach students the necessary concepts of Systems Simulation and ProModel®. The lessons to be provided for the online class are listed on the Table 2.

Table 2 - Laboratory Lessons

#	Description
LAB 1	Tutorial: The first lesson will introduce the user to ProModel's interface, basic functions, and basic modeling.

LAB 2	The lesson will focus on laboratory exercises 2.1 and 2.2 from the textbook, and will teach students how to build their first simulation models.
LAB 3	This lesson will focus on laboratory exercises 2.3 and 2.4 from the textbook, and will introduce students to the concepts of "Locations", "Entities", "Processing", and "Arrivals"; this lesson will also teach students how to incorporate a new location to an existing simulation model.
LAB 4	This lesson will focus on laboratory exercise 2.6 from the textbook, and will focus on teaching the concept of "Blocking".
LAB 5	This lesson will focus on the textbook laboratory exercise 4.1, and will introduce the concepts of "Multiple Locations", and "Multiple Entity Types".
LAB 6	This lesson will be based on laboratory exercise 4.4 from the textbook, and will focus on the "Routing Rules" concept.
LAB 7	This lesson will focus on laboratory exercise 4.7.1 from the textbook, and will introduce the concepts of "Temporary Batching".
LAB 8	This lesson will be based on laboratory exercise 4.7.2 from the textbook, and will introduce the concepts of "Permanent Batching".
LAB 9	A custom lesson that will focus on teaching the students a methodology for collecting data, and how to process it using the tools provided by ProModel®'s module Stat::Fit. The processing will result in probability distributions that are used as inputs for model construction processes.
LAB 10	This lesson will be based on the laboratory exercise 6.1 from the textbook, and will introduce students to the concept of "Atributes" and their uses.

LAB 11	This lesson will focus on the laboratory exercise 6.2 from the textbook, and will focus on teaching the students different methodologies to calculate the "Cycle Time" of entities in a simulation model.
LAB 12	This lesson will be based on the laboratory exercise 6.3 from the textbook, and will be used to teach the students how to program simulation logics for "Sorting", "Sample Inspection", and "Rework".

All the written instructions will follow a similar model. First, the lesson objective will be enunciated, and then it will be divided in steps and sub-steps. For example, in a lesson where the objective is to build a simulation model; first the description of the model will be provided, then the development process will be divided in steps accordingly to the model components (i.e. entities, locations, processes, arrivals, etc.), and these steps will be broken down to a simple step-by-step instructions set that when followed will guide the student on the construction of the simulation model enunciated on the lesson.

The step-by-step instructions will contain a high level of details that will include written descriptions of the actions to be performed, images showing where certain elements of ProModel's user interface are located, and will also provide images with the results of certain steps so the students can compare their results to what was requested by the instructions.

The video lessons

A set of step-by-step videos will be provided as a companion for the written instructions. The goal of this additional material is to offer the students a visual and

dynamic explanation of how to build simulation models, similar to the one that would be provided in the classroom by an instructor during the physical meetings.

Each video lesson will be created with the goal to show the process of development of the exercises from the lessons described on the Table 2. The multimedia material will present the students with a set of instructions that follows the execution order used in the written instructions guide. The fact that the guidelines are similar and follow the same order in both materials, makes it possible for students to use either (or both) material(s) to build their models, to verify if the correct steps are being taken, and to clarify eventual questions.

The multimedia material will be recorded using Tech-Smith's Camtasia Studio 8®; this software allows the recording of actions happening on the screen of a computer, and makes it easier to add visual effects, to crop images, to cut undesired parts of the video, to add voice narration and captions. The software structure also offers easy and intuitive tools that would allow the course instructor to easily perform future modifications or additions on videos. On top of these advantages, Eastern Illinois University already owns a copy of said software, which would not contribute to an increased cost when converting physical lessons to online classes. Figure 3 shows Camtasia®'s user interface.

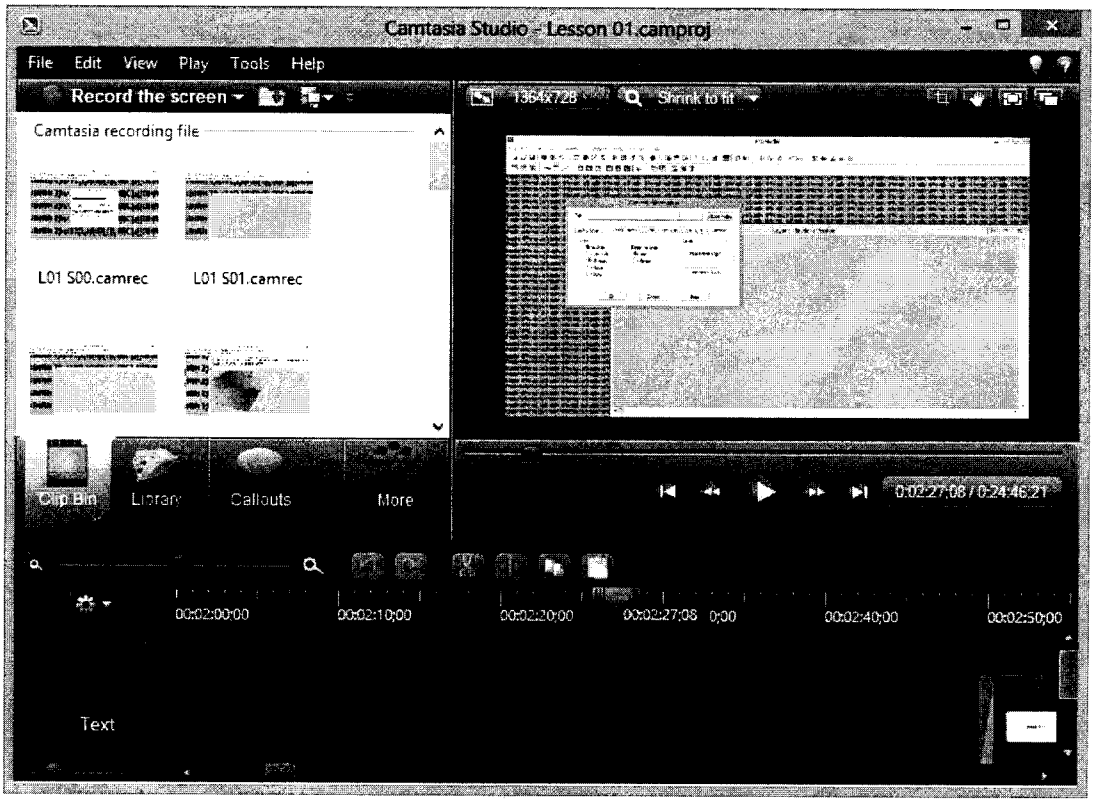

Figure 3 - Camtasia Studio 8

For this thesis, the multimedia lessons will be provided in a DVD format, but during the definite implementation of this online course the material will be distributed to the students using the Desire 2 Learn® portal.

Lessons evaluation

Once the material to be created as a result of this research is completely new and unique, it is necessary to evaluate its efficiency on transmitting the System Simulation knowledge to the students. This evaluation will be carried by distributing six lessons of the new material to three different graduate level students that are currently enrolled on the Masters in Technology Program at Eastern Illinois University. It is essential that the selected students have no previous knowledge of Systems Simulation; therefore, it will be

possible to evaluate the real efficacy of this material on transmitting the necessary knowledge for this course.

Once the students have completed assigned lessons, the models built by them will be compared to what was intended by the lessons and the eventual discrepancies will be analyzed in order to identify their possible causes. After the students complete their tasks, they will be asked to provide feedback on the material and also to complete an evaluation of the lessons based on a survey developed specifically for this case. The goal of this survey is to provide a method for the evaluation of multimedia learning resources, especially those delivered on an online environment.

The proposed course Syllabus

After the new lessons are formulated it will be necessary to adjust the class syllabus to fit the new online methodology. The current TEC 5523 Systems Simulation Syllabus was built as a hybrid course in mind, and parts of it will have to be adapted to fit the needs of a course that is delivery on an online environment. It is evident that several aspects of it will have to be modified, but the area that will be the target of most of the alterations will be the current course schedule. This part specifically determines that students will have to be physically present in class in specific days of the semester, what will not be the case when the course has completely shifted to an online deployment system.

CHAPTER FOUR

Results, Discussion and Conclusions

This research allowed the creation of a method that enables the students to learn the theoretical concepts and practical software knowledge from the course Systems Simulation offered by the School of Technology at the Eastern Illinois University. A material containing written lessons and video guides was developed to offer the practical software training that was once offered in class in a hybrid teaching model.

The written lessons

The written lessons cover a group of twelve laboratory lessons (presented on the Table 2) and focus on exercises that hold key ProModel and Systems Simulation concepts in order to ensure a successful learning process. The written lessons follow a standardized structure: first the requirements of the lesson are presented, the model is named, the locations are created, the entities are created, the processing and routing logics are created, an arrival logic is created for the entities, final setups are made, the final model is run and its results are analyzed.

The amount of activities in every laboratory varies sometimes from a few single activity to many more integrated and complete activities. As an example, the first lessons follow a more detailed approach that makes use of the graphical programming tool "Logic Builder". Some practices incentive the students to try and type some of the codes necessary for the simulation model. This approach was used to give the students more confidence in their abilities, and also to make the model building process more dynamic and streamlined. In the lessons where the students were encouraged to type the

programming logic, a tool known as "Compiler" was introduced to help students check for syntax errors in their codes.

The guide describes in detail a total of fourteen exercises divided into twelve individual lessons. All the written guides are rich with graphic and written instructions that will conduct the students in a step-by-step process of simulation model construction. The lessons have an average eighteen pages long, and the lessons combined sum up to two hundred and seventeen pages. The final edition of the lessons can be found on APPENDIX B.

The video lessons

After the written lessons were finished, a set of videos were created to complement the learning experience. These videos follow the step-by-step guides in order to offer a more dynamic approach to the transmission of knowledge. The videos follow the same model construction order that is presented on the written lessons, making it possible to combine both methods to obtain a more complete educational experience.

Each video represents one exercise, thus a total of fourteen videos were created. The videos show a live recording from the models' construction process, and are enriched with graphical aids, and also with a voice narration to make the whole process clearer to the students. The videos are available in HD (720p) and the format chosen for them is "mp4". This format has a good compression rate, is compatible with most computers and media players, and also can be easily distributed using a website or burned in DVDs. The videos have an average duration of 11 minutes, and they add up to a total of 2 hours and 47 minutes. The videos are available in a DVD located at the APPENDIX C of this research.

With the video lessons, individual recordings for each exercise are also provided as a Camtasia® format archive. With these files it would be easier and faster to make alterations to the video lesson in the future, if necessary.

The proposed syllabus

Once the course methodology has changed from a hybrid to a complete online approach, the syllabus had to be modified to in order to be compatible with the new system. The main alterations on the document were concentrated on the sections related with face-to-face meetings and attendance. The current syllabus calendar has to be designed from scratch because it has to reflect a 17 week plan distribution of activities that students have to follow, however part of the new syllabus is suggested without the details of each calendar that will be worked by the professor teaching the online modality. APPENDIX D show these suggestions.

Student evaluation

After the completion of the creation of the written guides and video lessons, three students that were currently enrolled on the Masters in Technology program at Eastern Illinois University and that had never taken the Systems Simulation course were selected to evaluate the first six lessons of the new learning program.

The students were requested to build the models described on the first six lessons of the lessons' guide. During the process, they had access to the course's textbook, to the written and video guides, and also to a computer with ProModel®. After the students finished the required lessons, their models were compared to what was expected as a final result, and they were also required to fill an evaluation form for each of the completed exercises. The used evaluation survey form is available on APPENDIX E.

After the evaluation forms were collected, the students' answers were compiled and analyzed. Their suggestions were useful to identify some phrases and steps that could be misinterpreted and lead to unwanted final results. Overall, the students were very satisfied with the lessons construction, and were able to obtain the desired results for all the evaluated exercises. Their most frequent complaint was with the way in which a few steps were described in the written guide. Their suggestions were considered, and a few alterations were made on the material. The compilation of the students' evaluations is available on APPENDIX F.

Conclusions

The main goal of this research was to develop a method to teach the concepts and practical applications behind the Systems Simulation technology, using a completely online method for the deployment of the lessons. The lessons would have to be created using a system that would allow the students to learn more independently from the instructor and with more time flexibility. The hypothesis of this research has been proved to be correct, therefore online lessons that would allow students to successfully learn about Systems Simulations and ProModel® software were created

The developed material will make the knowledge of this course available to a broader range of students and will help to overcome the traditional physical and time barriers that could stop some students from learning about this subject. This research will allow the elimination of regular physical meetings between students and instructor, but are not likely to eliminate the contact between the two parts once it is still possible that the learners will have questions that will require them to contact the professor responsible for the course.

As future developments for this research two main improvements could be implemented: currently only the first video of the guide has captions, if captions were created for all the other videos then they could be also useful for hearing impaired students. Also in the future more lessons could be created following the proposed methodology, so the students could have access to more advanced functions of ProModel®.

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APPENDIX A

Current Syllabus

TEC 5523: SYSTEMS SIMULATION

Spring 2013 EASTERN ILLINOIS UNIVERSITY

Instructor:	Rigoberto Chinchilla, PhD
Office:	KLEHM 4010
Phone:	217-581-8534
E-mail:	**ONLY** Use Desire2learn e-mail for course related matters

Course Description:

Numerical modeling of industrial processes and systems on digital computers. Course topics include: Problem formulation, model building, data acquisition, model translation, validation, and analysis of results.

Text: Harrell, Ghosh, and Bowden, "Simulation Using Promodel". McGraw-Hill, New York, 2012, Third Edition.

Objectives: Be able to:

- Describe key terminology and aspects of modeling used in simulation.
- Describe what simulation software is and how it is used to model processes and systems.
- Apply simulation techniques to specific complex situations.

- Interpret the results generated by simulation software.
- Use the results in management decision making.

Prerequisites: You have the pre-requisites to take this course IF AND ONLY IF:

- You have the ability to work independently, SELF-GUIDED and willing to use office hours when needed.
- You do NOT expect the instructor figures out that you need help with your readings, HW and course materials. Whenever you feel you are behind or need help please schedule an appointment with your instructor (Phone, Chat, and Messenger etc.) ASAP.
- You do not wait until one/two days before a HW is due to start to work on it
- You do not start studying for the exam one or two days before is due

Students with Disabilities:

If you have a documented disability and wish to discuss academic accommodations, please contact the coordinator of the Office of Disabilities (581-6583) as soon as possible.

Evaluation:	- 2 ONLINE Midterms (150 points each, one of them)	300 Points
	- Final Exam	100 Points
	- Homework (8 HW assignments @50 points each)	400 Points
	- 12 Process Simulations Laboratories	250 Points
	- Final project	250 Points

Your grade will be based on the total points "**X**" earned from the total as follows:

|X ≥901: A|; | 801 ≤ X ≤ 900: B|; | 701≤ X ≤ 800: C|; |600 ≤ X ≤ 700: D|; |X< 600:F|

Student Responsibilities:

- Study the PowerPoint (PP) presentations Posted on Desire2learn
- Use office hours to clarify your doubts about the PowerPoint presentations before the midterm (Same apply for your Textbook lectures)
- Bring questions about the PP presentations to the review time we will have at the beginning of each face-to-face meeting.
- Any document posted on Desire2Learn will be considered equivalent to be "handed out" to the student. Student can't claim ignorance of any material posted ONLINE
- The last page of this syllabus gives a detailed calendar of activities from the semester, use this page to keep up with all course activities.
- ONLINE And COMBINED COURSES are for students with a self-guidance attitude, that means They :
    - read the materials carefully every week and ask questions at the end of every week or use office hours to clarify the material
    - start working in the HW with anticipation : A cramming style is not part of their strategy
    - plan ahead course activities
    - are personally responsible to obtain the work assigned, discussion information, laboratories, lectures, handouts, etc. on their own if you miss any of these activities.

- Access the class web site (Desire2learn) at least once a week to keep up to date on specific class activities, download assignments review lectures etc.
- Be prepared by reading assigned materials, preparing appropriate questions, completing assigned projects, etc.
- Participate in all class activities.
- Participate through active listening, personal and group discussions, asking and answering questions.
- Use a professional attitude in your approach to the class, fellow classmates, and instructor; class written and oral work, tests and other activities. This will become part of your preparation for professional employment in technology fields.
- You are personally responsible to obtain the work assigned, discussion information, laboratories, lectures, handouts, etc. on your own if you miss any of these activities.
- ProModel software activities will be part of some HW assignments
- Do NOT e-mail your HW unless you have written approval from your instructor: HW should be dropped at the appropriate Desire2learn drop box.

Attendance

Policy: Attendance in our context means to submit all assignments and exams on time, if your "attendance" is perfect you might be granted to a final curve adjustment at the end of the semester typically done by the instructor. If you fail to have a perfect attendance you will NOT be granted with this curve grade adjustment if there is one.

Cheating/Plagiarism policy:

- Homework, exams, and laboratory workshops should be **done individually** (unless otherwise explicitly allowed by the instructor in writing). Failure to work individually will be considered as cheating and/or plagiarism. Cheating and/or plagiarism are not appropriate at anytime and can result in dismissal from the class and a report to the university authorities.
- Plagiarism/cheating in a homework or laboratory workshop will result in a zero grade the first time, the second time will be reported to the EIU authorities and will be penalized with a zero grade on the course. Cheating in an exam will be penalized with a zero grade on the course and report to the EIU authorities

Homework Policies:

a) Homework should be done individually, use office hours if you need help. Homework fulfills best the objectives when students do not cram.

b) Late Homework will be accepted with penalties applied as follows:

   a. Any late HW (within 24 hours late) 20% reduction (automatic) penalty from your grade

   b. HW submitted more than 24 hours late will have zero credit.

COURSE CALENDAR

The instructor reserves the right to change the syllabus at any time due to special circumstances. In case of a change this will be announced at least with 5 days of anticipation and in writing via e-mail.

APPENDIX B

Written Lessons Guide

EASTERN ILLINOIS UNIVERSITY

ProModel Lessons Guide

Systems Simulation

TEC 5523

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INTRODUCTION

Welcome to the ProModel® lesson guide for the Systems Simulation course. The lessons contained in this material are based on the textbook used for this class "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. At the beginning of each lesson the laboratory exercise being used is indicated, and can be found in the informed book.

In order to complete the lessons with maximum efficiency and absorb all the necessary knowledge, the student must identify the laboratory section being used on the lesson and then read it on the textbook (except for the lesson 1, once it was specifically made for this course). After this step the student can consult the corresponding video for each of the lessons to help on the model construction and result analysis phases. If even after following these steps some information is unclear, please contact the instructor of this course as soon as possible.

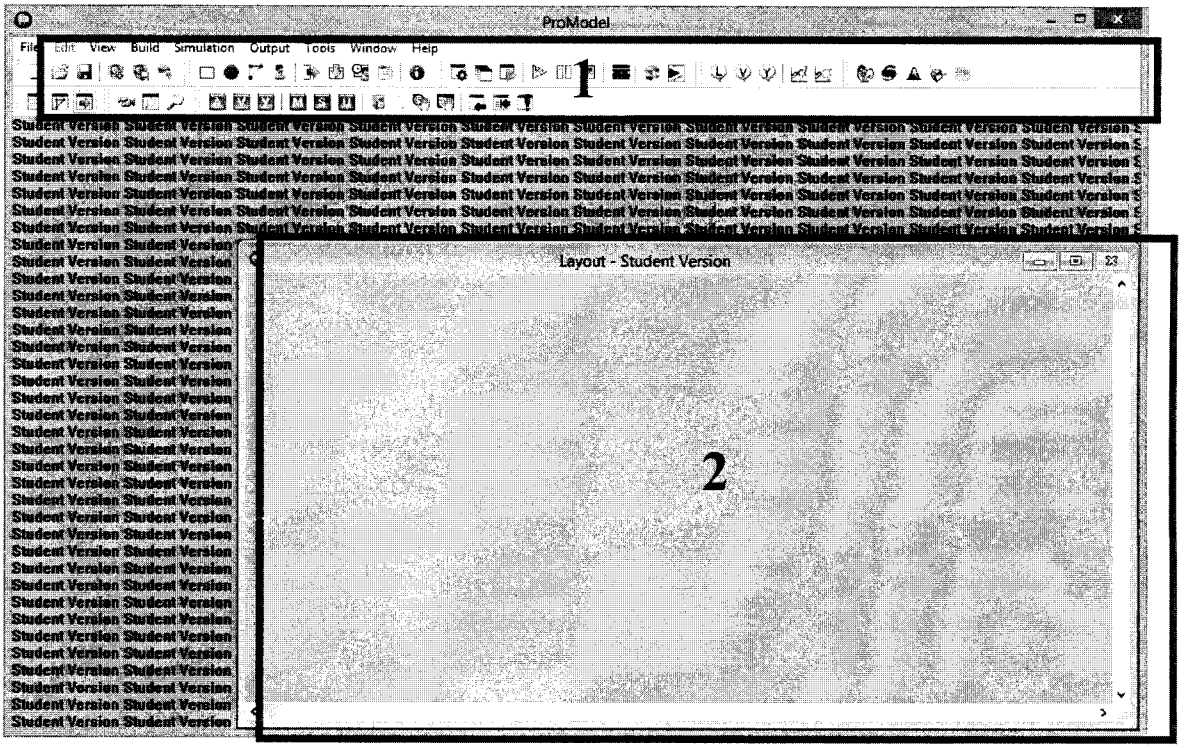
Follow the instructions presented here and on the videos carefully, and your outcomes should not be different from the ones expected. Remember to save your model as often as possible, and do not worry if some of your entity, location, variables, or attributes have different names once this will not impact your results.

LESSON 01

This first lesson has as a goal to introduce the student on the basic concepts behind the systems simulation and also on the basic functions of the system simulation software ProModel. For the purpose of this training the ProModel Student Version 8.2 will be used, therefore it is possible that some of the commands and paths presented here are slightly different for other versions.

First of all, it is necessary that the software is downloaded and installed on your personal computer. The installation method is very straightforward and only requires that the user selects the computer folder where the software will be installed. Once the software is installed, then it is time to start our tutorial.

When executing ProModel, the user will be presented with a few windows, more specifically the "ProModel Student Version" and the "Shortcut Panel" windows, both can be closed since they do not have great importance for our first lesson. Once those windows are closed, the user will be presented with the following screen setup.

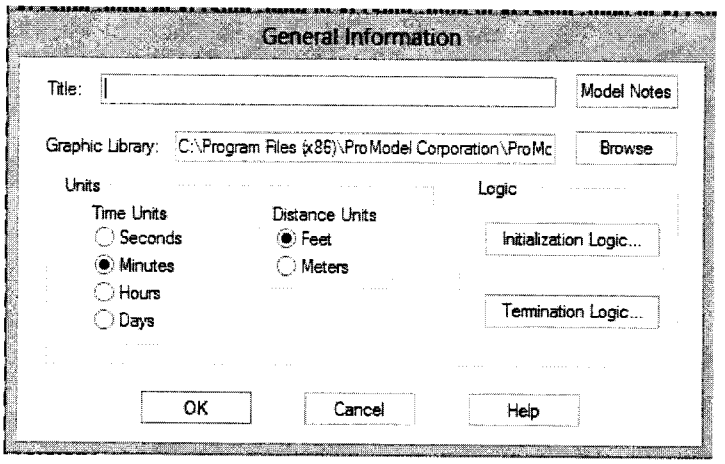


For those familiar with the common Windows software user interface it is easy to identify a few key areas of the software on the image above. The area identified as "1" is the toolbar from where all the functions from ProModel can be accessed, and the area "2" is the location where your system simulation model layout will be created. In an analogy with Microsoft Word, the area "2" would be the blank page where you would create a document.

Once the software interface has been introduced, the next steps of this lesson will guide the student on the development of a basic system simulation model using ProModel. The model will be based in a short production line setup.

Step 01 – Defining the model's file name and folder location

1.1. From the "**File**" menu, select the option "**New**". The following dialog box will show up.



1.2. On the field "**Title**" from the "**General Information**" dialog box, type a name for your model. For this example, use "**Tutorial_Your Name**" (For example: **Tutorial_Andrew**).

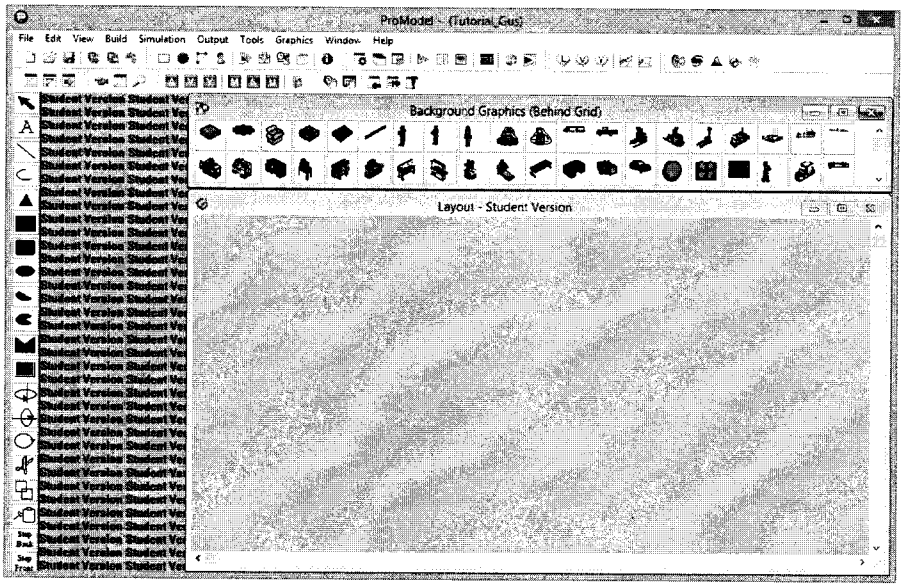
1.3. In the "**General** Information" dialog box, it is also possible to change default measuring units for your model, for this case you can leave them as they are presented.

1.4. Once all the alterations have been made, click the "**OK**" button.

Step 02 – Introducing background graphics

2.1. Select the "**Build**" menu on the toolbar, and then the option "**Background Graphics**".

2.2. Then click on the option "**Behind the grid**". You should be presented with the following screen.



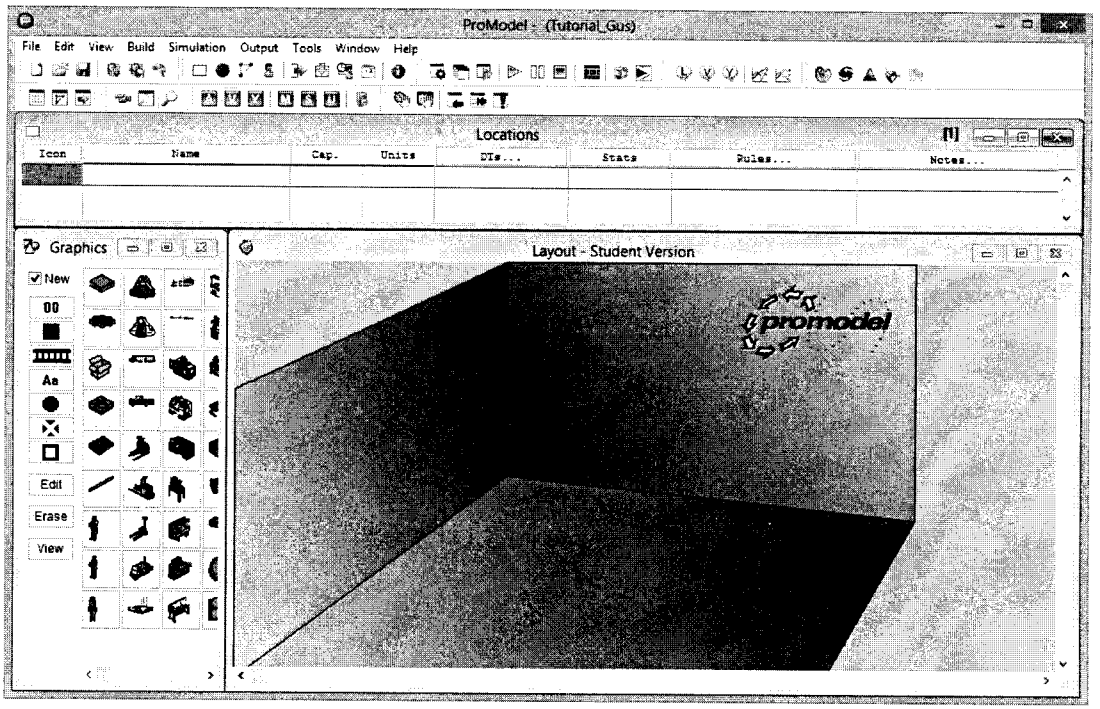
2.3. Select the menu "Edit" on the toolbar, then select the option "Import Graphic". When you do so, a window will prompt you to select an image.

2.4. Open the folder "_Samples", and select the file "Tutorialback" and click the button "Open".

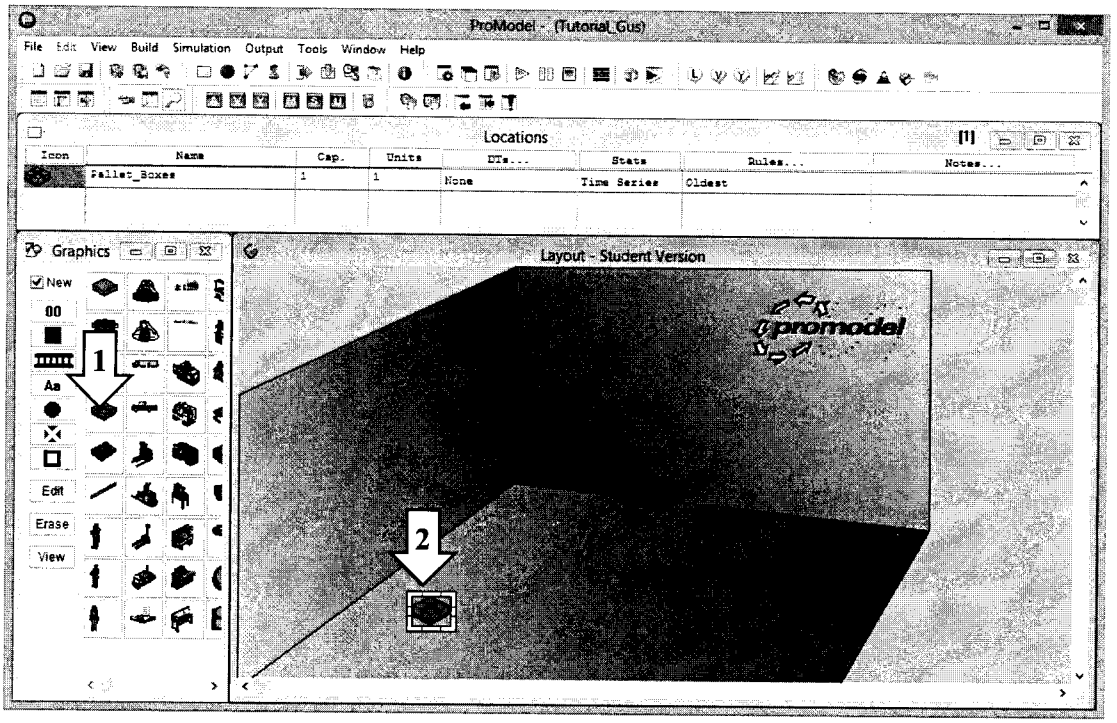
2.5. The image you just selected will show up on your layout window and can be resized to your own convenience by clicking and dragging the black squares located at the corner of the image.

Step 03 – Building Locations

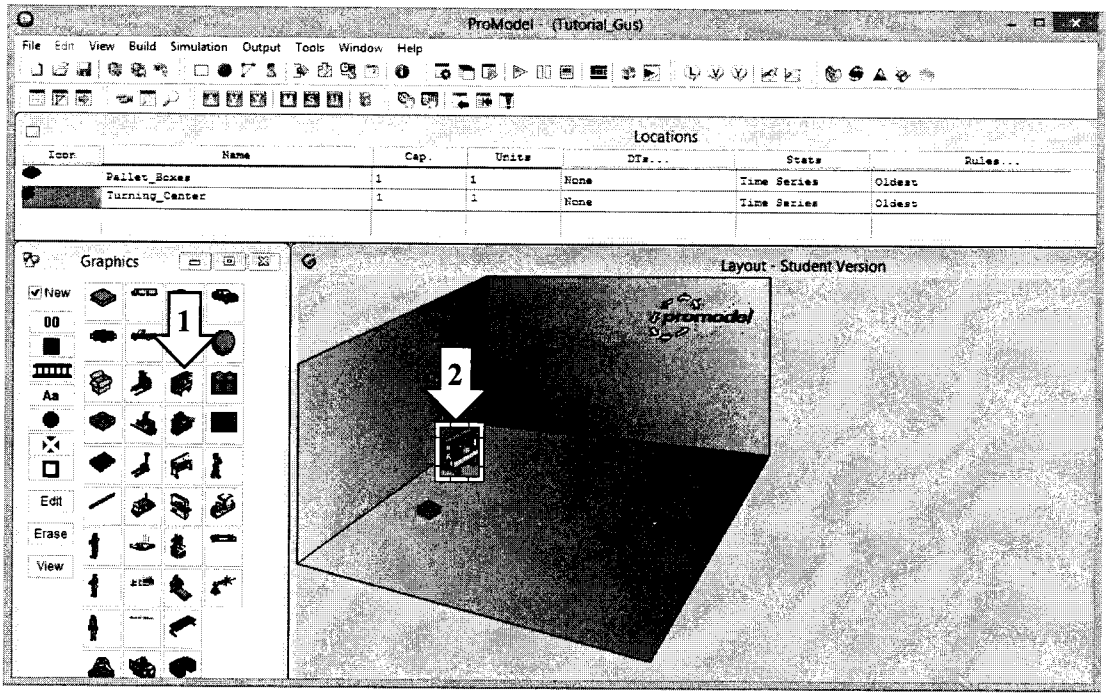
3.1. Select the menu "**Build**" from the toolbar, and then click on the option "**Locations**". You should see the following screen (notice that some of the elements used for the background creation will disappear to give room to the elements used for the "Locations" construction).



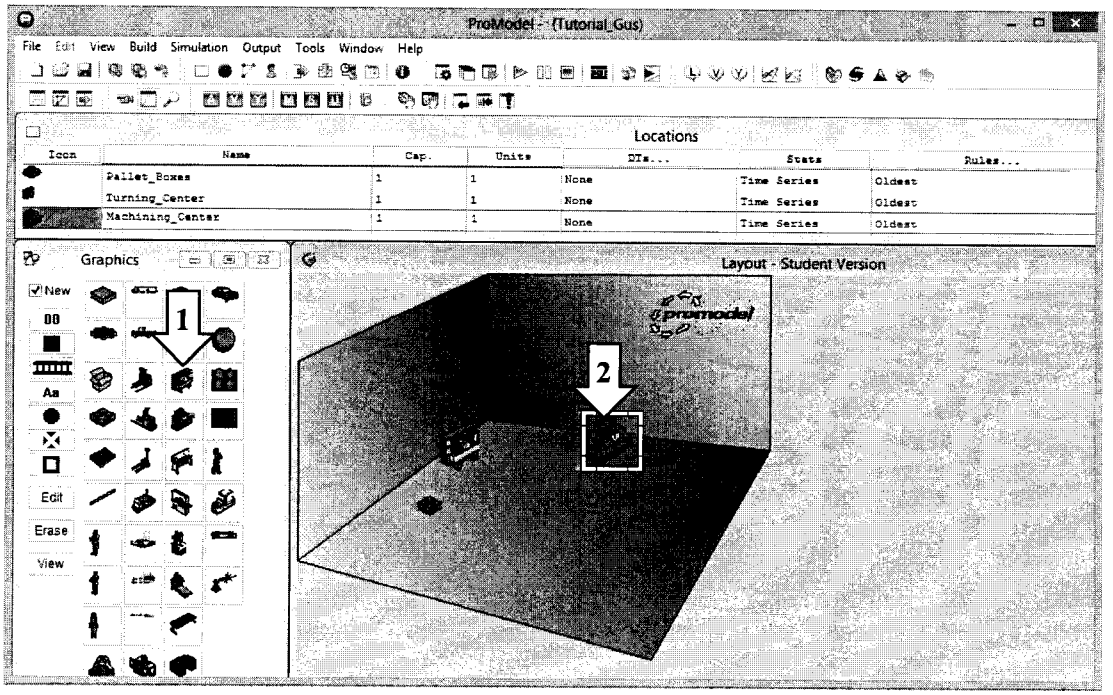
3.2. This model will be developed making use of four locations. To add the first location, on the "Graphics" window click on the first icon on the 4th row (**1**), and then click on the desired location on the layout window to place the "Location" (**2**). As shown on the following image.



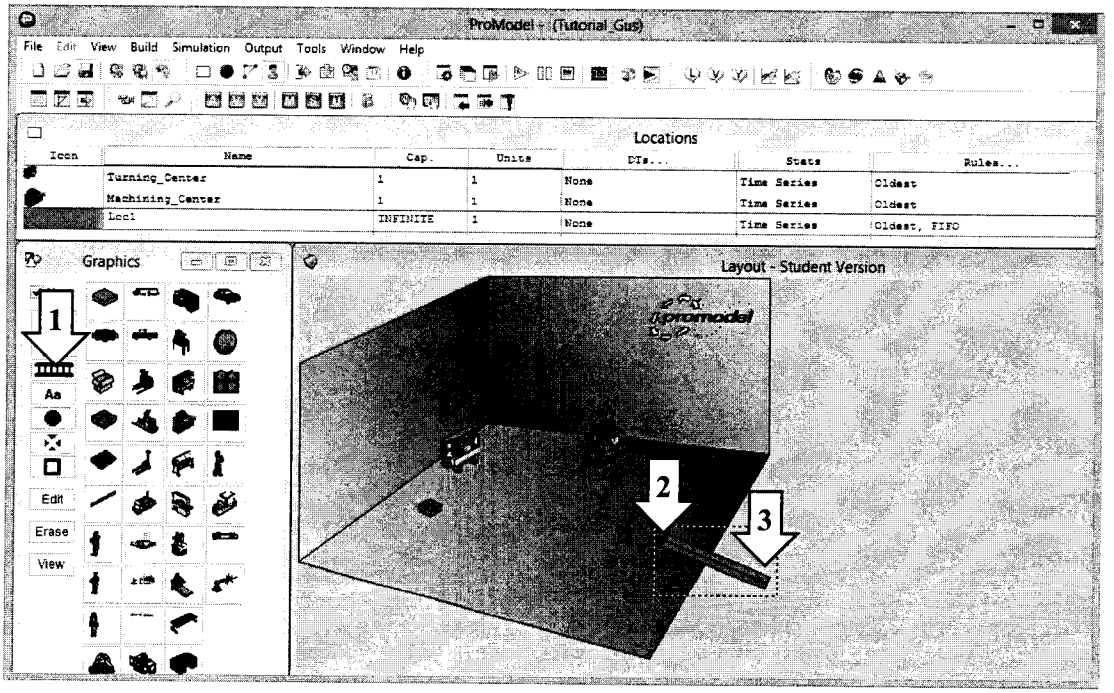
3.3. To insert the second location, click on the third icon of the third row (**1**), and then click on the desired location on the layout window (**2**), as shown on the following image.



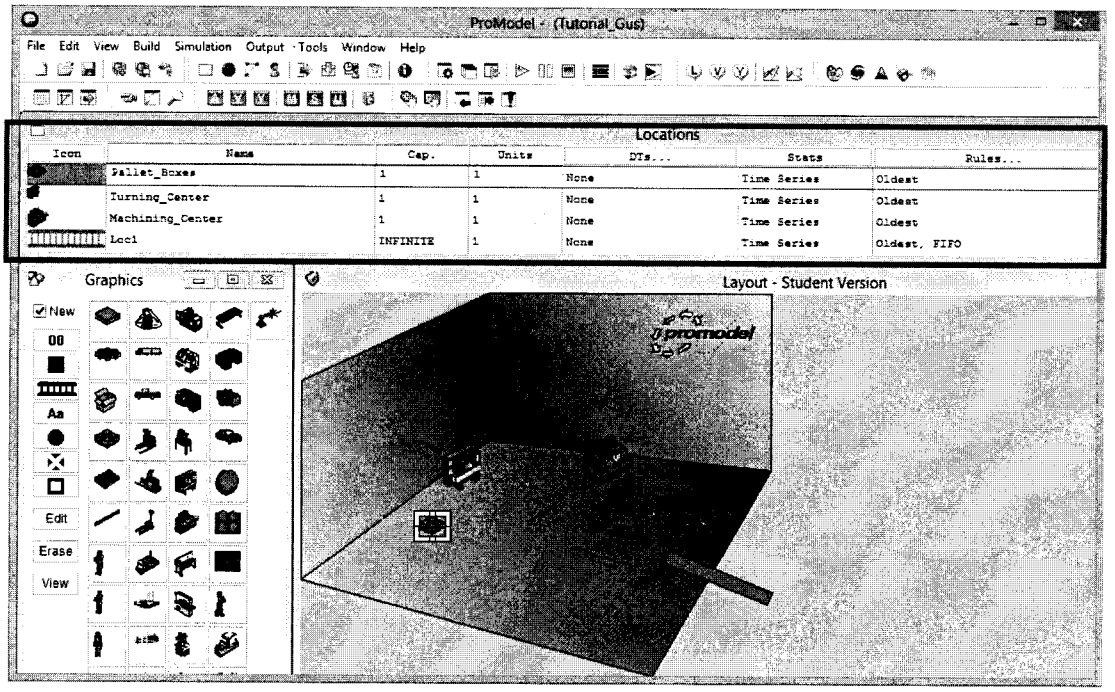
3.4. For the third location, click on the third icon of the fourth row (**1**), and then click on the appropriate location of the layout (**2**), as shown on the image bellow.



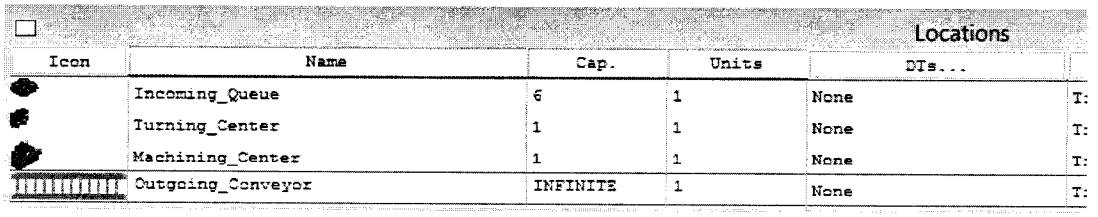
3.5. The procedure for the fourth location will be a little different. On the "**Graphics**" window it is possible to notice a column of icons on its left side. Select the third icon of this column (the one that looks like a black fence), this icon is used to create a **conveyor**. In this step we will create an outgoing conveyor, so following the image bellow: click on the "**Conveyor**" icon (**1**), then click on the layout to select the start point of the conveyor (**2**), and then right click on the location selected to be the end of the conveyor (**3**).



3.6. To name the locations: Select the "**Locations**" window (the table at the top of the layout window). The window is marked in red in the window bellow.

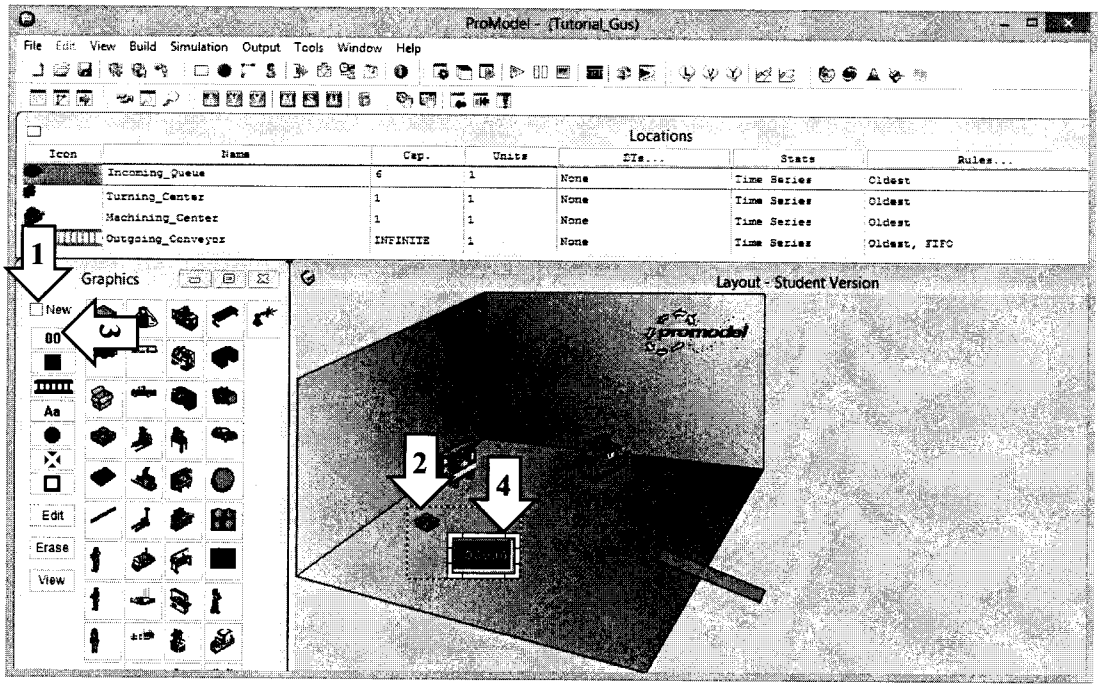


3.7. In the "**Locations**" window, change the name "**Pallet Box**" to "**Incoming Queue**", and change its capacity (**Cap.**) from 1 to 6. Next, change the name "**Loc1**" to "**Outgoing Conveyor**". Your table should look like the following.

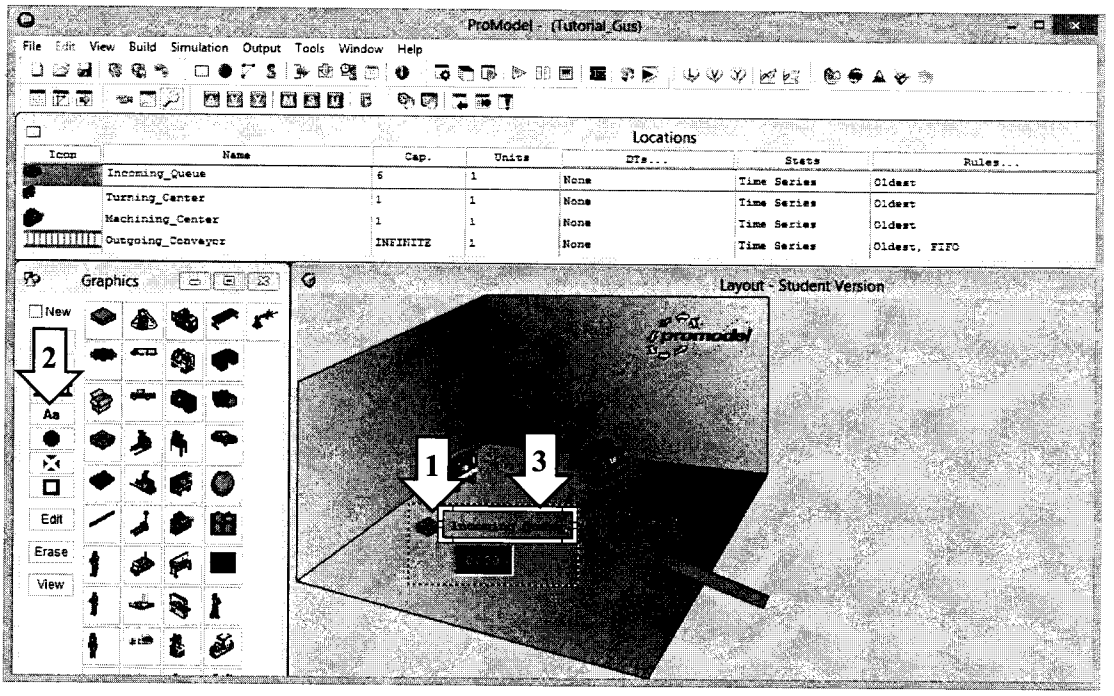


3.8. It is possible to add a counter that will show how many entities are in a location at any given moment of the simulation. In order to do so, first make sure to uncheck the "**New**" option on the "**Graphics**" window (**1**), then click on any location present on your layout window, for example your incoming queue (**2**),

click on the "**00**" button on the "**Graphics**" window (**3**), and finally click on the layout on the position desired to place the counter (**4**).



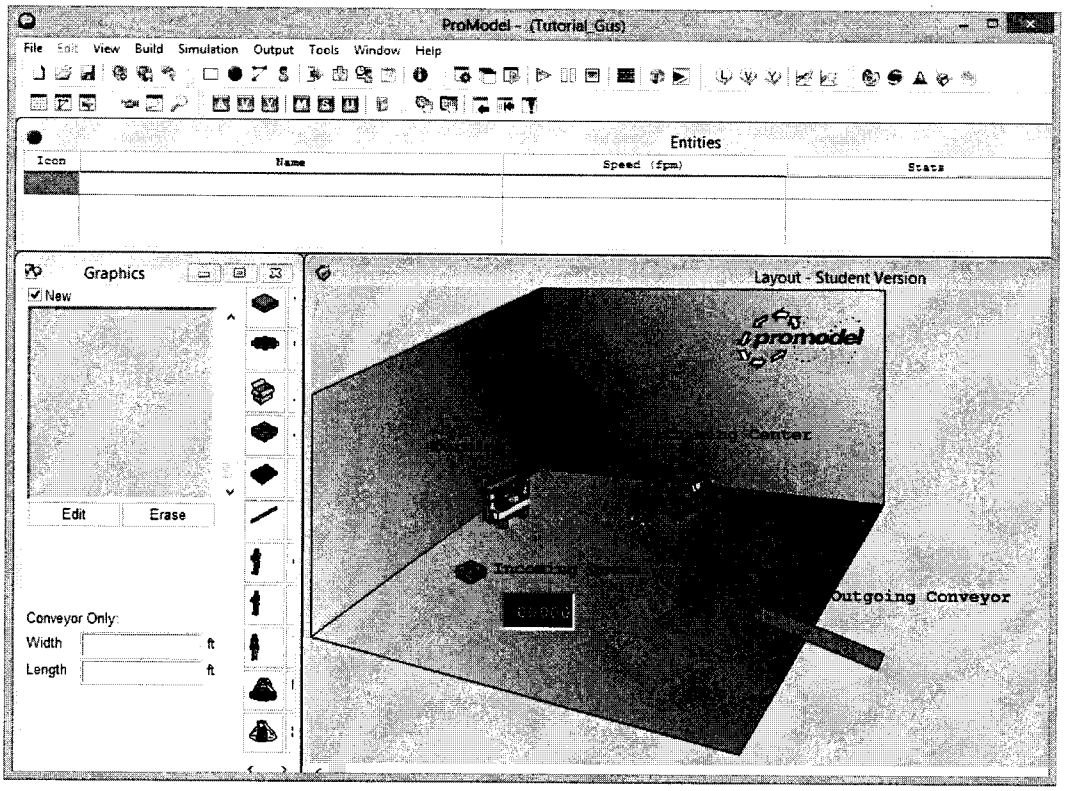
3.9. To display the location names on the "**Layout**" window, first make sure that the "**New**" option is unchecked on the "**Graphics**" window. Next, click on a location on your layout window (**1**), click on the button "**Aa**" on the "**Graphic**" window (**2**), and finally click on the "**Layout**" window to place the location name (**3**). The procedure is shown on the image bellow. Repeat the process for all the locations.



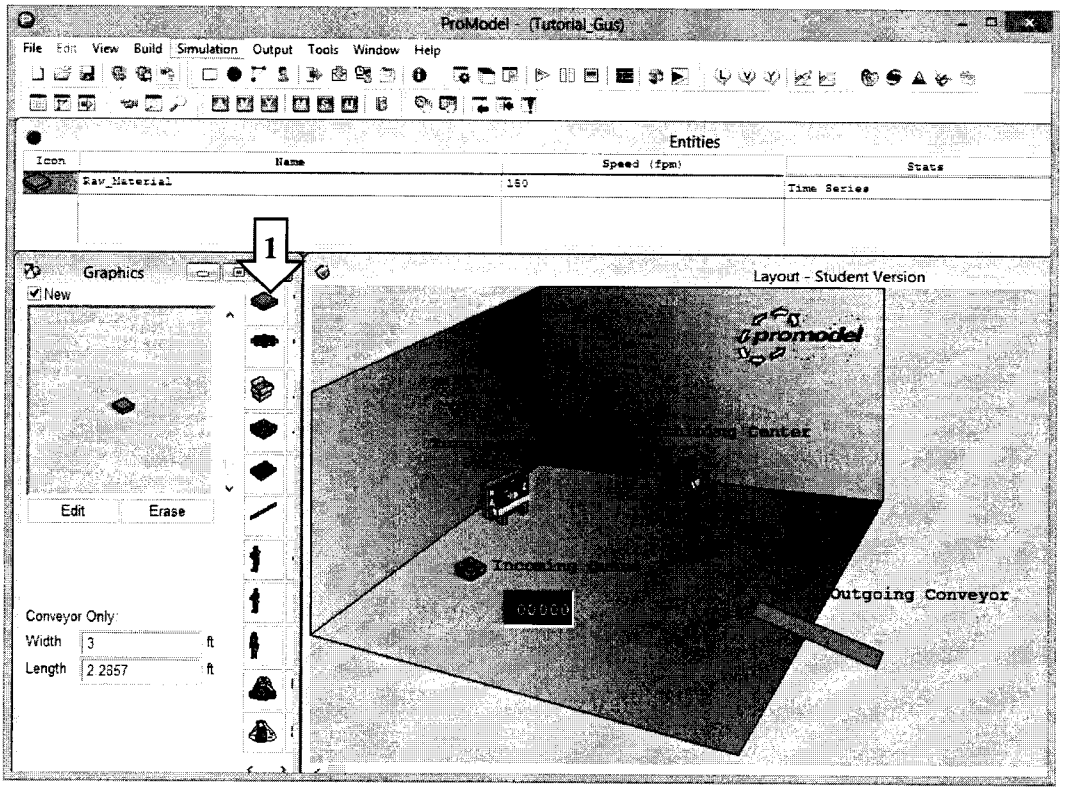
3.10. VERY IMPORTANT: The "**Locations**" table should only contain four rows. If for some reason your table contains more locations than the specified number, they should be deleted. To delete a location, select the desired row on your "**Locations**" table, click on the menu "**Edit**" and select the option "**Delete**".

Step 04 – Adding Entities

4.1. To add entities to your model, first select the menu "**Build**" on the toolbar and then click on the option "**Entities**". The ProModel user interface should be as the following image.



4.2. On the "Graphics" window, select the first icon from the list (**1**).



4.3. Next, click on the button "Edit" on the "Graphics" window. Then click on the button "Color" and pick a green color from the palate and hit ok. Next click on the "Dimensions" button and insert the value 5 and hit "OK".

4.4. On the table "Entities" change the name "Raw_Material" for "Product", in the same way we did for the locations on the step 3.7.

Step 05 – Add Path Networks

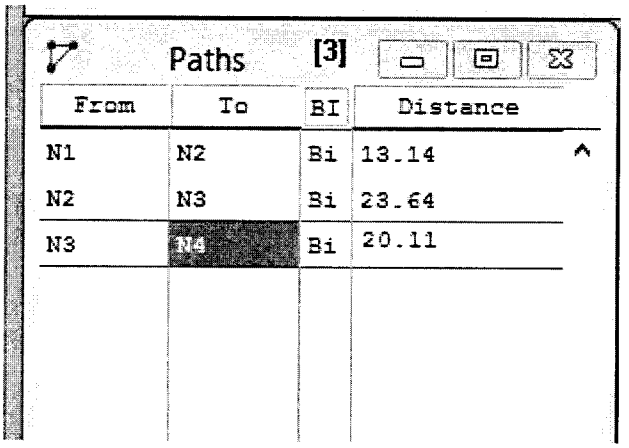
5.1. This step is critical to the success of the model, and the failure at following the steps here presented very carefully can result in modeling errors, which could create the need of completely redo this step.

5.2. From the toolbar, select the menu "**Build**" and then "**Path**".

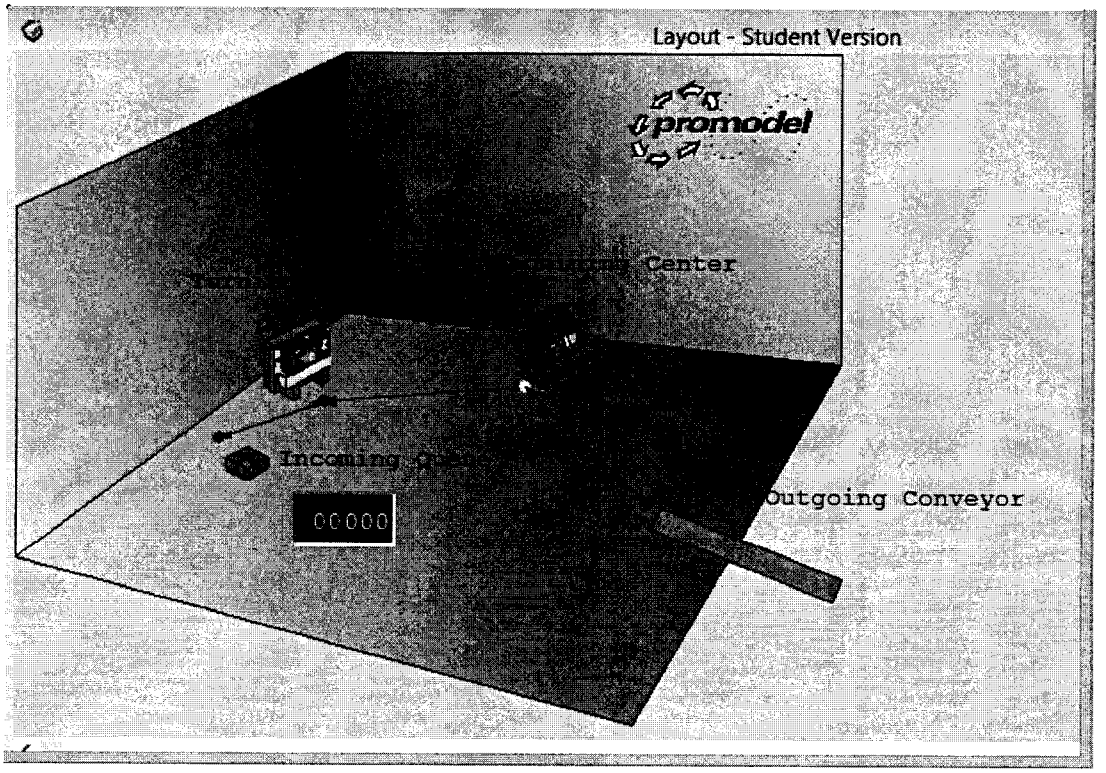
5.3. Now place the pointer of your mouse close to the location "Incoming Queue" and left click, then move the mouse to the next location (Turning Center) and repeat the procedure but instead of clicking with the left button of your mouse, use the RIGHT one. This is very important because this will allow the creation of an interface between the Path and the locations. The beginning and end of a Path segment is called a "Node".

5.4. Now place your cursor on top of the last node, click with the left button and move your cursor to the location "Machining Center" and perform a right click. This will create another path segment and another node. Now repeat the same process from the "Machining Center" to the "Outgoing Conveyor".

5.5. The "Paths" table on the left of the ProModel window should look like the following, and if it does not then delete the segments and redo this phase.

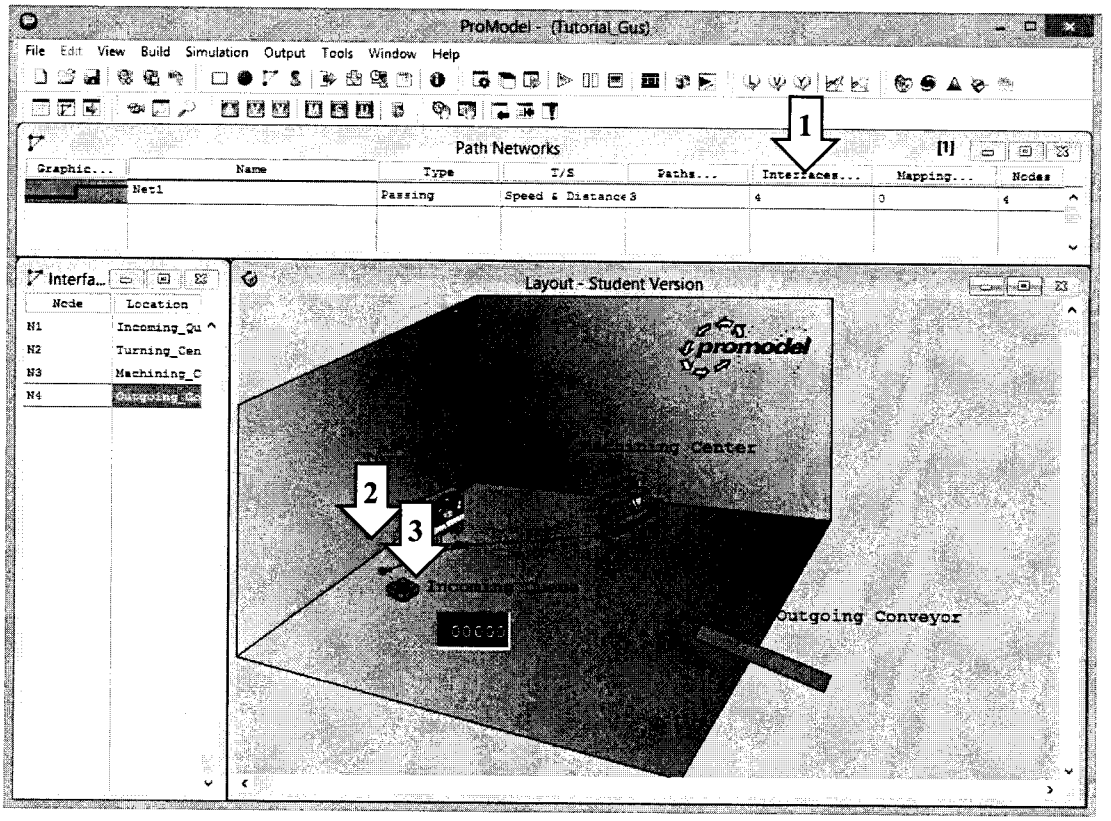


5.6. At this point, your model layout should be looking similar to the one presented below. If your model does not look like it, please review the steps taken by you.

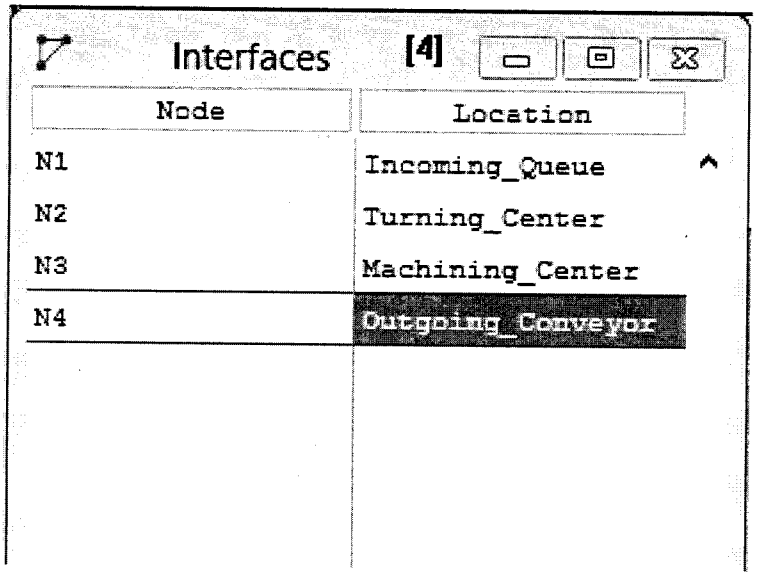


5.7. On the top table "**Path Networks**", click on the button "**Interfaces**" (**1**) then place your cursor on top of the first **Node** created on your Path until a **PLUS SIGN** appears on the right side of your cursor (**2**). Once that happens, left click on the

node and left click on the location most close to it (**3**). This will create an **INTERFACE** between the Path network and the Location. As shown on the image below.



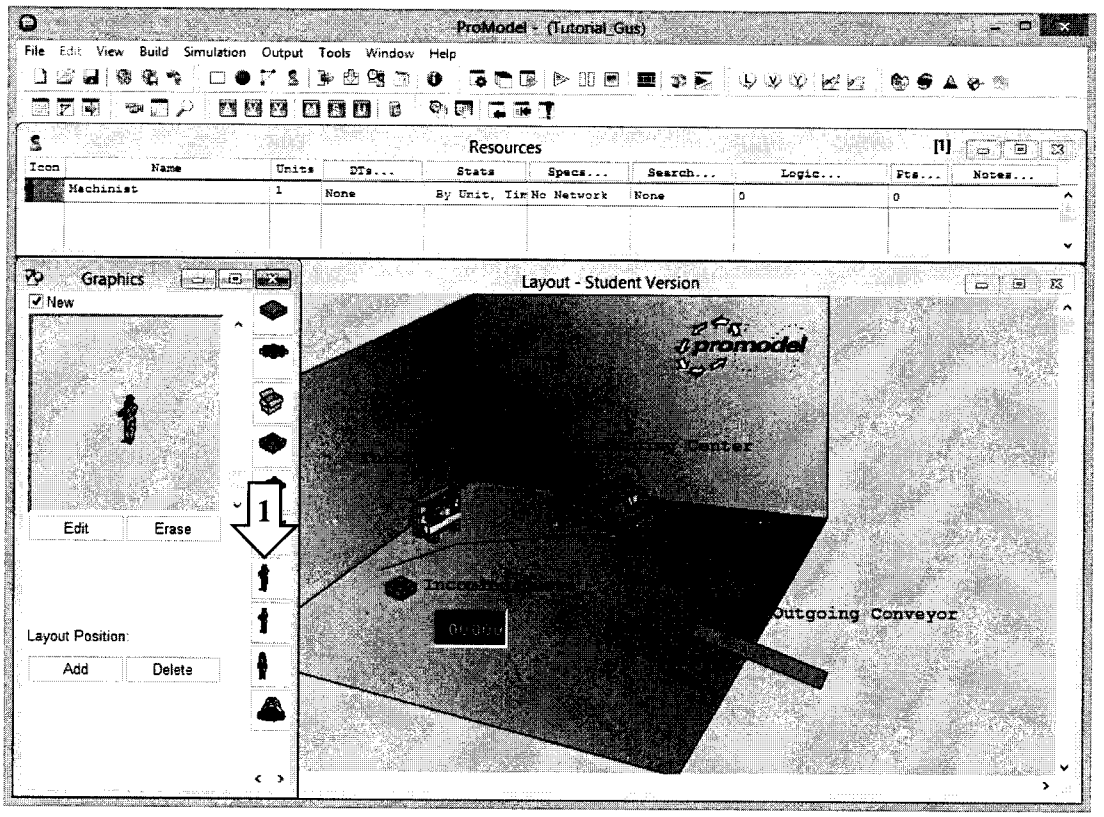
5.8. Repeat the 5.6 procedure to the other nodes on your path network. Your "**Interfaces**" table (located at the left side of the screen) should look as the following.



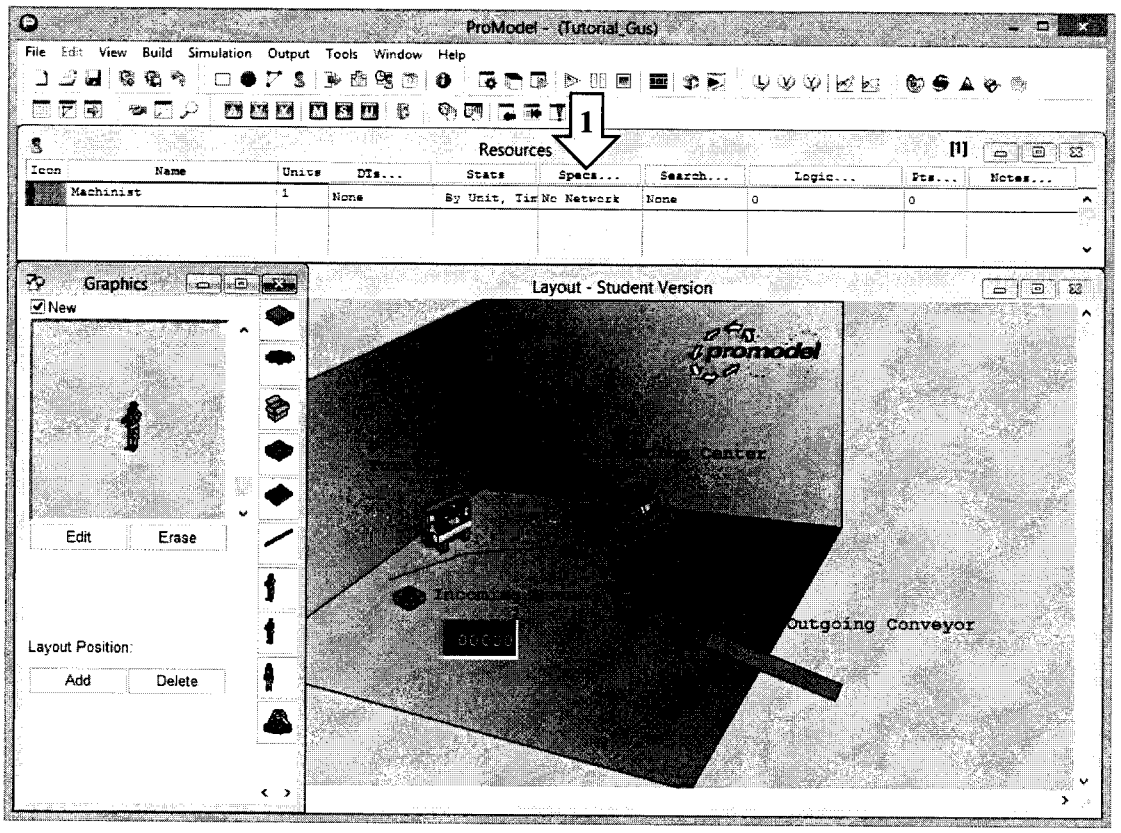
Step 06 – Building Resources

6.1. Select the menu "**Build**" from the toolbar and then the option "**Resources**". For this model we will need a machinist, but it is important to understand that not all simulation models will demand a resource to work.

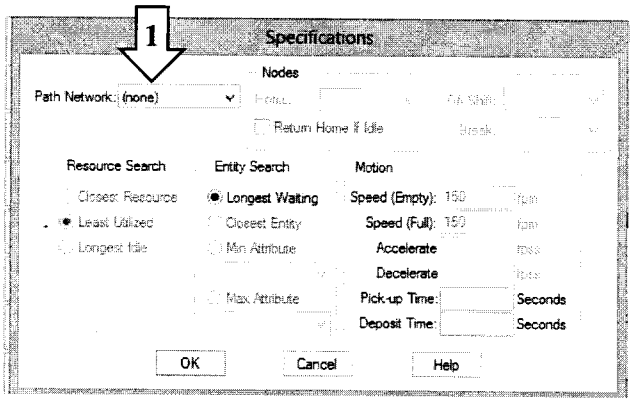
6.2. Select the seventh icon from the "**Graphics**" table on the left side of the window (**1**), as shown on the following image.



6.3. For this model, the resource will move from one location to the other; therefore it must be assigned to a "**Path**" where it will move on. In order to do so, on the top table "**Resources**" click on the "**Specs...**" button (**1**) and a dialog box will show up.



6.4. On this dialog box, click on the option for the "**Path Network**" and then select "**Net 1**" (**1**).

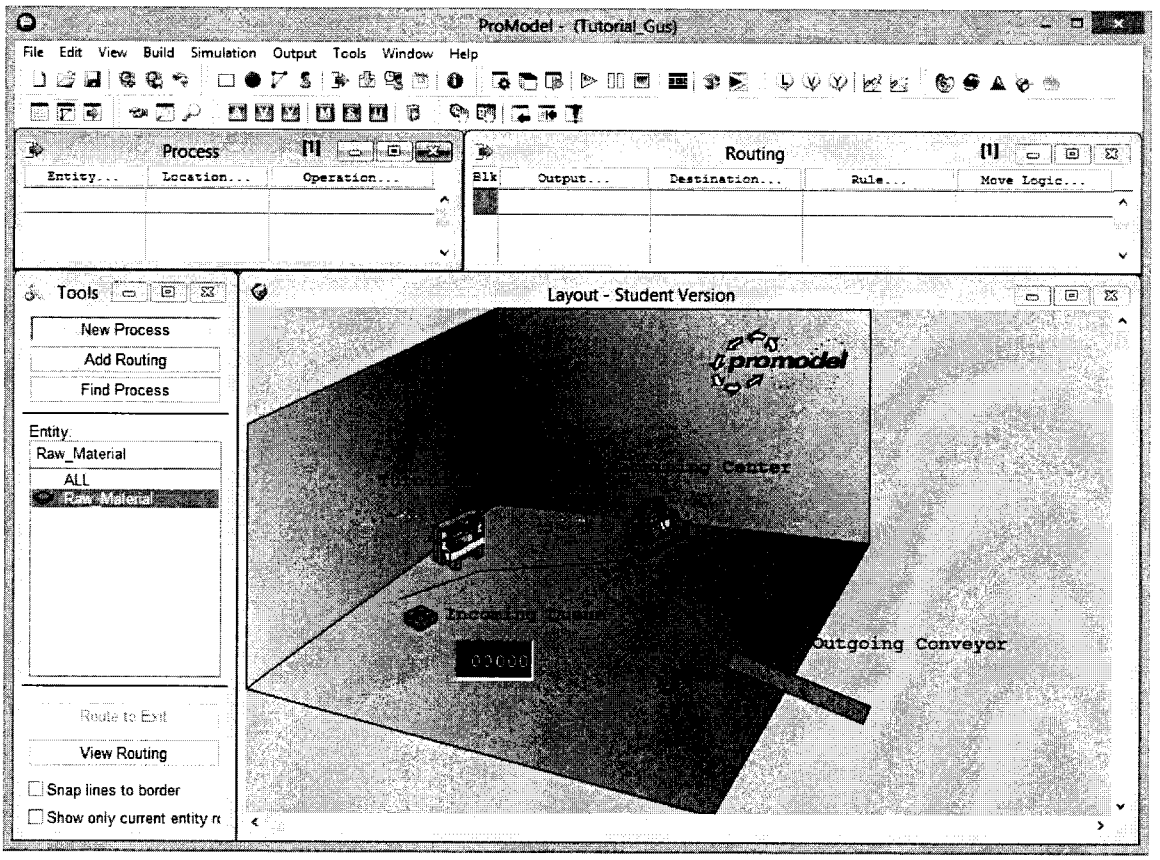


Step 07 – Adding Process Logic

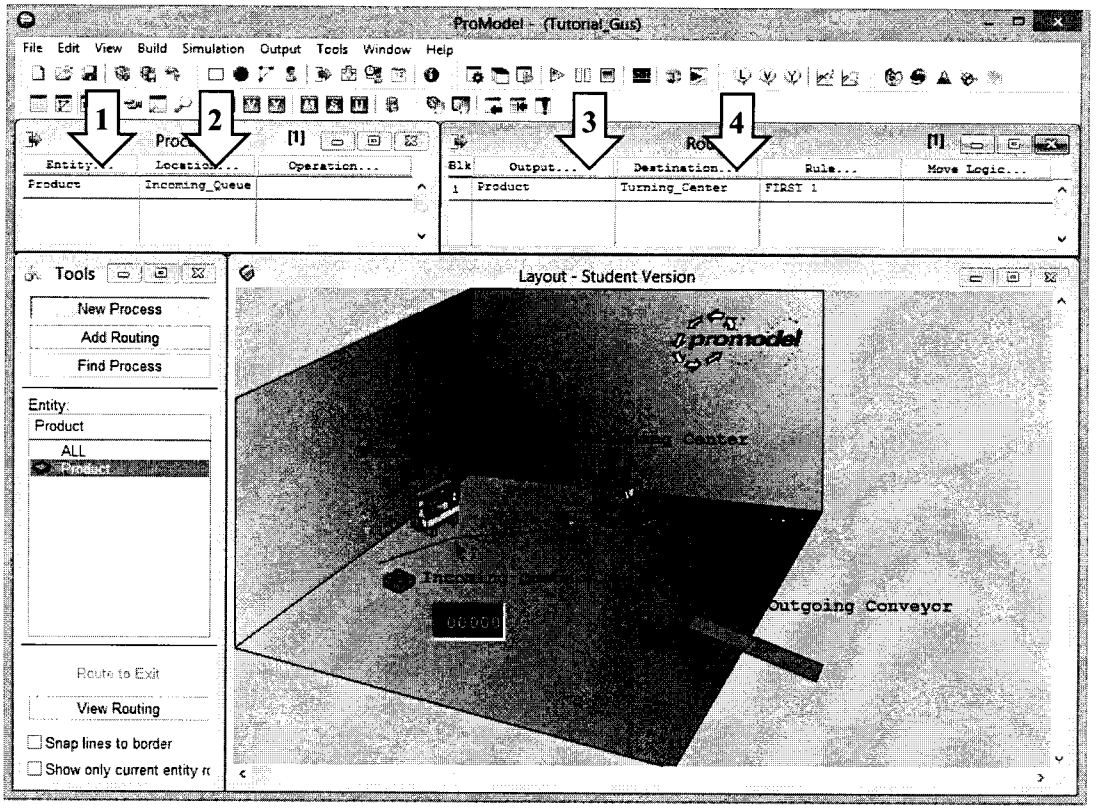
7.1. You must be careful during this step of the process! This part of the model constructions is very similar to programming, but it is also simpler than most programming languages.

7.2. The overall logic of the model is that the entities (**Products**) will be moved from the **Incoming Queue**, to the **Turning Center**, then to the **Machining Center**, and then to the **Outgoing Conveyor**. The resource **Machinist** will be responsible for moving the material along the manufacturing line. Some of the processes have a fixed processing time and other processes have their processing time statistically described by a probability distribution (the **Machinist** does not take exactly the same time to process the material, therefore we will work with averages and distributions)

7.3. Select the menu "**Build**" from the toolbar, and then click on the option "**Processing**". The following user interface should be displayed.

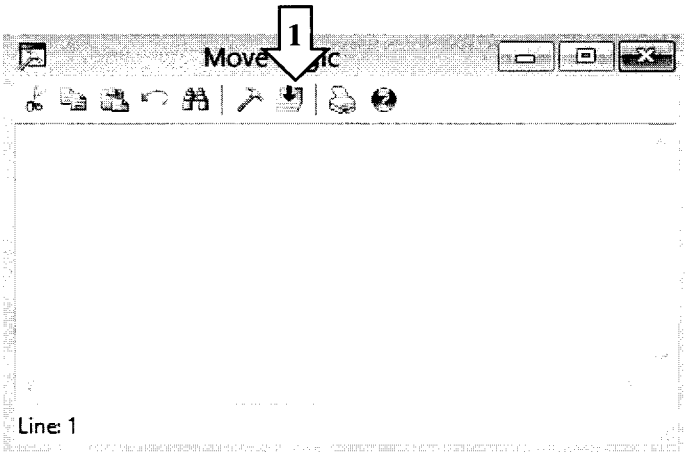


7.4. On the **Process** table at the top of the screen, click on the button "**Entity**" and then select "**Product**" from the dialog box (**1**). Still on the same table, click the button "**Location**" and then select "**Incoming_Queue**" from the dialog box (**2**). Then, on the "**Routing**" table, click on the "**Output**" button and select "**Product**" from the dialog box (**3**), and finally click on the "**Destination**" button and select "**Turning_center**" from the dialog box (**4**).



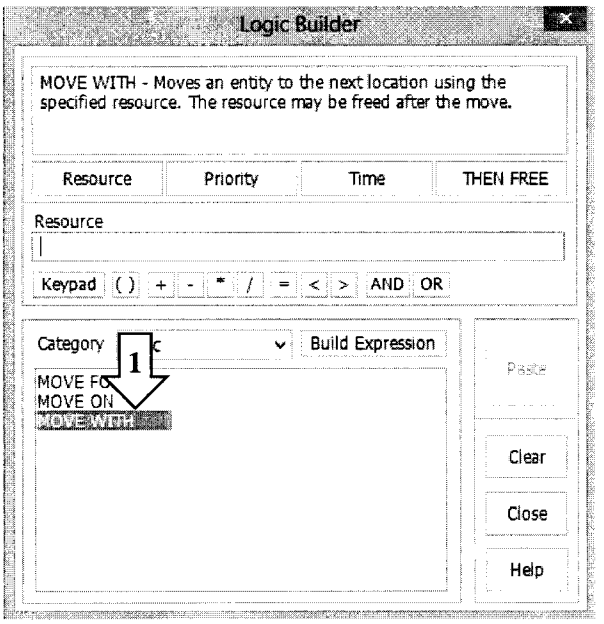
7.5. When you perform this step, you are telling ProModel that the entity "**Product**" that is located at the location "**Incoming_queue**", will keep the same identification name (**Output**) and will be moved to a destination (another location) called "**Turning_Center**".

7.6. After the past step is completed, click on the "**Move Logic**" button on the "**Routing**" table and a dialog box will open. On the "**Move Logic**" dialog box, click on the "**Hammer**" icon (**1**).

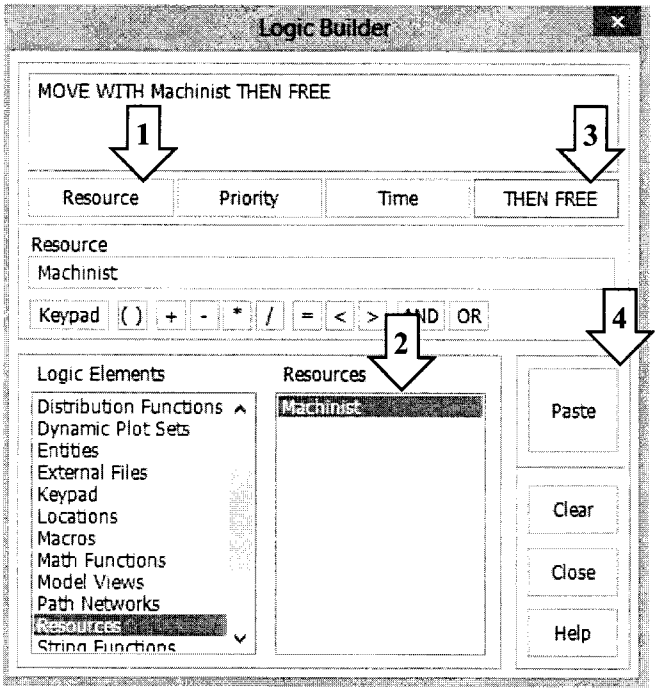


7.7. After you follow the past instruction, you will be taken to the "**Logic Builder**". This is a basic method to build your simulation logics on ProModel; after you get more comfortable with the syntaxes and structures of the software you can type your own logic.

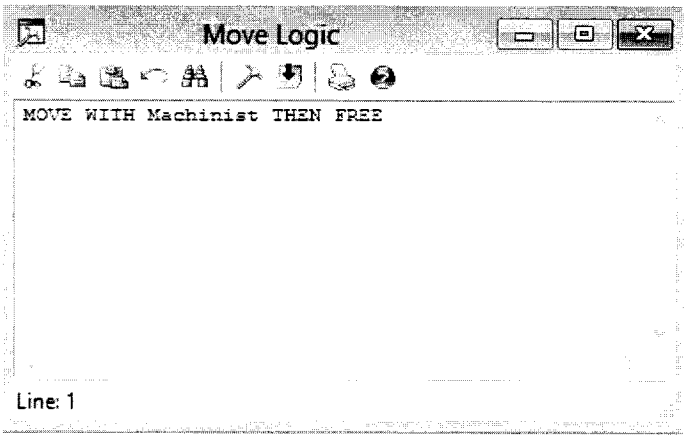
7.8. On the "**Logic Builder**" select the command "**MOVE WITH**" (**1**).



7.9. Then click on the button "**Resource**" (**1**) and select the "**Machinist**" from the "**Resources**" box (**2**). After following these steps, click on the button "**THEN FREE**" and click on the "**Paste**" button (**4**). Close the "**Logic Builder**" window.



7.10. The "**Move Logic**" window should look like the following.

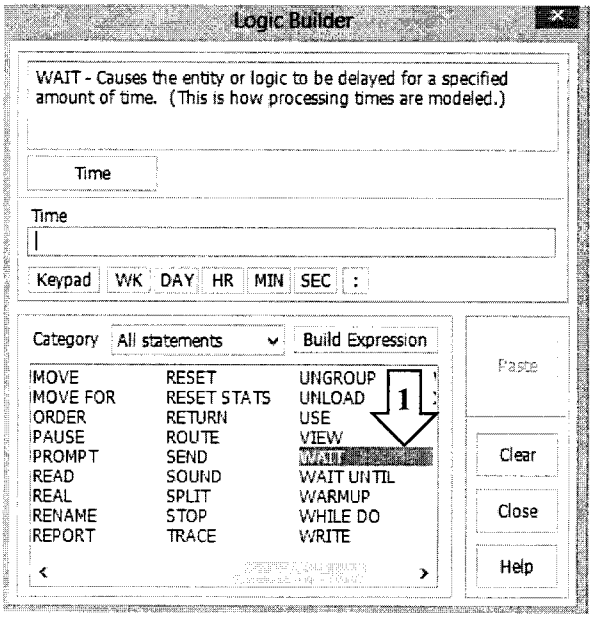


7.11. With this logic, you are telling the software to move the entity with the resource "**Machinist**" and then free the resource to complete any other duty if requested.

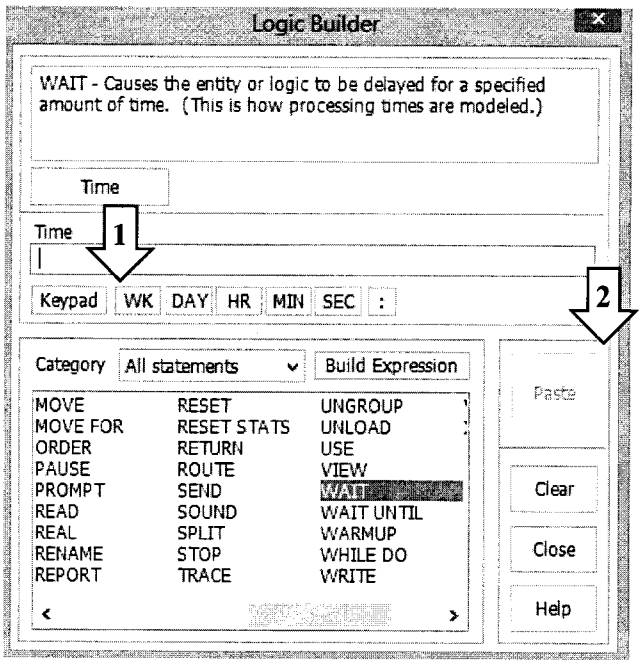
7.12. On the "**Process**" table, click on the "**Product**" on the "**Entity**" column and hit the enter key. This you add another row to your "**Process**" table.

7.13. With the second row selected, click on the "**Entity**" button and select "**Product**" from the dialog box. After this click on the "**Location**" button and select the "**Turning_Center**", and then click on the "**Operation**" button. This will cause the "**Operation**" window to open, and on that window click on the "**Hammer**" icon, which will cause the "**Logic Builder**" to open.

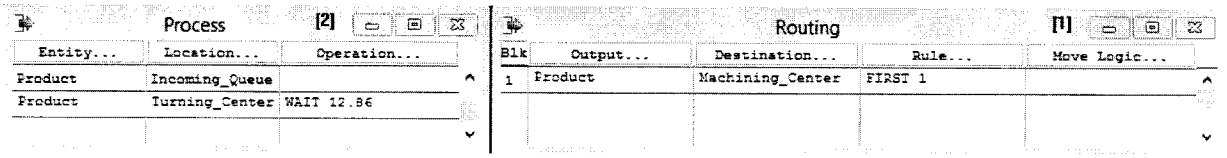
7.14. On the "**Logic Builder**", select the command "**WAIT**"



7.15. Then click on the button "**Keypad**" (**1**), and enter the value **12.86**. Click on the button "**Paste**" (2) and close the window.



7.16. On the "**Routing**" table, click on "**Output**", select "**Product**". Then click on "**Destination**", select "**Machining_center**". Your table should look as the one in the following image.

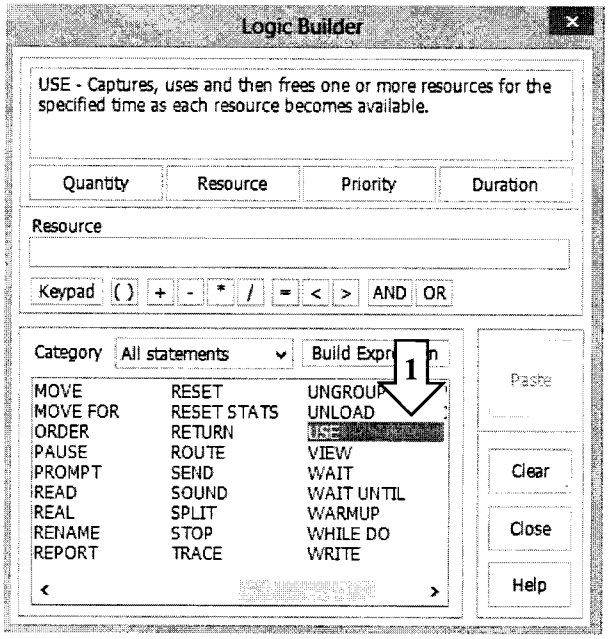


7.17. On the "**Routing**" table, click on the "**Move Logic**" button and click on the "**Hammer**" button and repeat from steps 7.3 to 7.7.

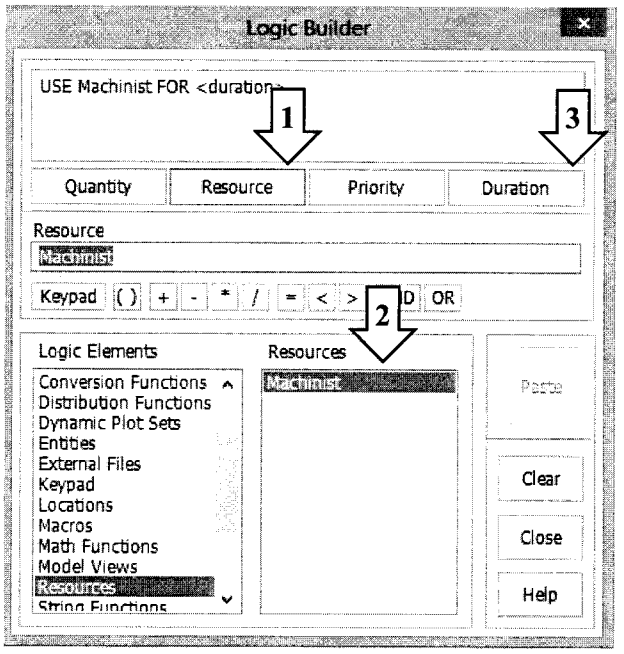
7.18. On the "**Process**" table, click on the second row and hit the enter key to create a new row.

7.19. On the third row, click on the button "**Entity**" and select "**Product**"; click on "**Location**" and select the "**Machining_Center**". Then click on the button

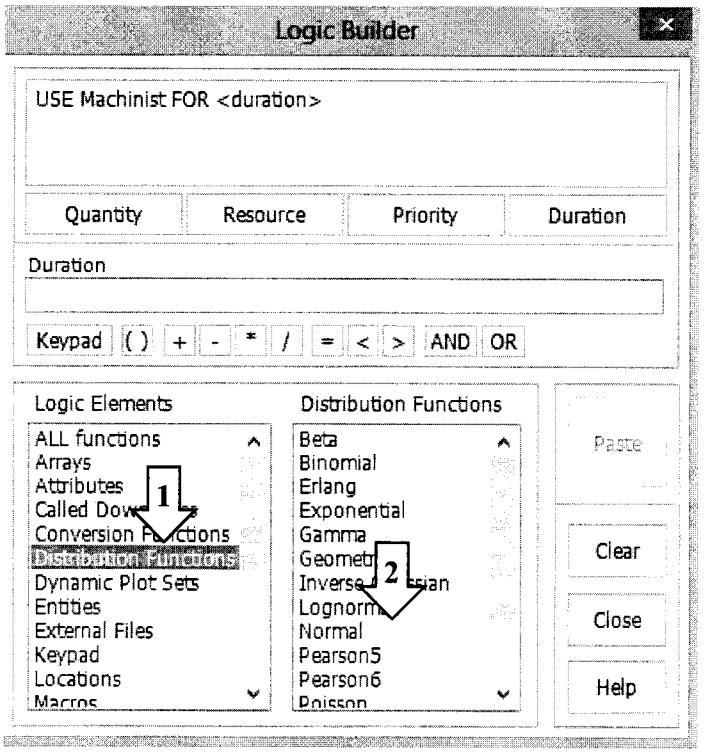
"**Operation**" and on the "**Hammer**" icon. On the "**Logic Builder**" window, select the command "**USE**" (**1**).



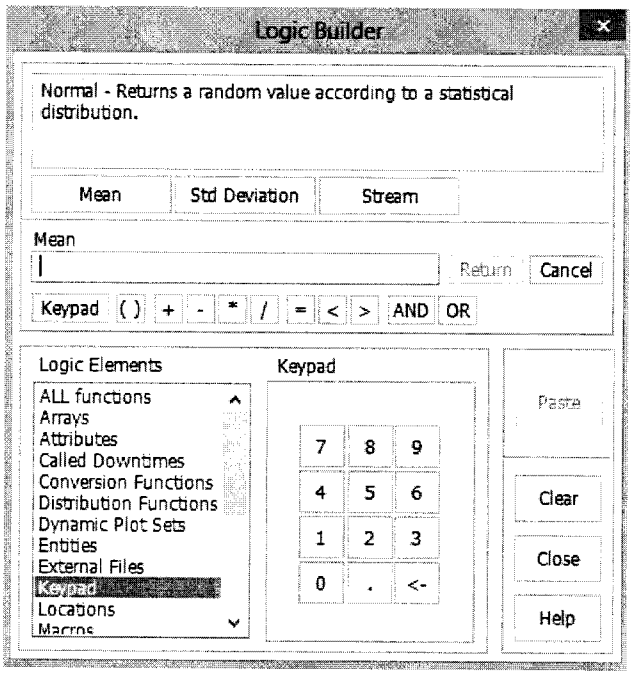
7.20. Then click on the "**Resource**" button (**1**), select the "**Machinist**" (**2**), and click on the "**Duration**" button (**3**).



7.21. On the "**Logic Elements**" box, select "**Distribution Functions**" (**1**), and on the new box select "**Normal**" (**2**).

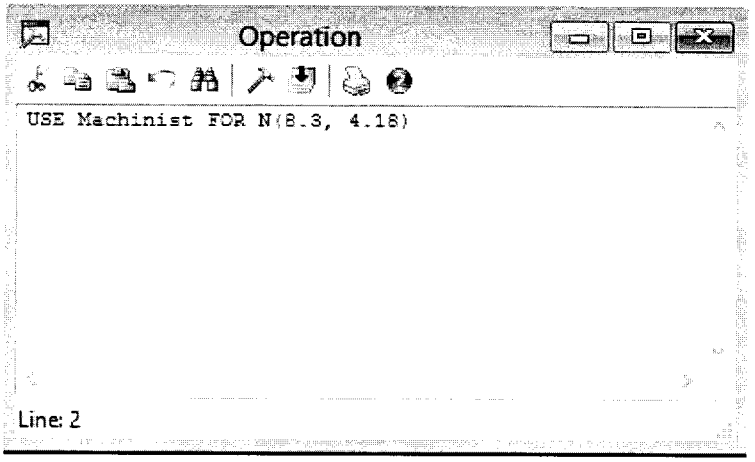


7.22. The following screen should be displayed.



7.23. Click on the "**Mean**" button and enter the value 8.3 on the text box. Click on the button "**Std Deviation**" and enter the value 4.18 on the text box. Next click on the button "**Return**", and finally click on the button "**Paste**". Close the Logic Builder.

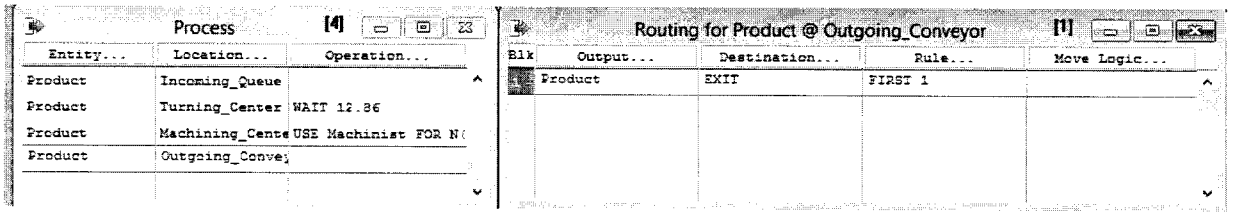
7.24. The "**Operation**" window should look as the following one.



7.25. Close the "**Operation**" window. Then on the "**Rounting**" table click on "**Output**", select "**Product**". Click on the "**Destination**" button, and select the "**Outgoing_Conveyor**". Still on the routing table, click on the button "**Move Logic**" and repeat the steps 7.3 to 7.7.

7.26. Insert a new row on the "**Process**" table. With the new row selected, click on "**Entity**" and select "**Product**". Next click on "**Location**" and select "**Outgoing_Conveyor**".

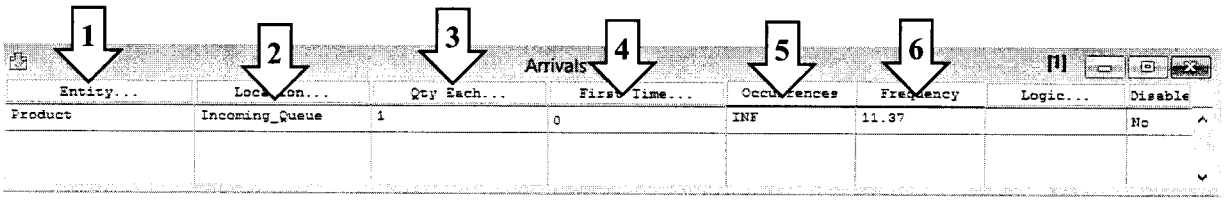
7.27. On the "**Routing**" table, click on "**Output**" and select "**Product**". Then, click on "**Destination**" and select "**Exit**". This indicates that the entity will leave the system. Your table should look like the following.



Step 08 – Building Arrivals

8.1. Select "**Build**" from the toolbar, and then click on "**Arrivals**"

8.2. On the "**Arrivals**" table click on the button "**Entity**" and select "**Product**" (**1**); click on the button "**Location**" and select "**Incoming_Queue**" (**2**); change the value under "**Qty Each**" to **1** (**3**) (meaning that one entity will arrive each time); On the "**First Time**" change the value to **0** (**4**) (meaning that the first entity will arrive at the beginning of the simulation); On the "**Occurrences**" type in **INF** (**5**) (meaning that the supply of entities is endless); change the value under "**Frequency**" to **11.37** (**6**) (meaning that an entity will arrive each 11.37 minutes).

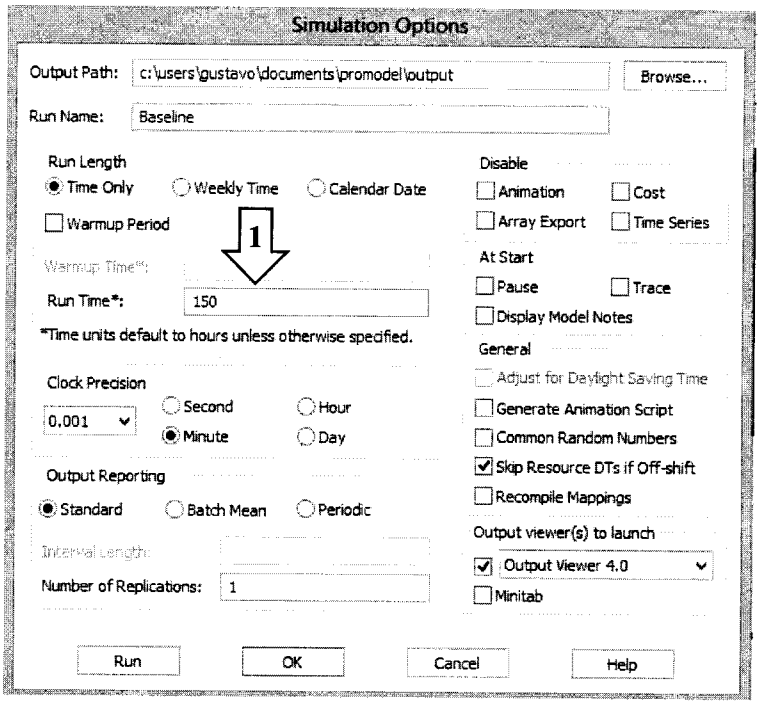


Step 09 – Setting Options, Saving the Model and Running

9.1. Save your model. (File > Save)

9.2. Select "**Simulation**" from the toolbar, and then click on "**Options**"

9.3. Change the "**Run Time**" to 150 (**1**). Meaning that the simulation will represent a period of 150 hours. Hit the button "**Ok**".



9.4. Select "**Simulation**" from the toolbar, and click on "**Save and Run**". Your model should start running.

Step 10 – Results

10.1. After the end of your simulation, the simulator will ask if you want to see the results of your simulation. Click on "**Yes**".

10.2. You should be presented with a report containing information about the components of your model: Entities, Locations, and Resources.

10.3. Analyzing the report, answer the following questions:

What is the percentage?

Machinist is in use _____

Machining center is in use _____

Turning Center is in use _____

Outgoing Conveyor is in use _____

Incoming queue is full _____

Outgoing conveyor is full _____

Outgoing conveyor is empty _____

Suggest at least three changes that can be implemented in order to optimize the process.

LESSON 2

Exercise 1

This first exercise from the second lesson will be based on the Laboratory 2.1 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the concepts of locations, entities, arrivals, processes, and routings will be used.

The exercise is described by Harrel, Ghosh & Bowden (2012) as follows:

"Customers visit the neighborhood barbershop Fantastic Dan for a haircut. The customer inter-arrival time is exponentially distributed with an average of 10 minutes. Dan (the barber) takes anywhere from 8 to 10 minutes (depending on the amount of gossip he has to share with that customer), uniformly distributed (mean and half-width of 9 and 1 minute respectively) for each haircut. This time also includes the initial greetings and the transaction of money at the end of the haircut. Run the simulation model for one day (8 hours or 480 minutes). Find these answers:

a. About how many customers does Dan process per day?
b. What is the average number of customers waiting to get a haircut? What is the maximum?
c. What is the average time spent by a customer in the salon?
d. What is the utilization of Barber Dan?"

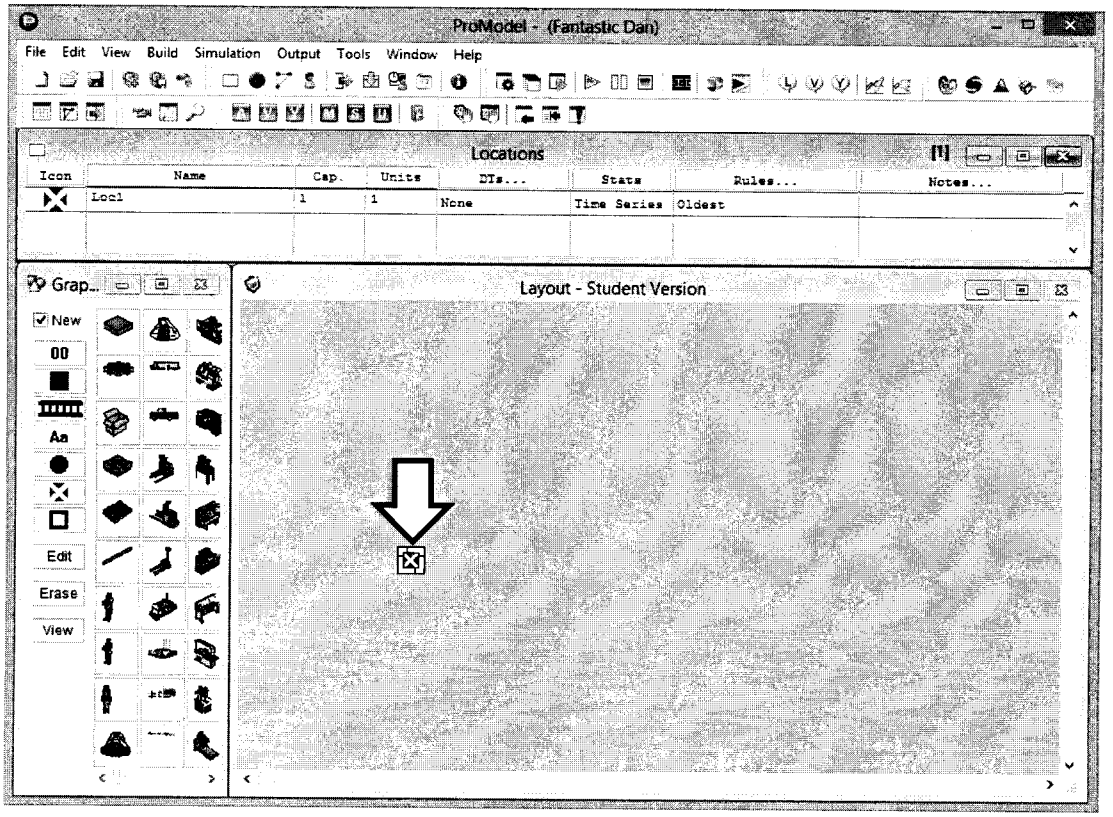
1. Creating a new model

1.1. At the toolbar select "**File**" and then click on "**New**" Change the title of the model to "**Fantastic Dan**". Click "**Ok**" to close the dialog box.

2. Creating Locations

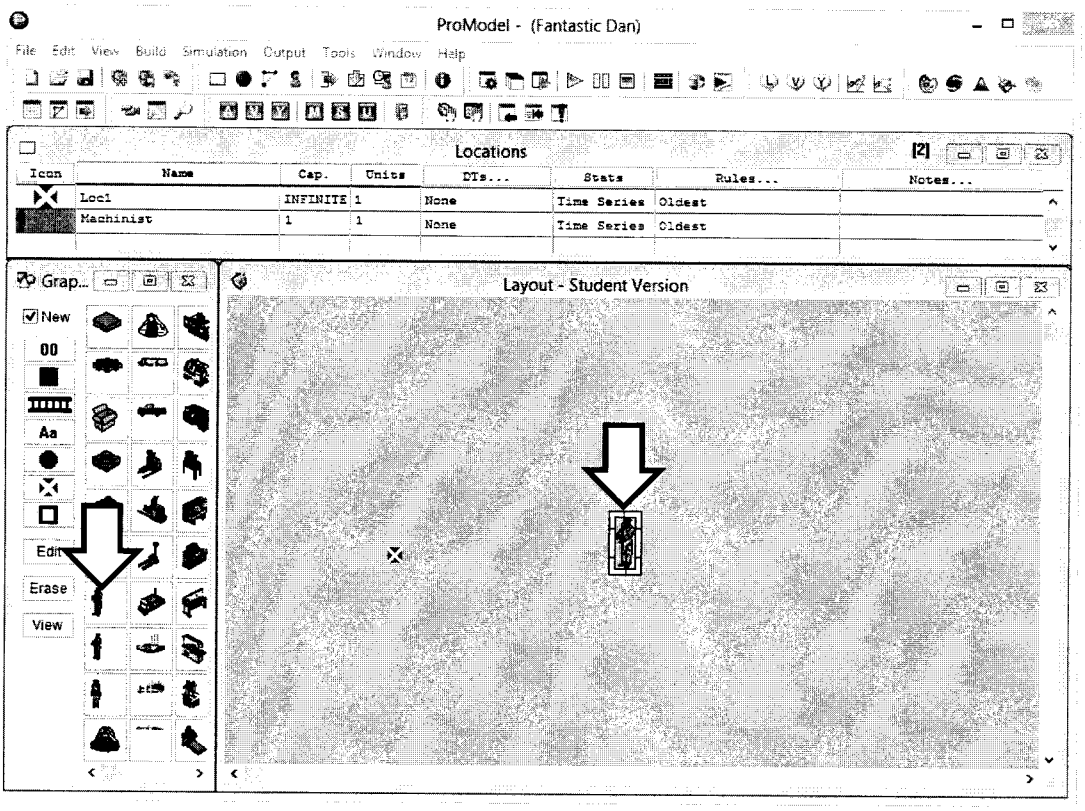
2.1. To create the locations, select the option "**Build**" and then click on "**Locations**".

2.2. Click on the icon at the left of the "**Graphic**" window that is a red square with a white x (**1**), and then click on a location on the "**Layout**" window to create the first location (**2**).



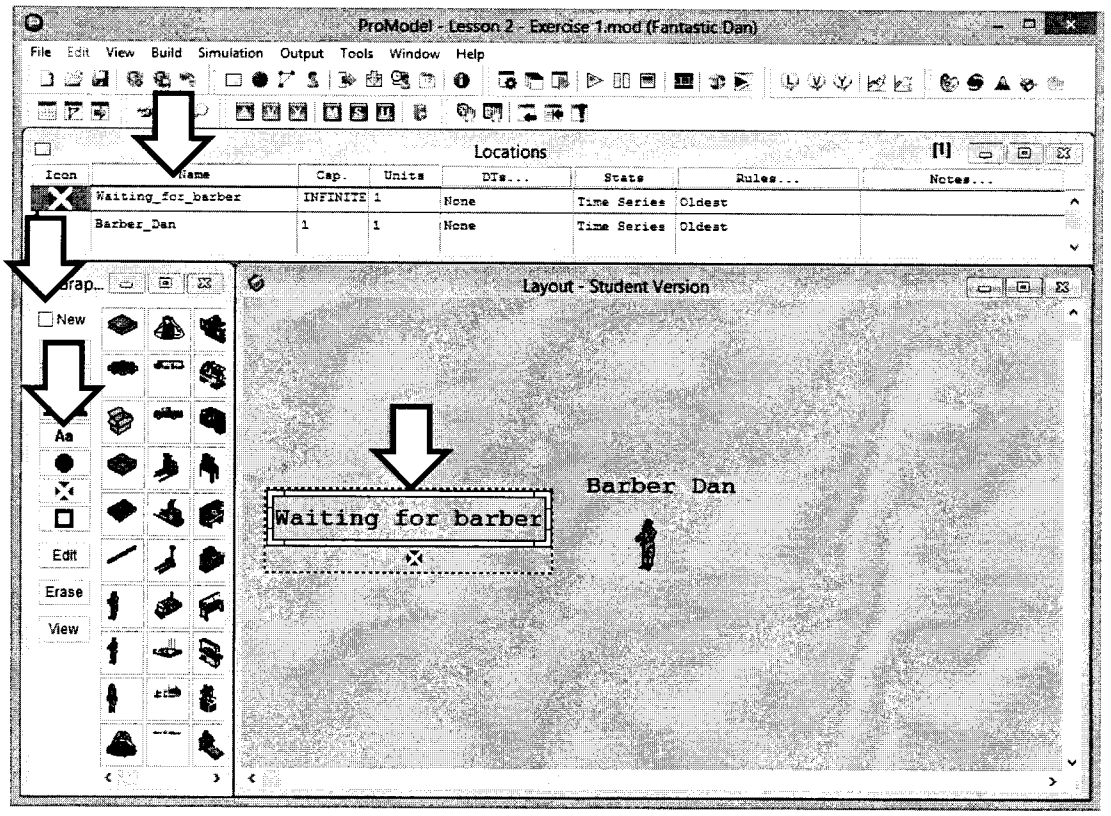
2.3. On the "**Locations**" table, change the location name to "**Waiting for barber**", and change the "**Cap.**" to **INFINITE**.

2.4. Add a second location. On the "**Graphic**" window, click on the **seventh** icon of the first column (**1**) and then click on the layout window to create the location (**2**).



2.5. Change the new location name to "**Barber Dan**".

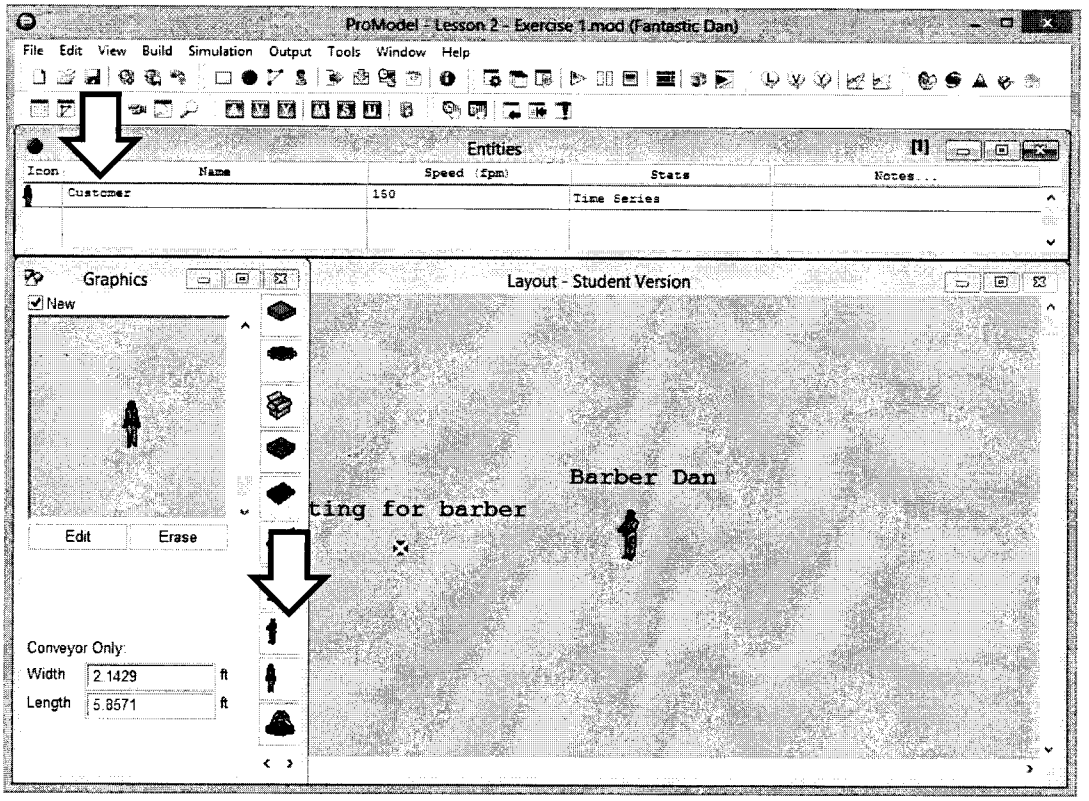
2.6. Adding the names of the locations to the model layout. Uncheck the "**New**" option on the "**Graphic**" window (**1**). Click on the location "Waiting for barber" (**2**), then click on the button "Aa" (**3**), and click on the layout by the location to add the name (**4**). Repeat the steps 2-4 for the location "**Barber Dan**".



3. Creating entities

3.1. Select the menu "**Build**" from the toolbar, and then click on "**Entities**".

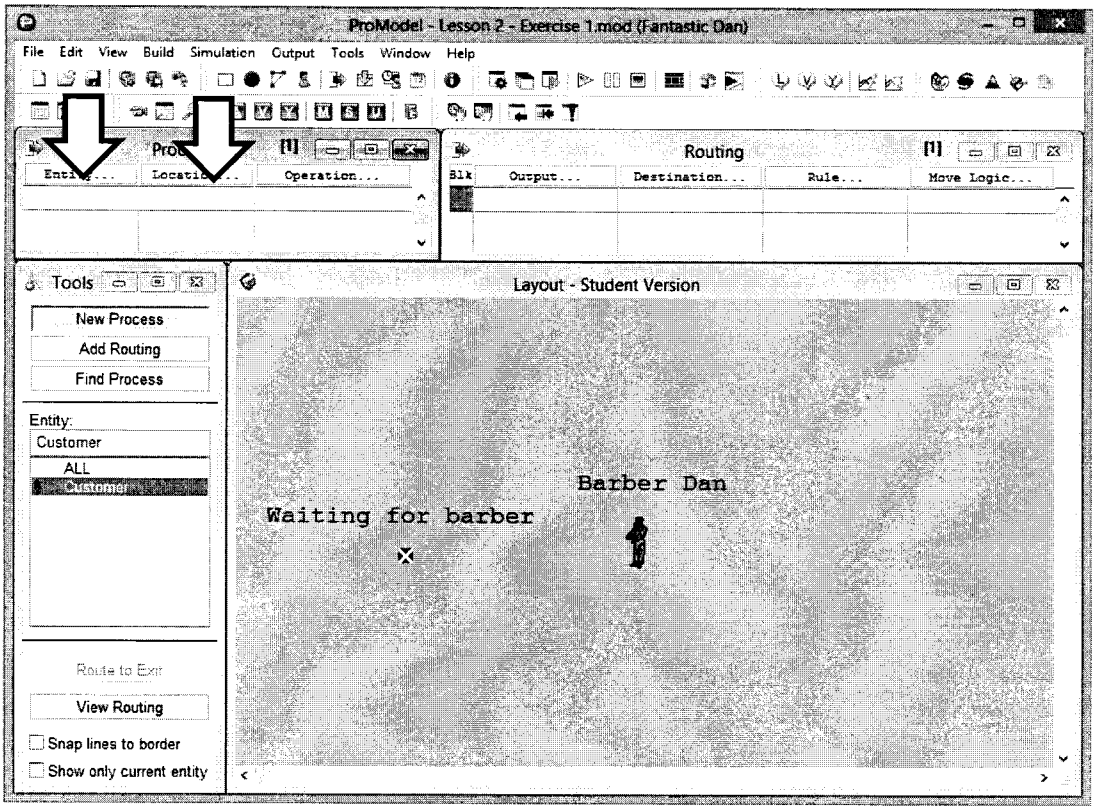
3.2. Select the eighth icon from the first row on the "**Graphics**" window (1), on the "**Entities**" table; change the entity name to "**Customer**" (**2**).



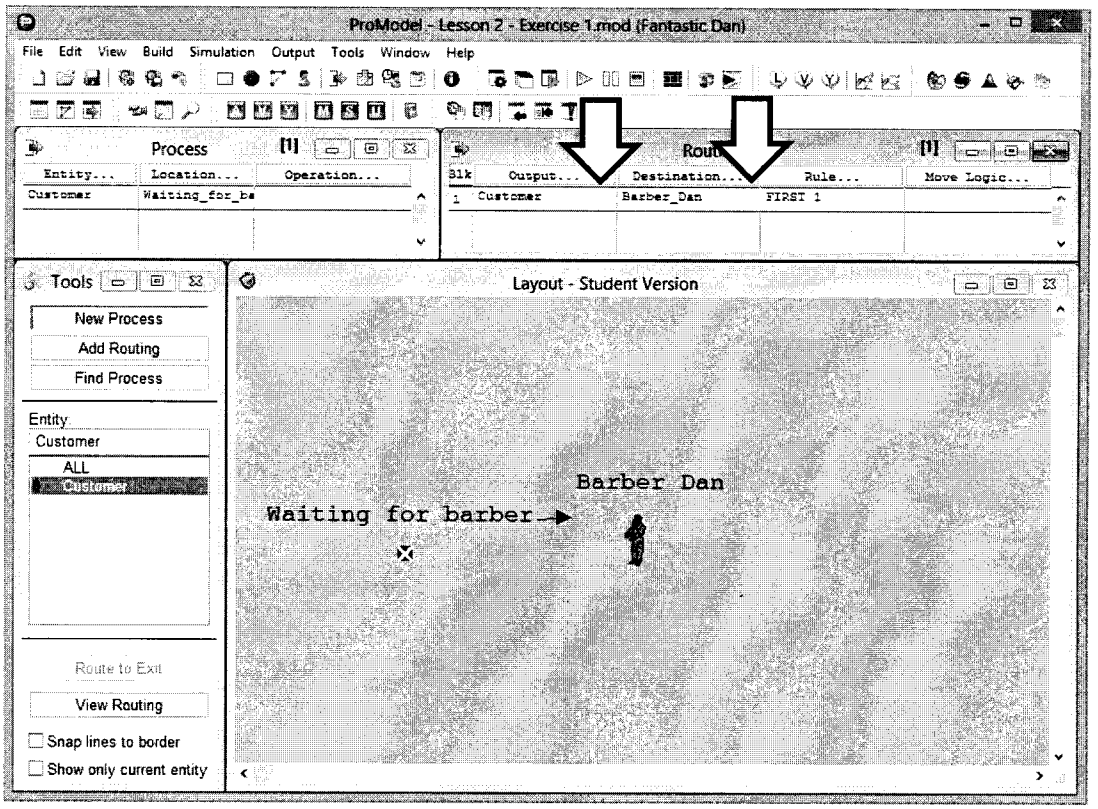
4. Creating processes

4.1. Customers that arrive at the salon, have to wait in the location "**Waiting for barber**" until Barber Dan is available. To create this process, select the option "**Build**" from the toolbar and then click on "**Processing**".

4.2. On the first row of the "**Process**" table, click on the "**Entity**" button and select the entity "**Customer**" (**1**). Click on the button "**Location**" and select "**Waiting for barber**" (**2**).

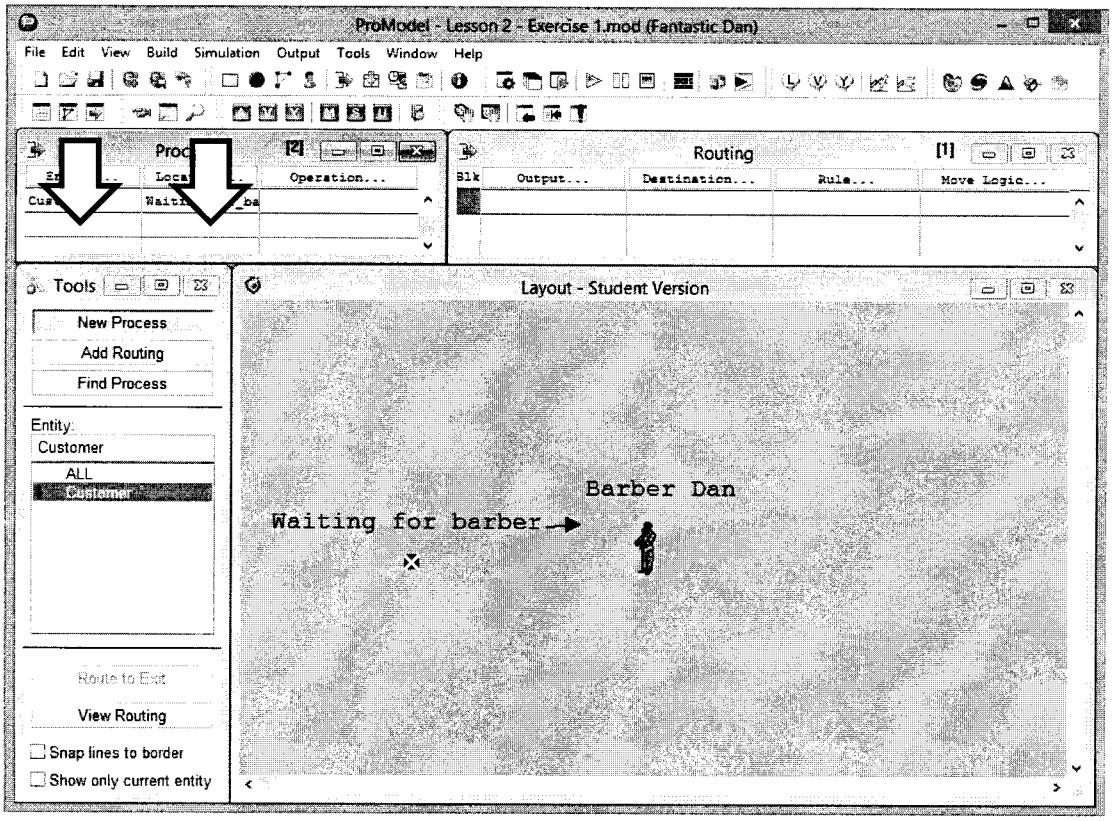


4.3. On the "**Routing**" table, click on "**Output**" and select "**Customer**" (**1**), then click on "**Destination**" and select the location "**Barber Dan**" (**2**).



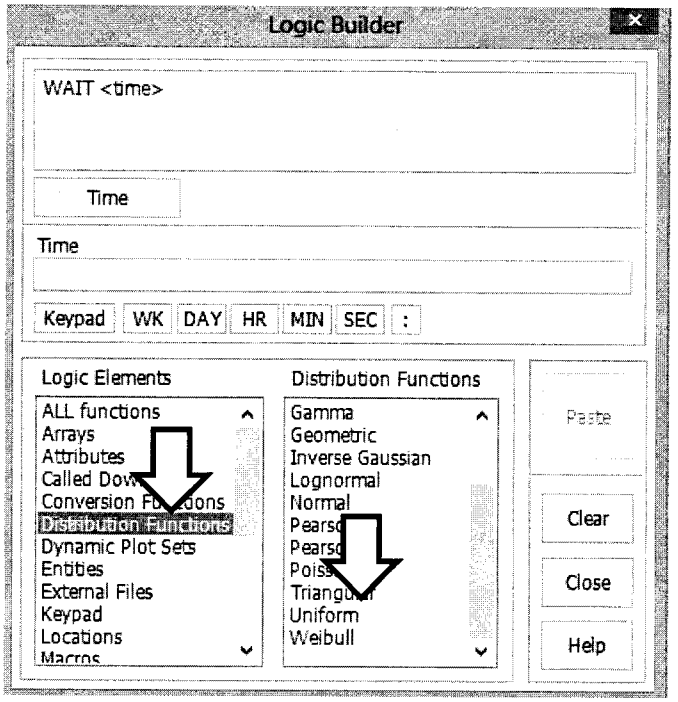
4.4. Add a new process. Click on the first row of the "**Process**" table and hit the enter key.

4.5. On the new process row, click on "**Entity**" and select "**Customer**" (**1**). Click on "**Location**" and select "**Barber Dan**" (**2**).

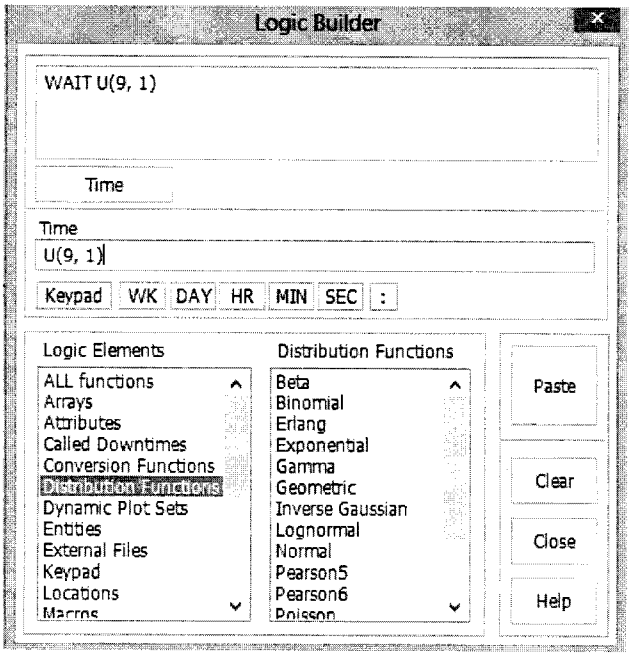


4.6. Still on the "**Process**" table, click on the "**Operation**" button. Once the "**Operation**" window has opened click on the "**Hammer**" icon, this will open the "**Logic Builder**" window.

4.7. On the "**Logic Builder**" select the function "**WAIT**" with a double click. Then on the "**Logic Elements**" select the item "**Distribution Functions**" (**1**). Once this item is selected, a panel named "**Distribution Functions**" will show on the right side; select the item "**Uniform**" (**2**).

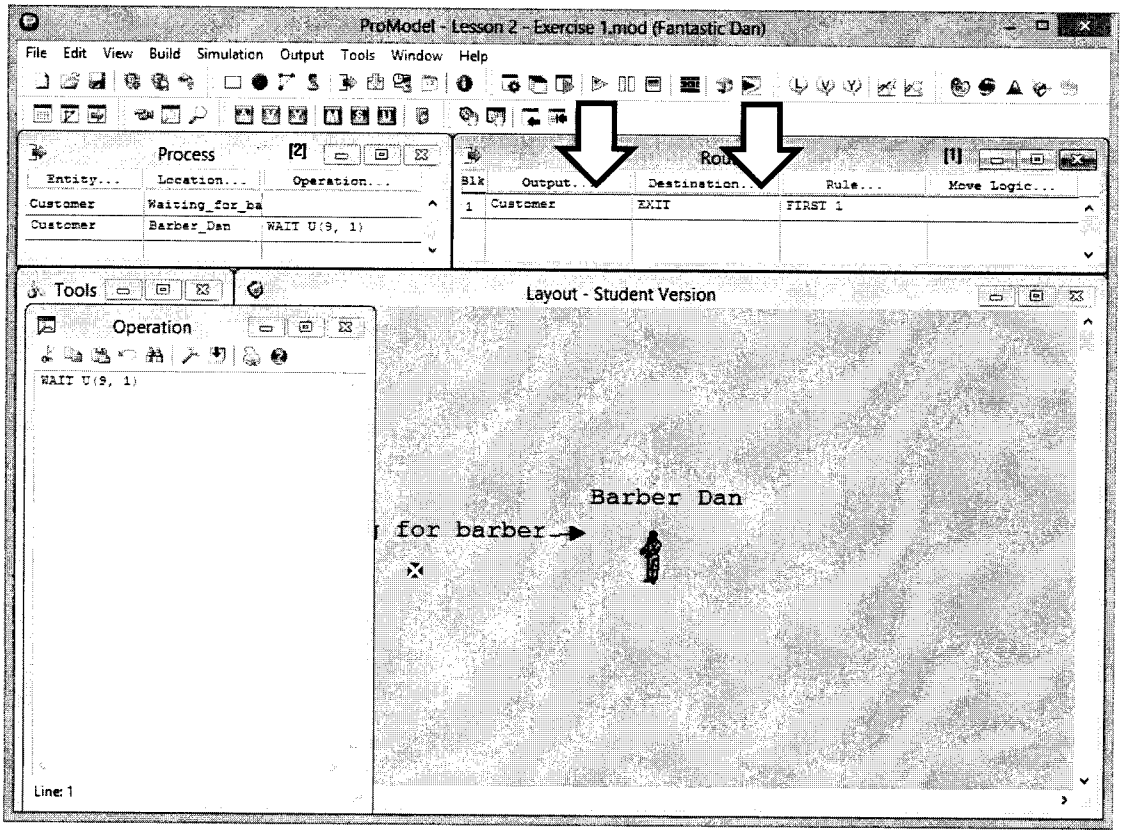


4.8. Click on the button "**Mean**" and enter the value **9**, then click on the button "**Half Range**" and enter the value **1**. Then click on the button "**Return**". Your logic builder window should show the following information.



4.9. Click on the button "**Paste**". Close the "**Logic Builder**" and "**Operation**" windows.

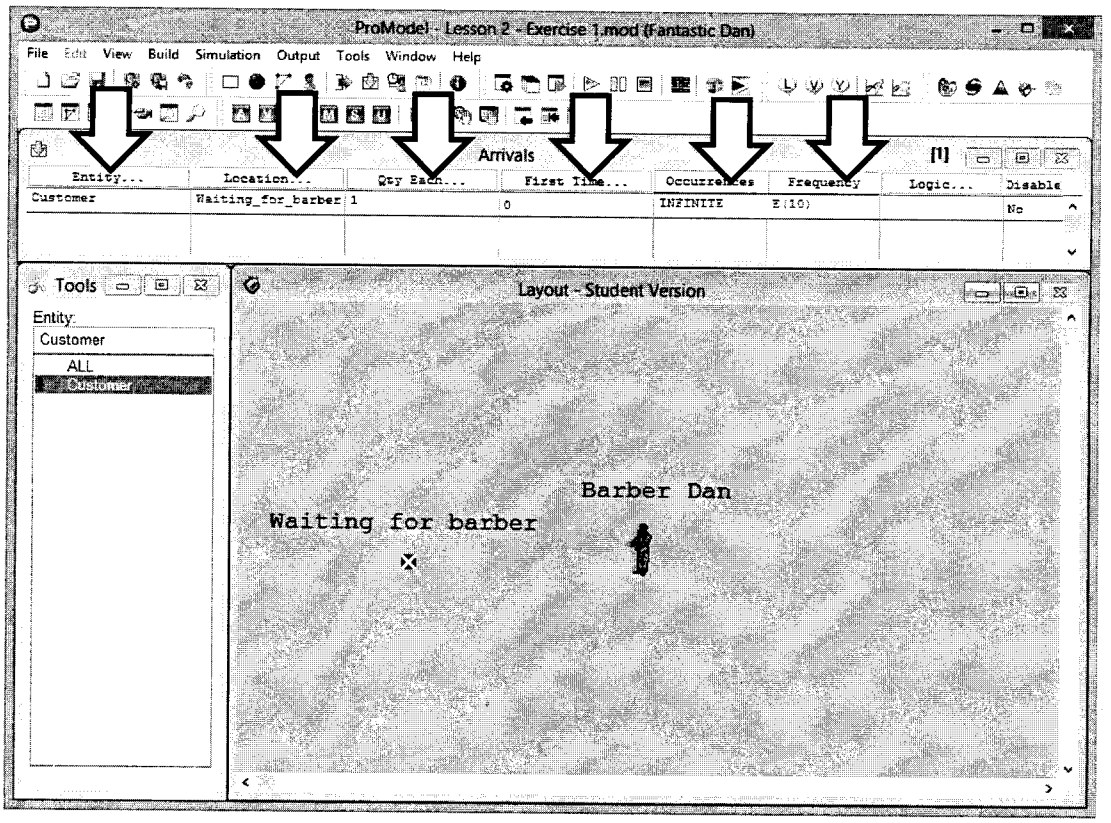
4.10. Now on the "**Routing**" table click on "**Output**" and select "**Customer**" (1), and then click on "**Destination**" and select "**EXIT**" (2).



5. Creating Arrivals

5.1. Select the menu "**Build**" from the toolbar and then click on the option "**Arrivals**"

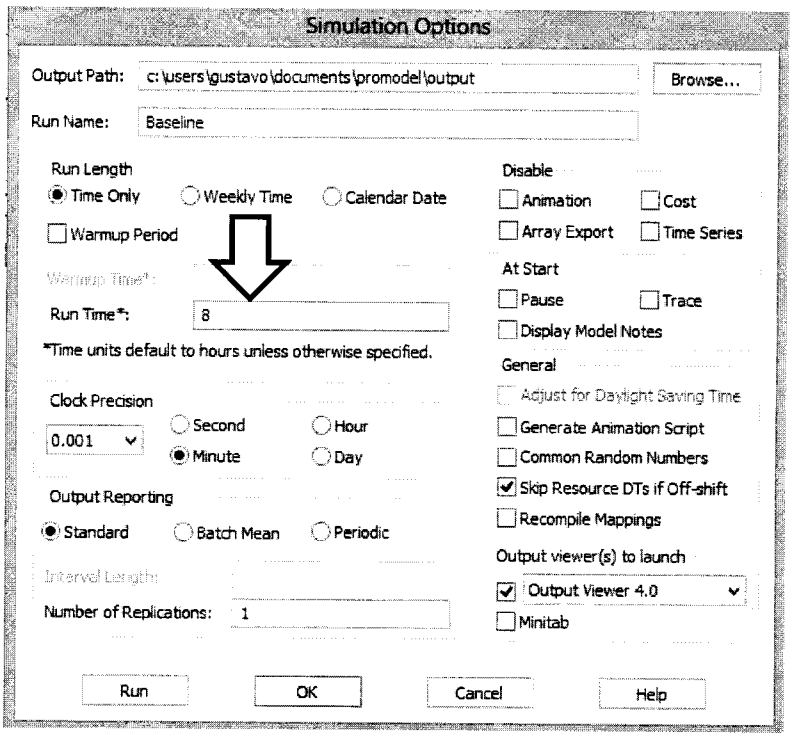
5.2. Click on the button "**Entity**" and select "**Customer**" (1); click on "**Location**" and select "**Waiting for barber**" (2); click on "**Qty. Each**" and type **1** (3); on "**First Time**" type **0** (4); on "**Occurrences**" type **Infinite** (5); and on "**Frequency**" type **E(10)** (this means that the arrival interval is exponentially distributed in 10 minutes) (6).



6. Defining Simulation Options, Saving, and Running the Model

6.1. From the "**Simulation**" menu on the toolbar, select the item "**Options**".

6.2. Change the "**Run Time**" to 8 (representing that the simulation will represent an eight-hour period).



6.3. Click "**Ok**" to close the "**Simulation Options**" window.

6.4. Save your model.

6.5. Run your mode. Select the menu "**Simulation**" and click on the option "**Run**".

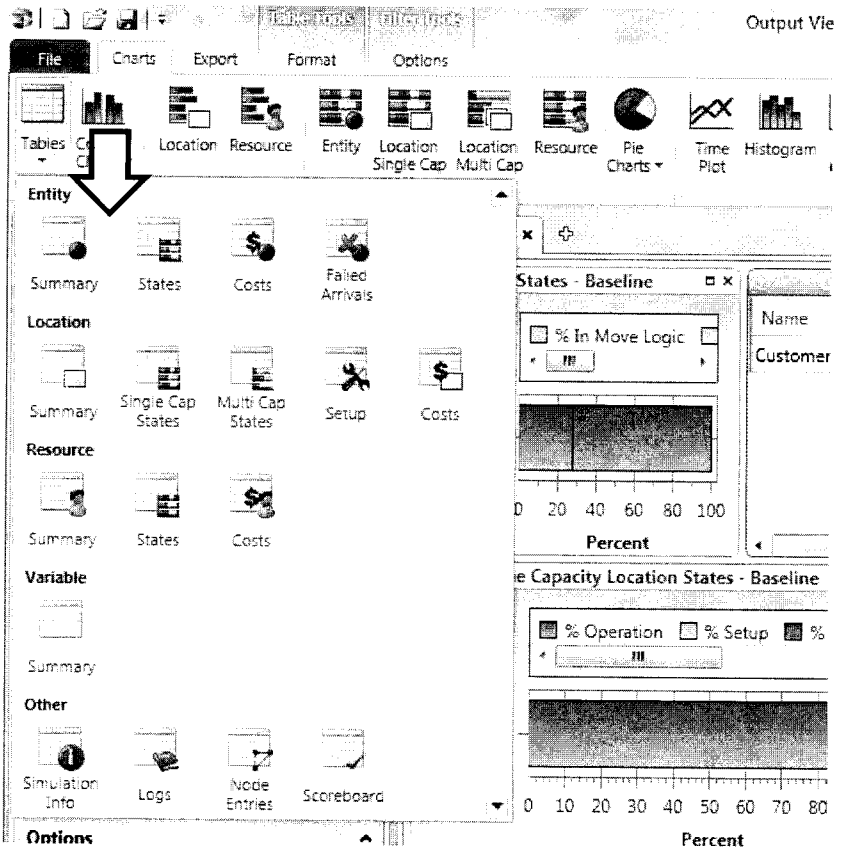
6.6. When prompted asking if you want to see the results of your model, click on the button "**Yes**".

7. Analyzing the Results

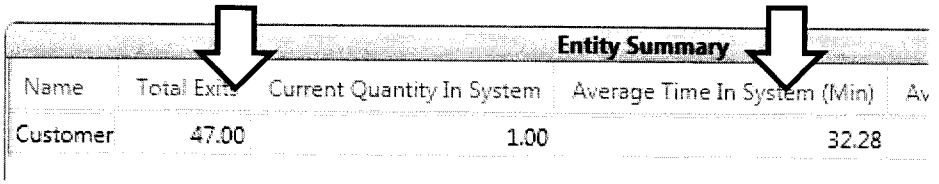
7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. To answer questions "a" (About how many customers does Dan process by day?), and "c" (What is the average time spent by a customer in the salon?): click

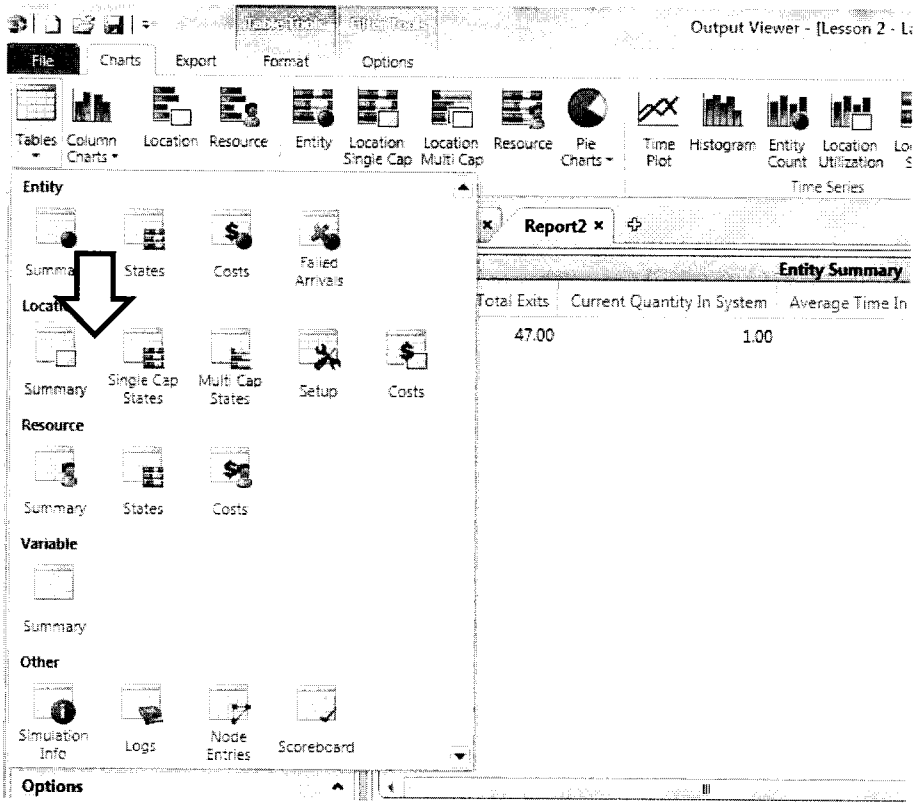
on the button "Tables" and under the section "Entities" select the option "Summary".



7.3. The second column of the table (Total Exits) displays the number of processed customs (question "a"), and the fourth column (Average Time in System) responds questions "c".



7.4. To respond question "b" (What is the average number of customers waiting to get a haircut? What is the maximum?), click on the button "Tables", and under the section "Location" select the option "Summary".



7.5. The column Average Contents and Maximum Contents for the row "Waiting for Barber" has the information to answer the question "b".

Location Summary

Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	Maximum Contents
Waiting for Barber	8.00	999,999.00	48.00	22.95	2.30	8.00
Barber Dan	8.00	1.00	48.00	8.92	0.89	1.00

7.6. To answer the last question (What is the utilization of Barber Dan) the same table used for the last step can be used. The last column of this table is called "Utilization" and the second row of that column contains the utilization of Barber Dan.

Location Summary

Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	Maximum Contents	Current Contents	% Utilization
Waiting for Barber	8.00	999,999.00	48.00	22.95	2.30	8.00	0.00	0.00
Barber Dan	8.00	1.00	48.00	8.92	0.89	1.00	1.00	89.15

Exercise 2

This second exercise from the second lesson will be based on the Laboratory 2.2 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. The exercise is described by Harrel, Ghosh & Bowden (2012) as follows:

"Customers arrive to use a Bank of USA ATM. The average customer inter-arrival time is 3.0 minutes exponentially distributed. When customers arrive to the system they join a queue to wait for their turn on the ATM. The queue has capacity to hold an infinite number of customers. Customers spend an average of 2.4 minutes exponentially distributed at the ATM to complete their transactions, which is called the service time of the ATM. Build a simulation model of the Bank of USA ATM. Run the simulation model for 980 hours.

a. How many customers are served per hour?
b. What is the average time spent by a customer in the system?
c. What is the utilization of the ATM?
d. What are the maximum and average numbers of customers waiting in the ATM queue?"

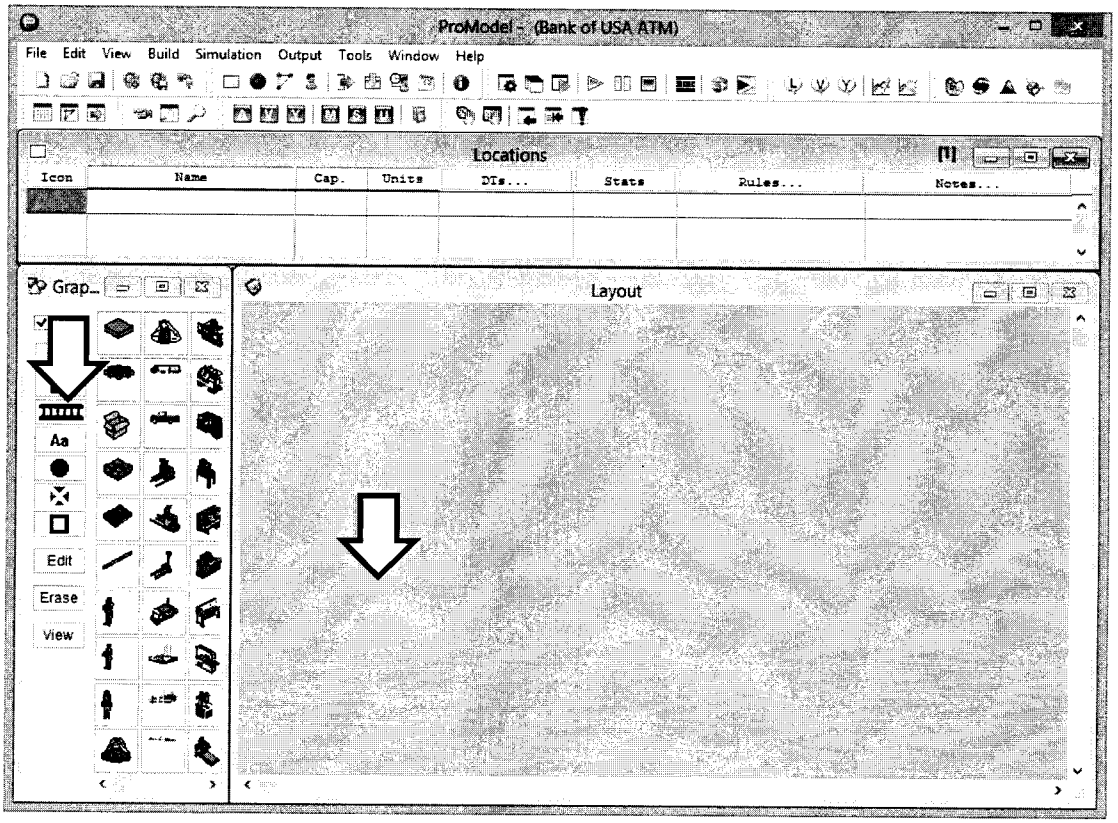
1. Creating a new model

1.1. At the toolbar select "**File**" and then click on "**New**" Change the title of the model to "**Bank of USA ATM**". Click "**Ok**" to close the dialog box.

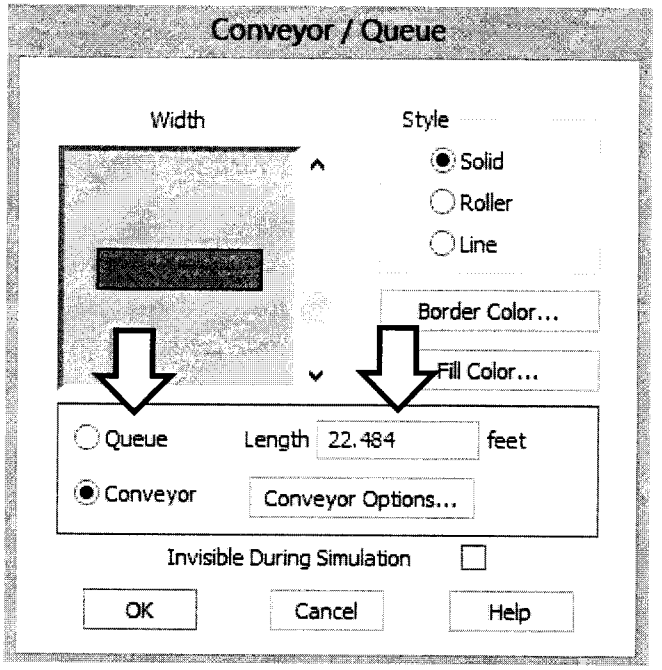
2. Creating locations

2.1. From the toolbar select the menu "**Build**" and then the option "**Locations**".

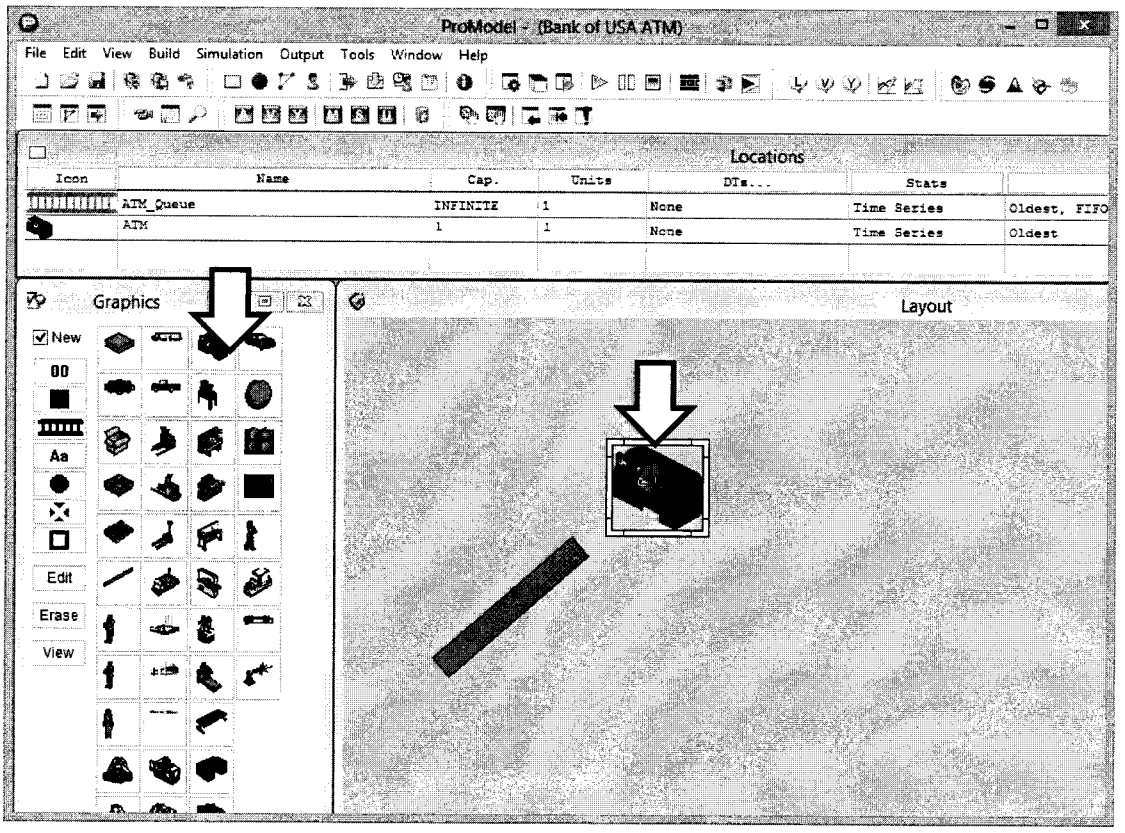
2.2. For this model two locations will be used. To define the first location: select the third icon on the left end of the "**Graphics**" window (the one that looks like a ladder on its side) (1), and to place it on your layout first click on the point where your queue will start, move your mouse to where the queue will end, and then click with the right button of your mouse (2). Change the location name from "**Loc1**" to "**ATM_Queue**" on the "**Locations**" table.



2.3. Double click on the queue on your layout. This will cause a "**Conveyor/Queue**" window to open. Select the option "**Queue**" (1), this will allow the entities to move at their own speed. Change the "**Length**" value to **0** (2).



2.4. To define the second location, select the first icon of the third column (1) on the "**Graphics**" window and click on the layout window (2), insert this location by the end of your ATM Queue.

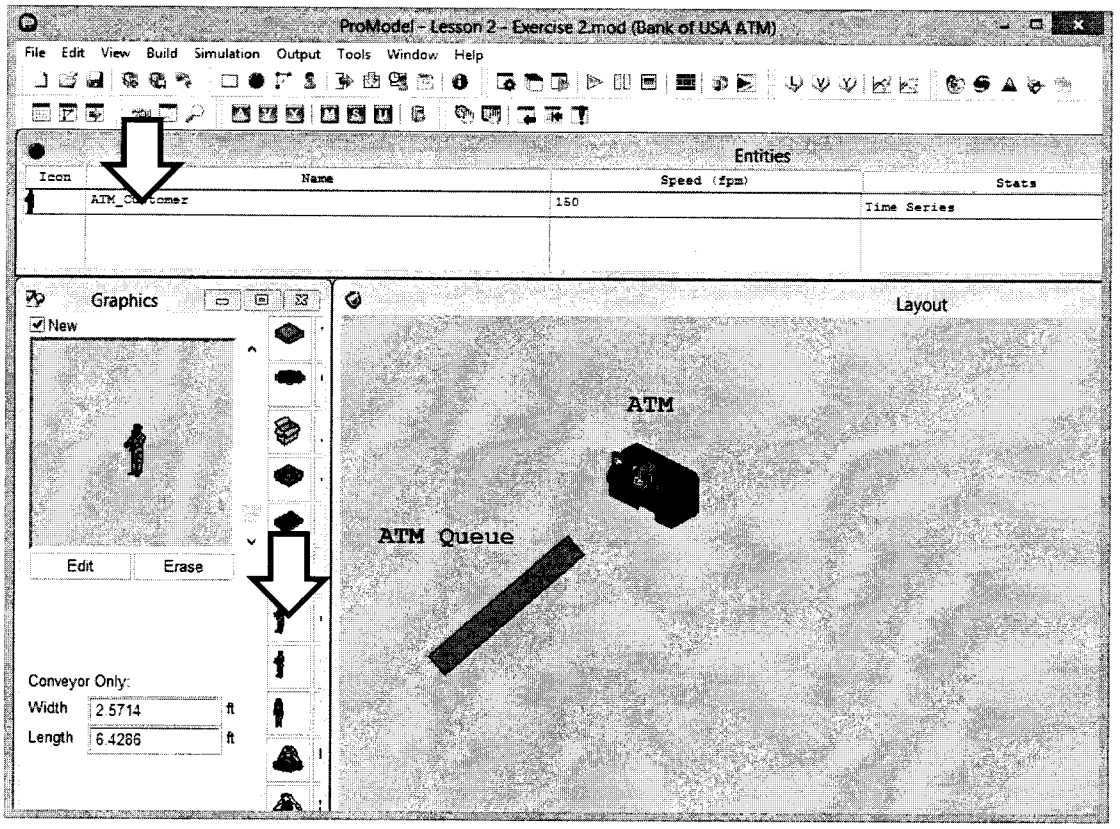


2.5. Display the location names on the layout by repeating the **step 2.6 of the Exercise 1**.

3. Creating entities

3.1. To create an entity, select the menu "**Build**" from the toolbar and then click on the option "**Entities**".

3.2. The only entity for this model will be the Customer. To create it, click on the seventh icon from the "**Graphics**" window (1). Change the entity name from "**Machinist**" to "**ATM Customer**" on the "**Entities**" table (2).



4. Creating processes

4.1. At this stage, the processing logic of the model will be created. Customers will arrive at the "ATM Queue" and then will proceed to the location "ATM", where they will perform their tasks that can take an average of 2.4 minutes exponentially distributed. Follow the detailed instructions on **item 4 of the exercise 1** to complete this part. A detailed execution of this phase can be found on the companion video, or in the finished model provided for this exercise.

4.2. Your processing logic should look similar to the below.

Process		
Entity	Location	Operation
ATM_Customer	ATM_Queue	
ATM_Customer	ATM	WAIT E(2.4)

Routing				
Blk	Output	Destination	Rule	Move Logic
1	ATM_Customer	ATM	FIRST 1	
1	ATM_Customer	EXIT	FIRST 1	

5. Creating Arrivals

5.1. To configure the entity arrivals of this model, select the menu "**Build**" and then the option "**Arrivals**".

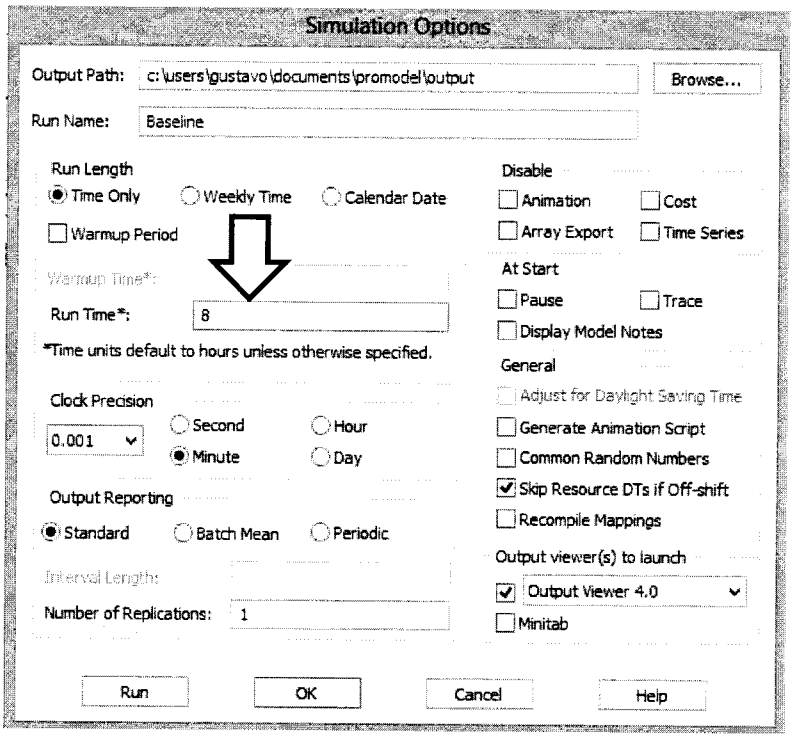
5.2. In the "**Arrivals**" table; select the "**ATM_Customer**" for the entity; the "**ATM_Queue**" for the location; input the value **1** for "**Qty. Each**", type in **0** for "**First Time**"; input **INF** for the "**Occurrences**"; and input **E(3.0)** for the "**Frequency**". Your arrival table should look like the following.

Entity	Location	Qty. Each	First Time	Occurrences	Frequency	Logic	Disab
ATM Customer	ATM Queue	1	0	INF	E(3.0)		No

6. Defining Simulation Options, Saving, and Running the Model

6.1. From the "**Simulation**" menu on the toolbar, select the item "**Options**".

6.2. Change the "**Run Time**" to 980 (indicating that the simulation will represent a 980-hour period).



6.3. Click "**Ok**" to close the "**Simulation Options**" window.

6.4. Save your model.

6.5. Run your mode. Select the menu "**Simulation**" and click on the option "**Run**".

6.6. When prompted asking if you want to see the results of your model, click on the button "**Yes**".

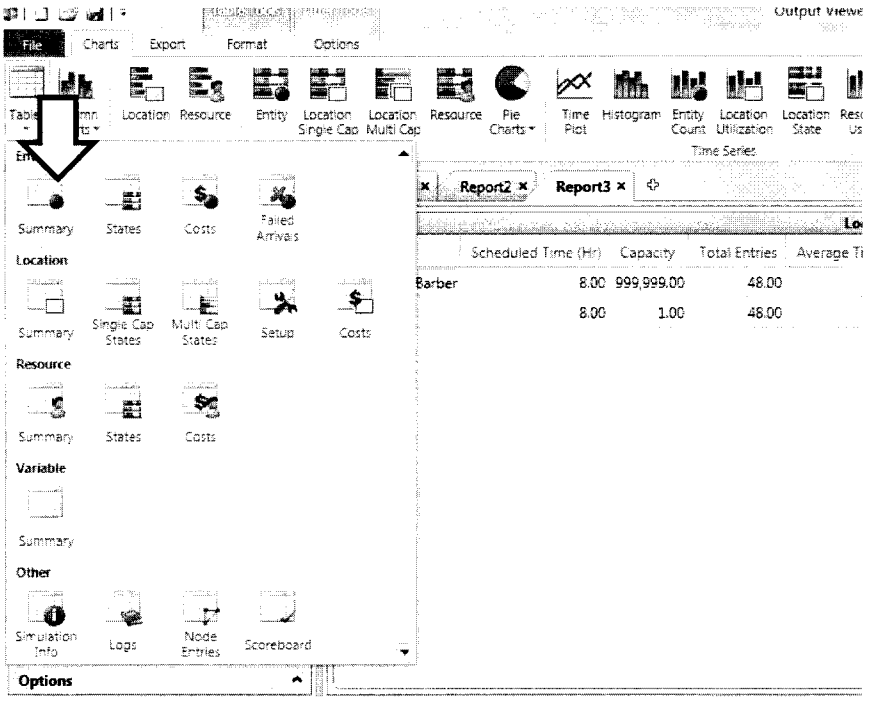
6.7. On the "**Output Viewer**" look for the answers for the exercise questions.

7. <u>Analyzing the Results</u>

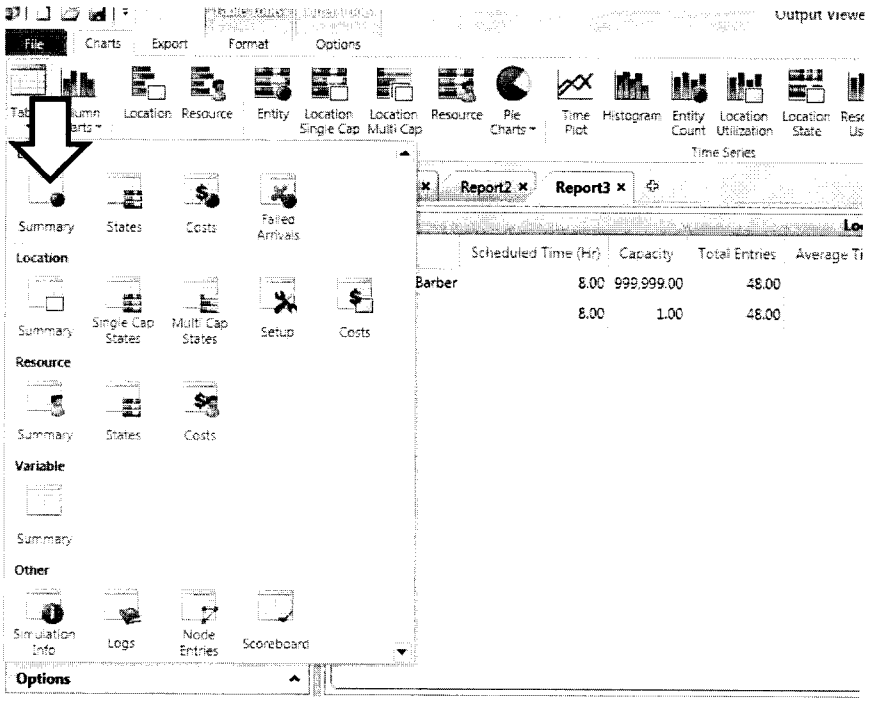
7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. The questions for this model can be answered in the same fashion as they were answered on the first exercise of this lesson (Lab 2.1).

7.3. To answer questions "a" (About how many customers are served per hour?), "b" (What is the average time spent by a customer in the system?), and "c" (What is the utilization of the ATM?). Click on the button "Tables", and under the section "Entity" click on the option "Summary".



7.4. To answer question "d" (What is the maximum and the average number of customers waiting in the ATM queue?), click on the button "Tables", and under the section "Location" select the option "Summary".


Output Viewe
File
Charts
Export
Format
Options
Location
Resource
Entity
Location Single Cap
Location Multi Cap
Resource
Pie Charts
Time Plot
Histogram
Entity Count
Location Utilization
Location State
Time Series
Report2
Report3
Summary
States
Costs
Failed Arrivals
Location
Summary
Single Cap States
Multi Cap States
Setup
Costs
Resource
Summary
States
Costs
Variable
Summary
Other
Simulation Info
Logs
Node Entries
Scoreboard
Options
Scheduled Time (Hr)
Capacity
Total Entries
Average Ti
Barber
8.00
999,999.00
48.00
8.00
1.00
48.00

LESSON 3

Exercise 1

This first exercise from the third lesson will be based on the Laboratory 2.3 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the concepts of locations, entities, arrivals, processes, and routings will be used.

The exercise is described by Harrel, Ghosh & Bowden (2012) as follows:

"Wooden logs are received at the receiving dock of the **USA Furniture Factory** at the rate of one every 17 minutes. Logs go to the splitter, where to pieces are made from each log. The splitting time is Normal(3.1) minutes. The individual pieces go to the lathe, where they are turned into round legs [Triangular(3,6,9) minutes]. The round legs go on a painting booth, where they are converted to painted legs. Painting time is Exponential(5) minutes. Painted legs go on to the assembly facility, next door. Consider a material handling time of one minute between each process. Build a simulation model and run it for 2,000 hours."

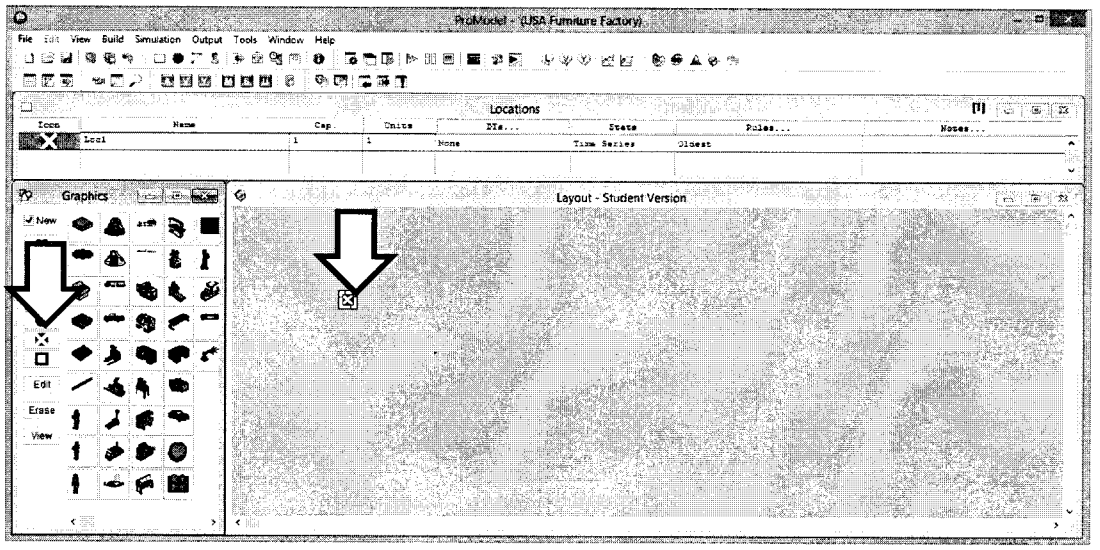
1. Creating a new model

    1.1. At the toolbar select "**File**" and then click on "**New**" Change the title of the model to "**USA Furniture Factory**". Click "**Ok**" to close the dialog box.

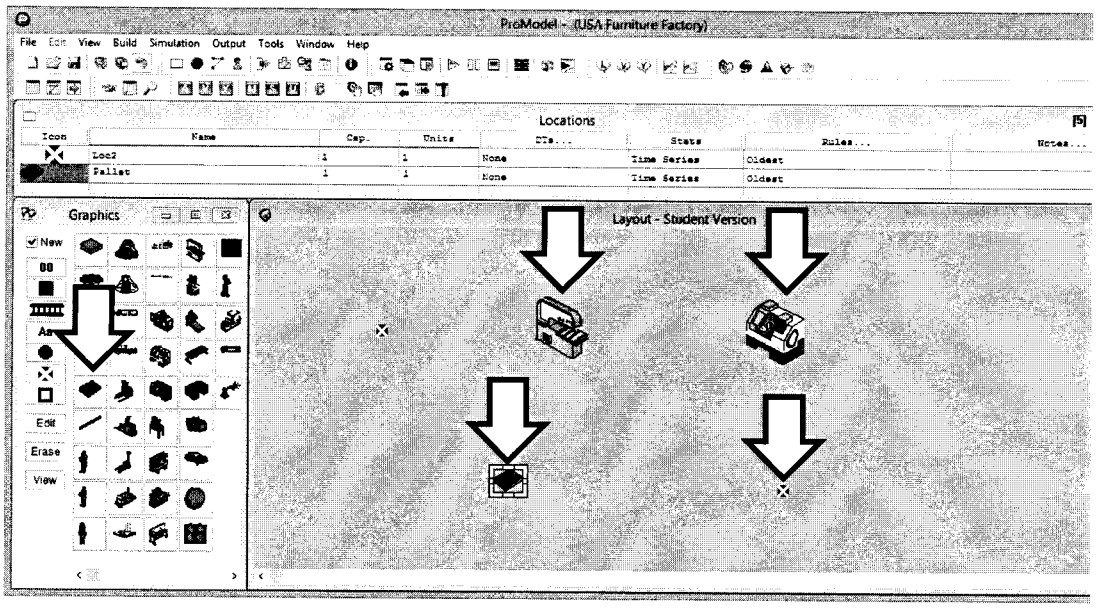
2. Creating Locations

    2.1. To create the locations, select the option "**Build**" and then click on "**Locations**".

2.2. For this model, five locations will be created. To create the first one, on the "**Graphic**" window on the left, select the icon that is a red square with a white "X" on it (1) (sixth icon on the first column) and select its position on the "**Layout**" window (2). As shown on the image below.



2.3. For the next location click on the fifth icon on the second column (a pallet) (1) and select its position on the layout (2). Repeat the same process for the other locations as shown on the image below (select the according icons for the other locations)

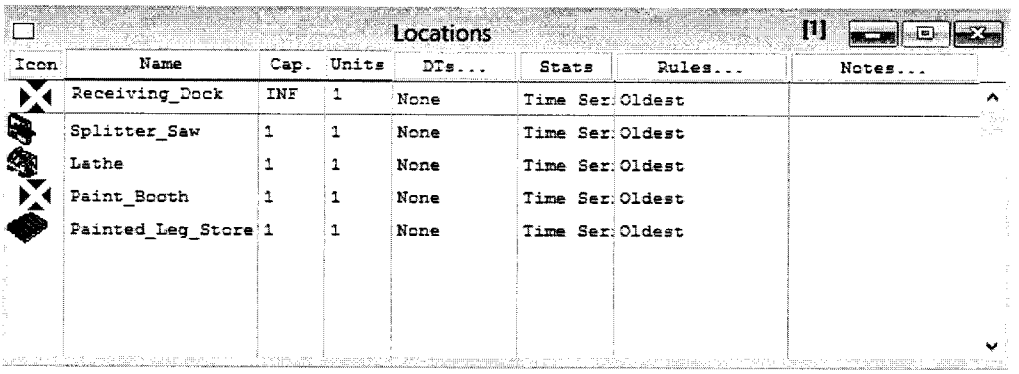


2.4. On the "**Location**" table at the top of the screen rename the locations according to the following instructions:

Present Name	**New Name**
Loc1	Receiving Dock
Saw	Splitter Saw
Lathe	Lathe
Loc2	Paint Booth
Pallet	Painted Leg Store

2.5. On the "**Locations**" table, change the information on the field "**Cap.**" from 1 to INF on the "**Receiving Dock**" row, to make sure that all the entities that arrive on the system can be received.

2.6. Your "Locations" table should look similar to the following:

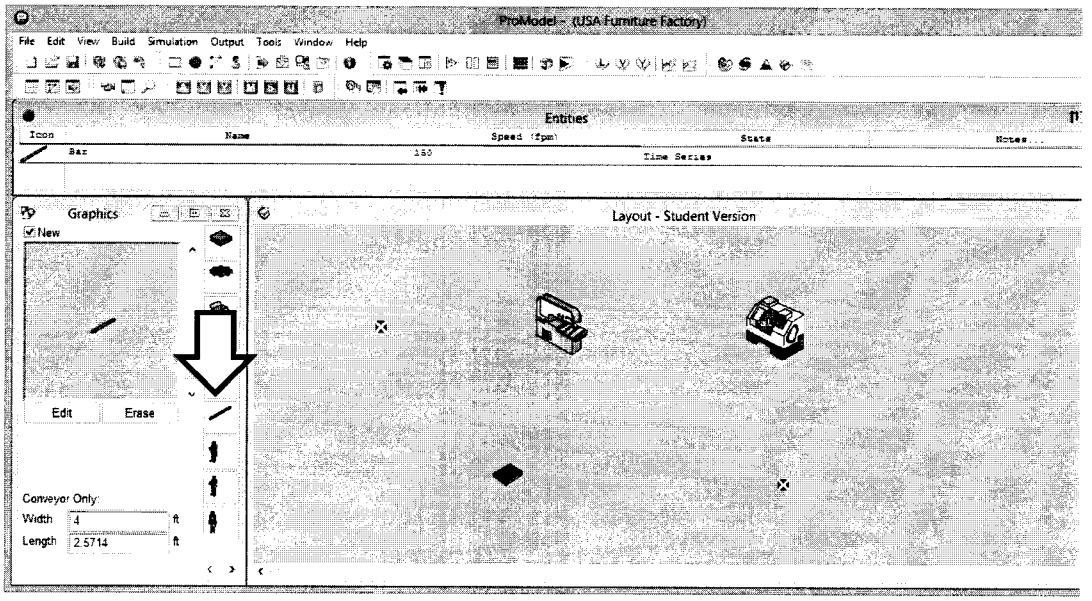


3. Creating entities

3.1. For this model, we will work with four different entities because they are transformed as they move from one process to another.

3.2. To create the entities, select the option "**Build**" and then click on "**Entities**".

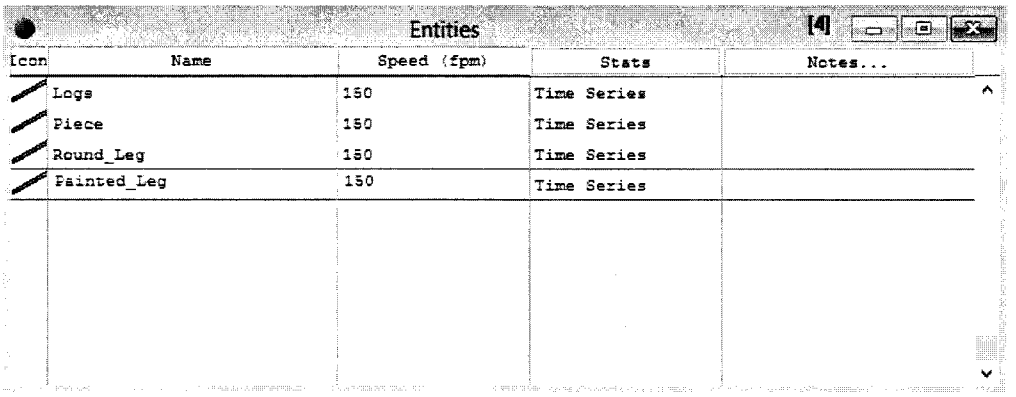
3.3. On the "**Graphics**" window, select sixth icon on the first row as shown on the picture below. This will create the entity "**Bar**".



3.4. For this exercise we will make use of the same graphic to represent the four different entities, but the user can select different icons if desired.

3.5. Click on the same graphic from step 3.3 to create another 3 entities: "**BarA**", "**BarB**", and "**BarC**".

3.6. On the "**Entities**" table, rename the entities to "**Logs**", "**Piece**", "**Round Leg**", and "**Painted Leg**". Your entities table should look like the following.



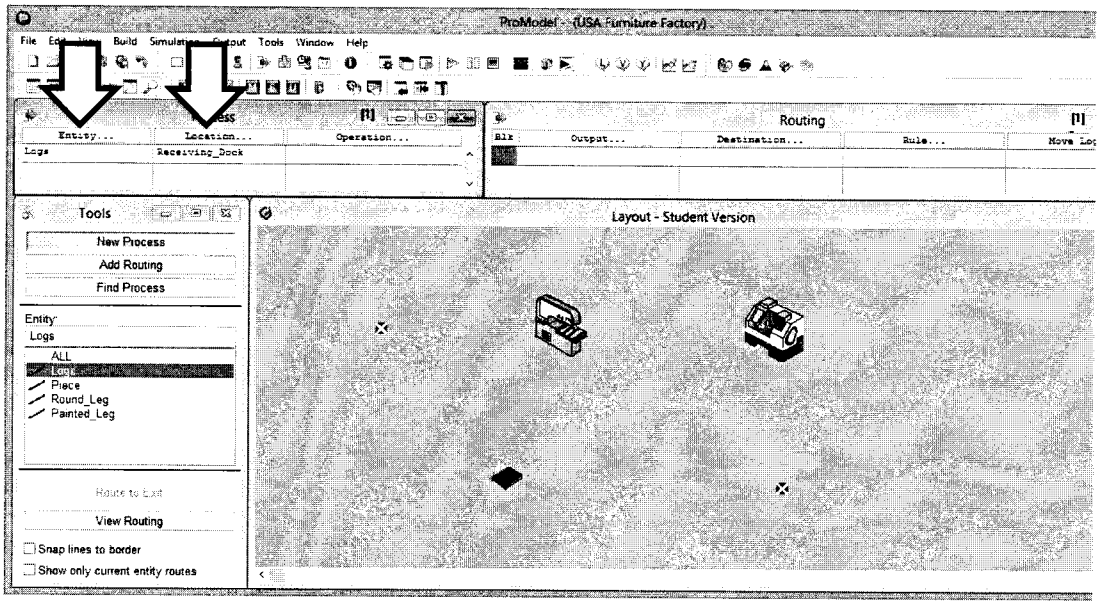
3.7. If you added more rows than necessary accidently, select the row to be deleted and select the menu "**Edit**" from the tool bar, and then the option "**Delete**".

4. Creating processes

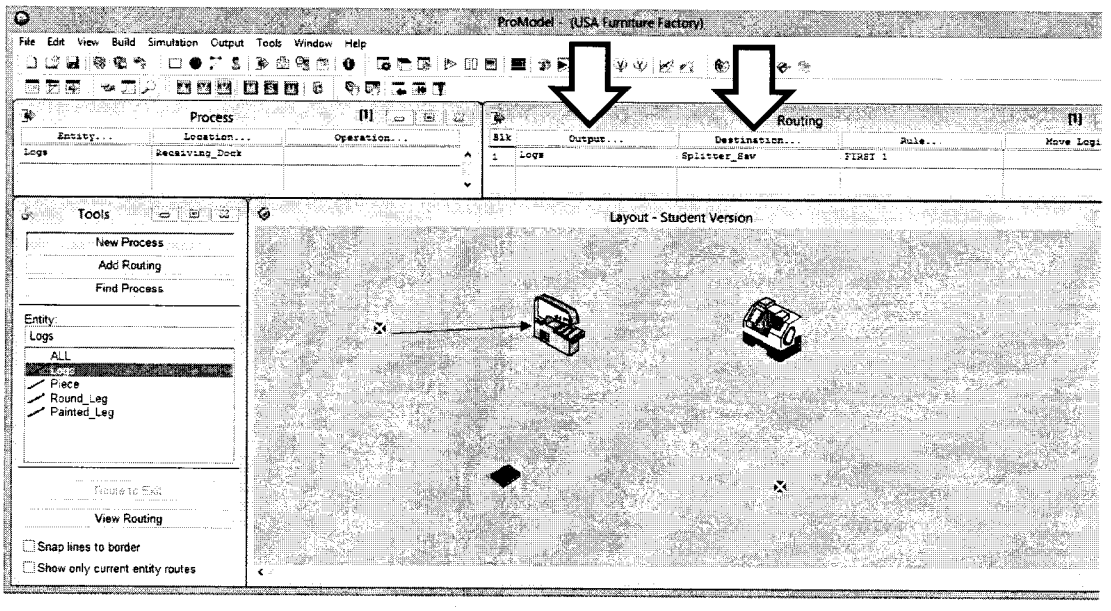
4.1. In this model, the entities will start at the receiving dock, will be moved to the Splitter Saw, to the Lathe, to the Paint Booth and finally to the Painted Leg Store. The entities may or may not suffer some sort of processing in each of those locations. Keep in mind this flow for this phase of the model construction.

4.2. To create the processes, select the option "**Build**" and then click on "**Processing**".

4.3. In order to create the first process, on the "**Process**" table, select the first row and click on the button "**Entity**", select the option "**Logs**" and hit "**Ok**". On the same row, click on the button "**Locations**", select the location "**Receiving Dock**" and hit "**Ok**". Follow the image bellow.

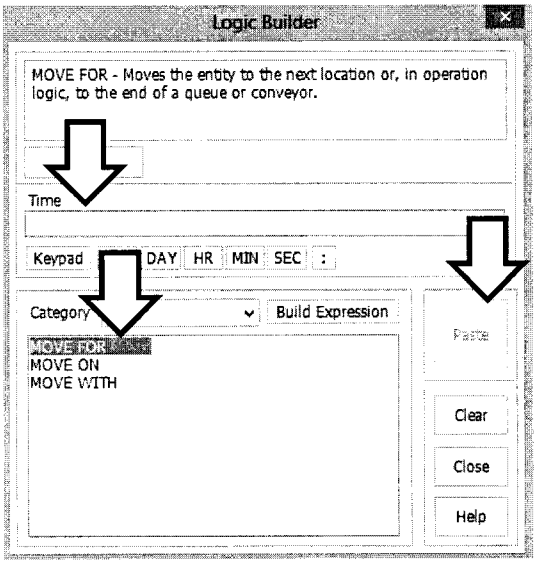


4.4. On the "**Routing**" table, select the first row. Click on the button "**Output**" and select the option "**Logs**", hit "**Ok**". Click on the "**Destination**" button and select the destination "**Splitter Saw**", hit "**Ok**". Follow the image bellow.



4.5. Still on the same row, click on the button "**Move logic**". On the window that will appear, click on the "**Hammer**" icon to open the logic builder.

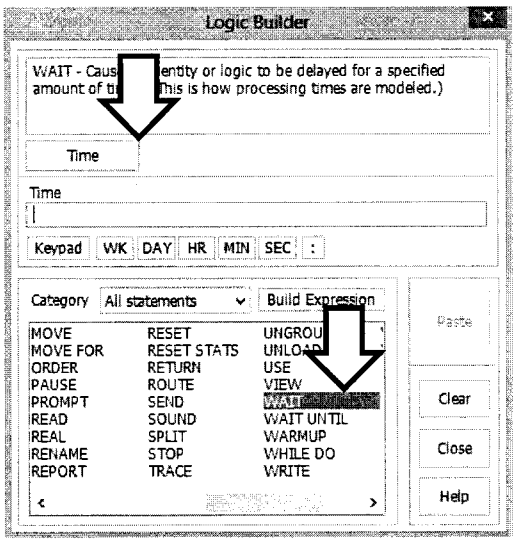
4.6. On the logic builder select the command "**MOVE FOR**" (1), and insert the value "**1**" on the time textbox (2). Click on the button "**Paste**" (3). Close the logic builder and move logic windows. By doing this you are informing ProModel that the entity will take 1 minute to move from the origin (Receiving Dock) to its destination (Splitter Saw).



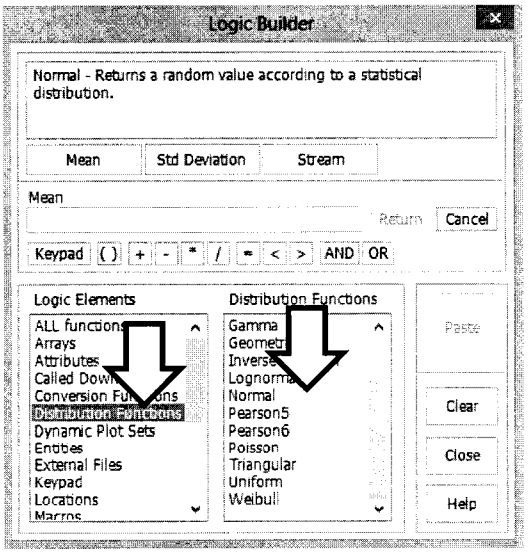
4.7. For the next process, select the first row of the "**Process**" table and hit enter to create another row. Select the "**Logs**" as the entity of this process, and the "**Splitter Saw**" as the location. Follow the process 4.3 if you are not sure on how to do it.

4.8. Still on the "**Process**" table, click on the button "**Operation**". On the Operation window, click on the "**Hammer**" icon to start the logic builder.

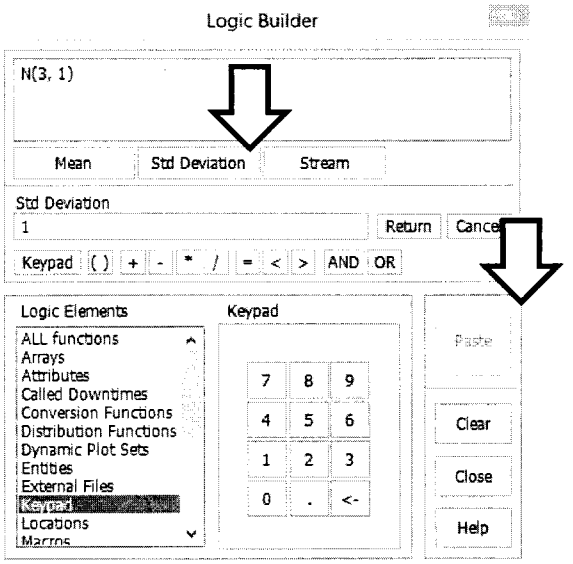
4.9. On the logic builder select the function "**WAIT**" (1) and click on the button "**TIME**" (2).



4.10. Select the option "**Distribution Functions**" from the list on the left side (1), and then the option "**Normal**" from the list on the right side (2).

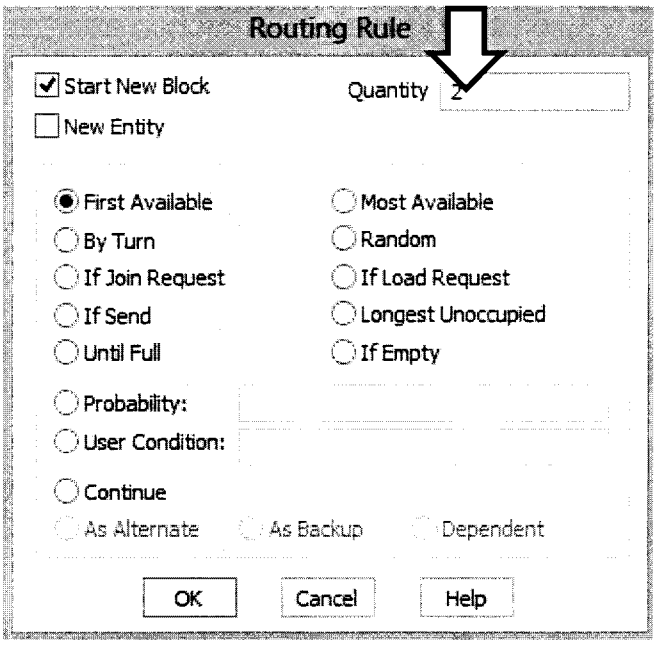


4.11. Type in the value **3** in the "**Mean**" text box. Hit the button "**Std Deviation**" (1) and type in the value **1** on the new textbox. Click on the button "**Paste**" (2). Close the logic builder and operation windows. By doing this, you are informing ProModel, that this process have a duration equal to a Normal Distribution function with average of 3 minutes and standard deviation of 1 minute.



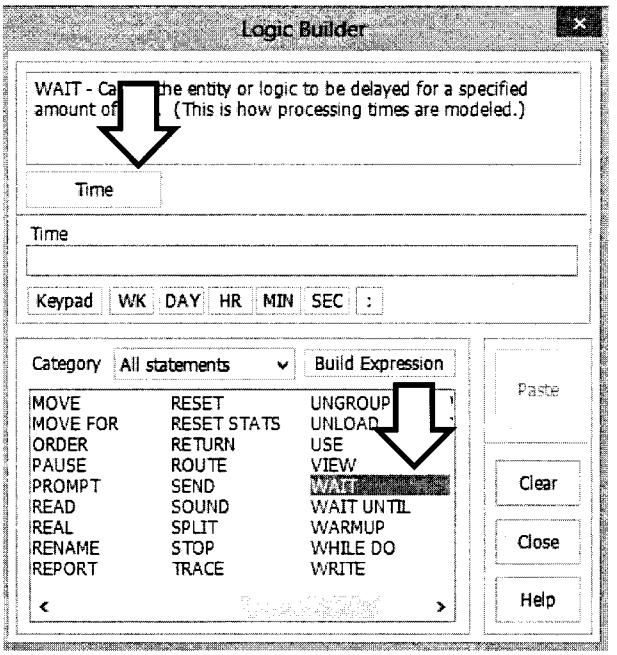
4.12. On the "**Routing**" table, select the entity "**Piece**" for the output, the location "**Lathe**" for the destination, and repeat step 4.6 for the "**Move Logic**". By doing this you are informing ProModel that the product of the process on the Splitter Saw is a "Piece" that will be moved for the "Lathe" for 1 minute.

4.13. Still on the same row of the routing table, click on the button "**Rule**", and change the quantity value to **2**. This way, 2 pieces will be created by the process at the splitting saw, as required by the exercise description.



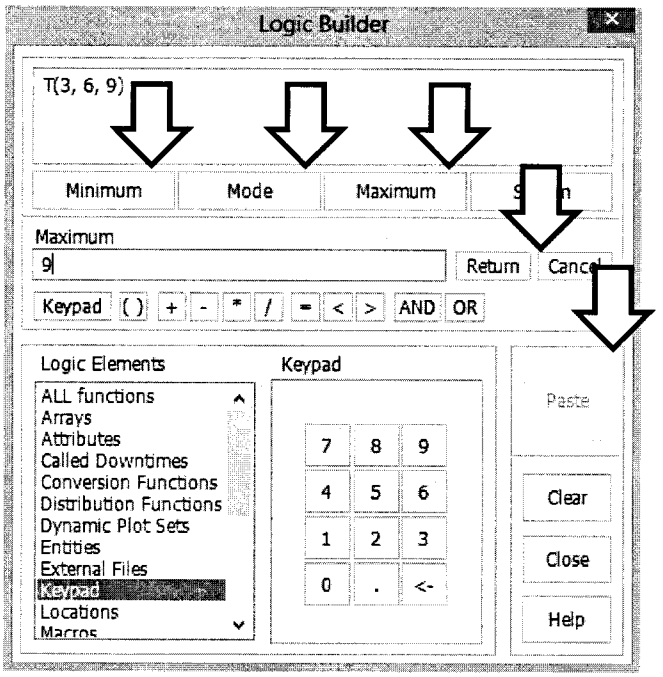
4.14. To create the next process, click on the last row of the "**Process**" table and hit enter. On the new row, select "**Piece**" for the entity, and "**Lathe**" for the location. Click on the button operation to bring up the "**Operation**" window and click on the "**Hammer**" to bring up the logic builder.

4.15. On the logic builder window, select the command "**WAIT**" (1) and click on the button "**Time**" (2).



4.16. Select the "**Distribution Functions**" from the "**Logic Elements**" list on the left, and then select the option "**Triangular**" from the "**Distribution Functions**" list on the right side.

4.17. Now we will insert the parameters for the triangular distribution: minimum, mode, and maximum. First click on the button "**Minimum**" (1) at the top of the window and type in the **3** on the textbox below, then click on the button "**Mode**" (2) and type in the value **6**, and finally click on the button "**Maximum**" (3) and type in the value **9**. After this, click on the button "**Return**" (4) and then the button "**Paste**" (5). Close the logic builder window, and the process window.



4.18. On the "**Routing**" table: Select "**Round Leg**" for the output and the "**Paint Booth**" for the location. This is informing ProModel that the output from the process at the Lathe is the entity Round Leg and that it will be moved to the Paint Booth. On the "**Move Logic**", inform the software that the entity will take one minute to be moved to its next location (Step 4.6).

4.19. Back to the "**Process**" table: Click on the last row and hit enter to create a new row. Select the "**Round Leg**" for the entity and the "**Paint Booth**" for the location. On the operation window bring up the "**Logic Builder**" (click on the hammer icon on the operation window).

4.20. On the "**Logic Builder**" select the option "**WAIT**" and click on the button "**Time**" (Step 4.15).

4.21. On the "**Logic Elements**" list select the option "**Distribution Functions**", and on the distribution functions list, select the option "**Exponential**". (Similar to step 4.16)

4.22. Click on the button "**Mean**" (1) and type in the value **5**. Hit the button "**Return**" (2) and then click on "**Paste**" (3). This will inform ProModel that this process has a duration that can vary according to an exponential distribution with mean equal to 5. Close the logic builder and operation windows.

4.23. On the "**Routing**" table, select the "**Painted Leg**" for the Output and the "**Painted Leg Store**" for the Destination. Next, on the Move Logic, inform ProModel that the entity will take one minute to be moved to the next location (Step 4.6)

4.24. For the next process, create a new row on the "**Process**" table (select the last row and hit the enter key). Select the "**Painted Leg**" for the entity and the "**Painted Leg Store**" for the location. There is no need to define the operation logic for this process.

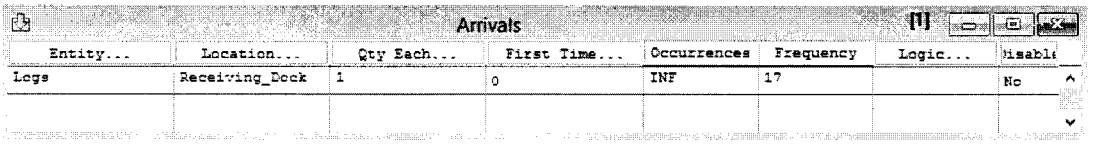
4.25. Move along to the "**Routing**" table. Select the "**Painted Leg**" for the output and the "**EXIT**" for the destination. This routing informs the software that the entity has served its purpose (has passed by all the processes) and now will leave the system.

5. Creating Arrivals

5.1. To create the arrivals, select the menu "**Build**" from the tool bar and then select the option "**Arrivals**". We will inform the software that the logs will arrive at

the receiving dock every 17 minutes, and that only one log will be delivered per time.

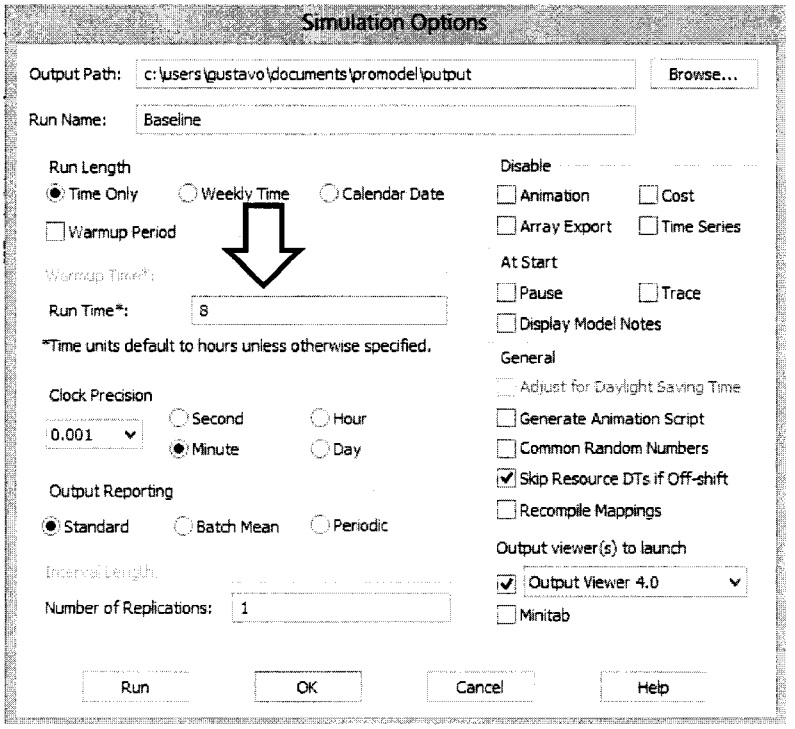
5.2. On the Arrivals table, select the entity "**Logs**" (1), the location "**Receiving Dock**" (2), type in the value **1** for the "Qty. Each" field (3), type in the value **0** for the "First Time" (3), type in the value **INF** for the Occurrences field (4), and the value **17** for the Frequency field (5). Once you are done, your arrivals table should look like the following.



6. Defining Simulation Options, Saving, and Running the Model

6.1. From the "**Simulation**" menu on the toolbar, select the item "**Options**".

6.2. Change the "**Run Time**" to 2,000.



6.3. Click "**Ok**" to close the "**Simulation Options**" window.

6.4. Save your model.

6.5. Run your mode: Select the menu "**Simulation**" and click on the option "**Run**".

6.6. When prompted asking if you want to see the results of your model, click on the button "**Yes**".

6.7. On the "**Output Viewer**" analyze the model results.

7. Analyzing the Results

7.1. On the output viewer, analyze the following tables.

7.1.1. Entity Summary (Click on the "Table" button, then under the "Entity" section, select the option "Summary")

7.1.2. Location Summary (Click on the "Table" button, then under the "Location" section, select the option "Summary")

7.1.3. Location States (Click on the "Table" button, then under the "Entity" section, select the option "Single Cap States")

Exercise 2

This second exercise from the third lesson will be based on the Laboratory 2.4 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the concepts of locations, entities, arrivals, processes, and routings will be used.

The exercise is described by Harrel, Ghosh & Bowden (2012) as follows:

"Now let us add a location to an existing model. For the USA Furniture Factory example in section L2.3, we will add an oven after the painting booth for drying the painted legs individually. The drying takes a time that is normally with a mean of 20 minutes and a standard deviation of 2 minutes. After drying, the painted legs go on the painted legs store."

1. Creating a new model

    1.1. This model will be based on the model developed on the Exercise 1 of this lesson.

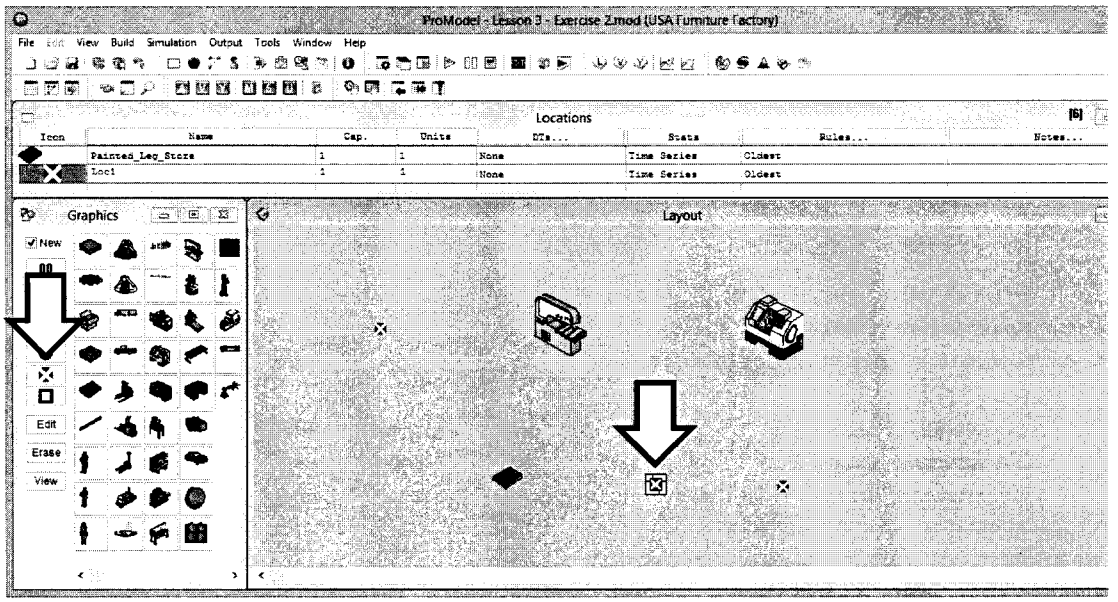
    1.2. Open the model from the last exercise.

    1.3. Select the menu "File" and then the option "Save As...", and save your model as "**USA Furniture Factory 2**"

2. Creating Locations

    2.1. To create the location Oven, first select the menu "**Build**" and then the option "**Locations**".

2.2. Select the sixth icon from the first column (1) and then select a position on the layout window to place your new location (2). Try to insert it between the "Paint Booth" and the "Painted Leg Store" locations. As the image below shows.



2.3. Rename your new location as "**Oven**" on the Locations table.

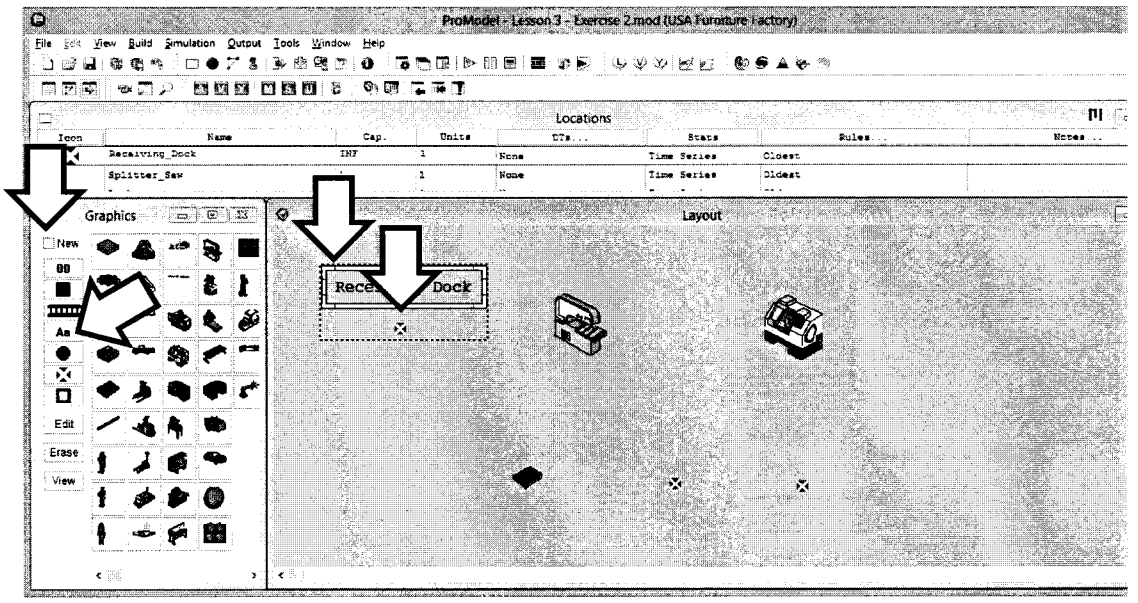
2.4. For this model we will change the capacity of some locations. The term capacity refers to how many entities can be allocated in a single location, for example, if the capacity of the Oven is 5; it means that it can process 5 entities at once.

2.5. On the Locations table, change the value of the "Cap." column for the Paint Booth to **10**, and for the Oven to also **10**. Your location table should look similar to the one below.

Locations

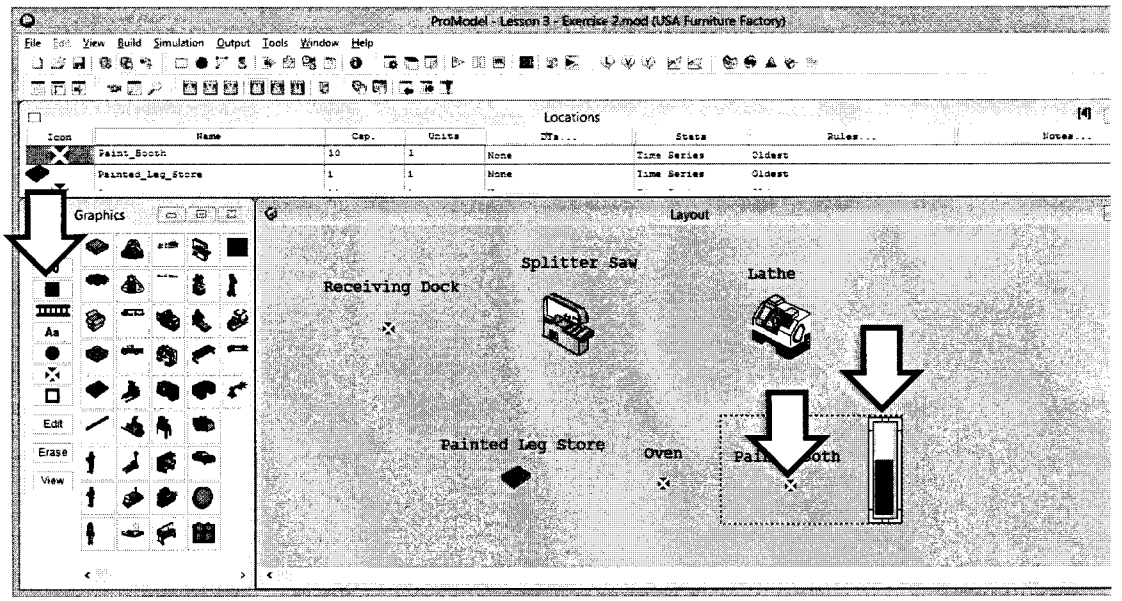
Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Receiving_Dock	INF	1	None	Time Serie	Oldest	
	Splitter_Saw	1	1	None	Time Serie	Oldest	
	Lathe	1	1	None	Time Serie	Oldest	
	Paint_Booth	10	1	None	Time Serie	Oldest	
	Painted_Leg_Store	1	1	None	Time Serie	Oldest	
	Oven	10	1	None	Time Serie	Oldest	

2.6. Insert the location names on the layout: In order to do this, uncheck the "**New**" option on the Graphics window (1). Click on a location on the layout (2), click on the "Aa" Button (3), and then click on the layout to place the location name (4). Do this for all the locations.

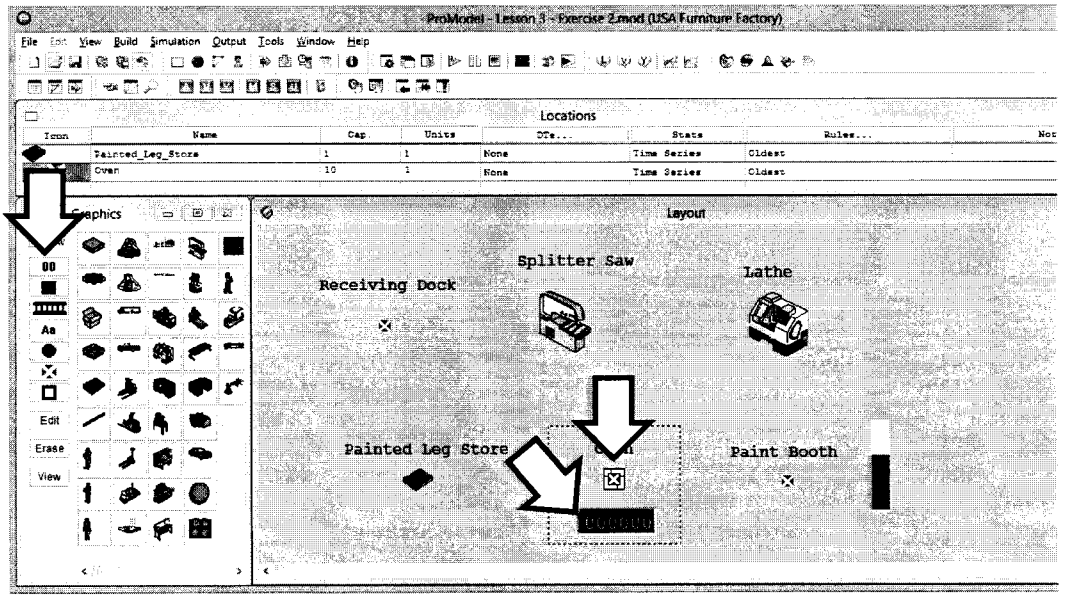


2.7. Now we will insert a way to instantly identify the contents of a location, this can be done by two components of ProModel: A gauge or a counter. We will use both for this exercise as an example. This function is indicated for locations with capacity larger than one.

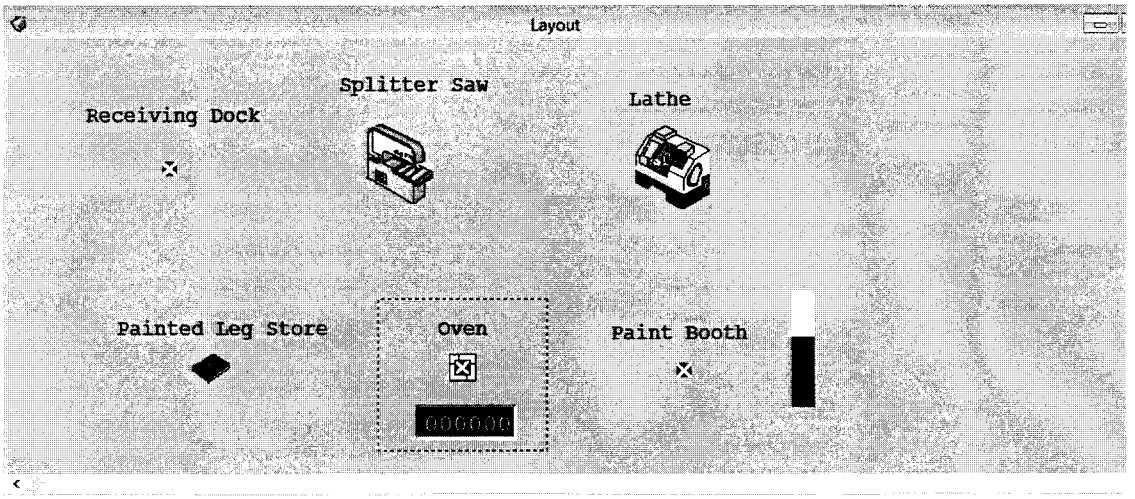
2.8. First we will insert the gauge. Make sure that the option "**New**" on the graphic window is unmarked, then select the location "Paint Booth" (1), click on the second icon of the first row of the Graphic window (2), and then click on the layout to place the gauge.



2.9. To insert the counter, click on the location "Oven" (1), click on the first icon of the first row on the Graphic Window (2), and then click on the layout to place the counter (3).



2.10. Your layout window should look approximately as the one below (or at least contain the same elements).



3. Creating entities

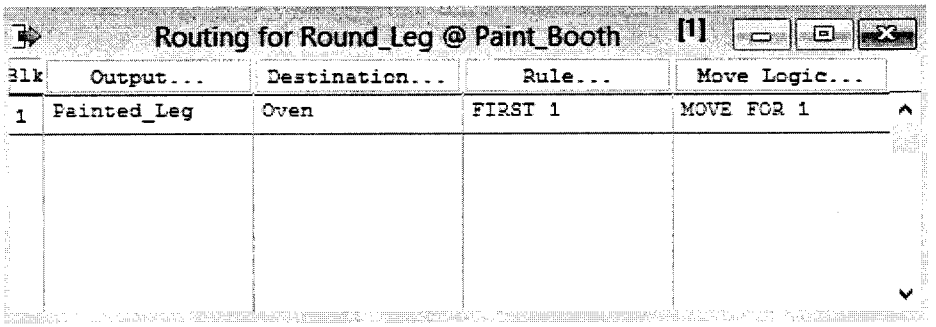
3.1. There will be no new entities for this model.

4. Creating processes

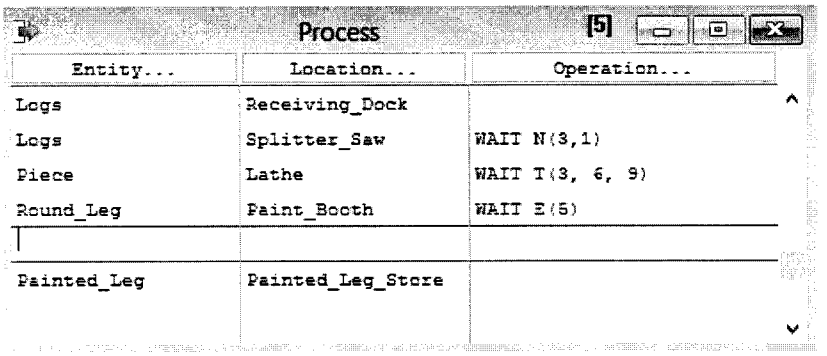
4.1. To make sure that the new location "Oven" will be used, we must make sure that it is included in the model processes as it was requested by the exercise description.

4.2. Go to the menu "**Build**" and select the option "**Processing**".

4.3. Select the fourth line of the "Process" table (the one with the entity "Round Leg" and location "Paint Booth"), and on the corresponding "Routing" table, change the destination from "Painted Leg Store" to "**Oven**". Your Routing table should look like the following.

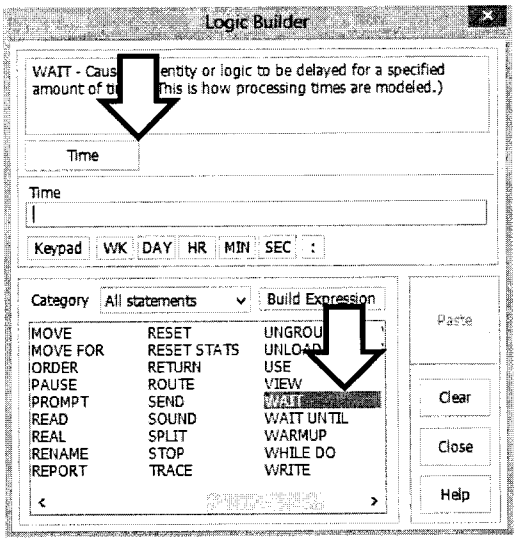


4.4. Now we must create a new entry on the process table for the "Oven" process. In order to keep the processes in order, we will use a different approach this time. Select the last row of the Process table, and then select the menu "**Edit**" from the toolbar and click on the option "**Insert**". This will create a blank row between the fourth and fifth rows. As shown on the image below.

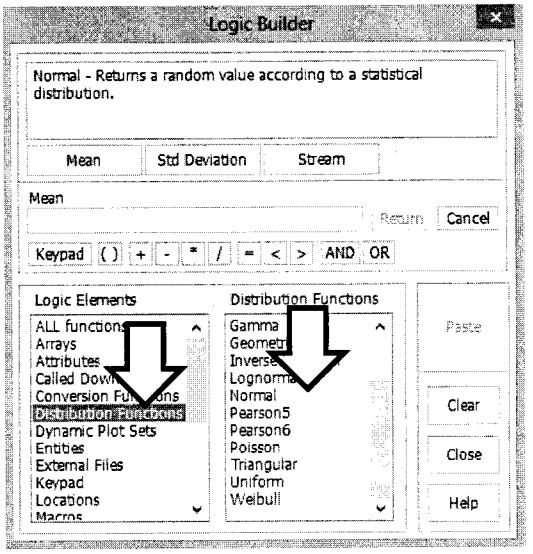


4.5. On the new row select the "**Painted Leg**" for the entity and the "**Oven**" for the location. For the operation, we will bring up the Operation window, and open the Logic Builder (Click on the hammer icon on the operation window).

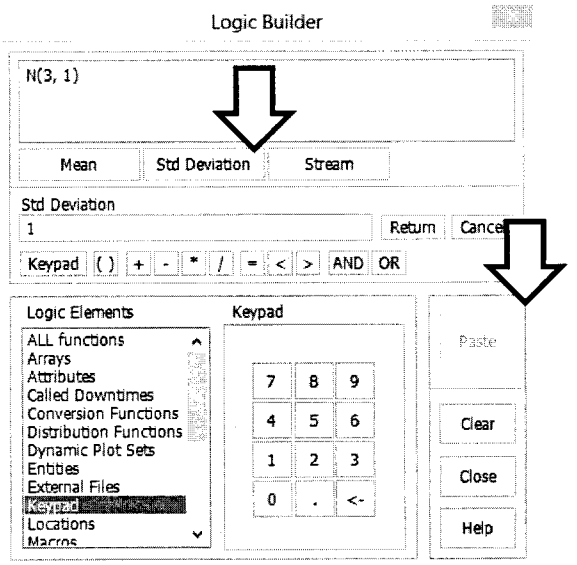
4.6. On the logic builder select the function "**WAIT**" (1) and click on the button "**Time**" (2).



4.7. Select the option "**Distribution Functions**" from the list on the left side (1), and then the option "**Normal**" from the list on the right side (2).



4.8. Type in the value **20** in the "**Mean**" text box. Hit the button "**Std Deviation**" (1) and type in the value **2** on the new text box. Click on the button "**Paste**" (2). Close the logic builder and operation windows. By doing this, you are informing ProModel, that this process has a duration equal to a Normal Distribution function with an average of 20 minutes and standard deviation of 3 minute.



4.9. Now on the "**Routing**" table, select the "**Painted Leg**" for the output, and the "**Painted Leg Store**" for the destination. On the same Routing table row, open the Move Logic window, bring up the logic builder, and inform ProModel that the entity will move for 1 minute to achieve its next location. (Step 4.6 of exercise 1)

4.10. The Processing and Routing tables should look like the following.

Process		
Entity	**Location**	**Operation**
Logs	Receiving_Dock	
Logs	Splitter_Saw	WAIT N(3,1)
Piece	Lathe	WAIT T(3,6,9)
Round_Leg	Paint_Booth	WAIT E(5)
Painted_Leg	Oven	WAIT N(20,2)
Painted Leg	Painted_Leg_Store	

Routing				
Blk	**Output**	**Destination**	**Rule**	**Move Logic**
1	Logs	Splitter_Saw	First 1	MOVE FOR 1
1	Piece	Lathe	First 2	MOVE FOR 1
1	Round_Leg	Paint_Booth	First 1	MOVE FOR 1
1	Painted_Leg	Oven	First 1	MOVE FOR 1
1	Painted_Leg	Painted_Leg_Store	First 1	MOVE FOR 1
1	Painted_Leg	Exit		

5. Creating Arrivals

5.1. There will be no need to create new arrivals for this model.

6. Defining Simulation Options, Saving, and Running the Model

6.1. Save the model.

6.2. The options will not have to be altered.

6.3. Run the model; observe the model dynamics (the entities moving, the gauge, and the counter).

6.4. Analyze the model results.

LESSON 4

This lesson will introduce the concepts of the way that statistics are shown on the ProModel output viewer. Harrel, Ghosh & Bowden (2012) describe each statistic status for the entities in the system as follows:

- **Average time in system:** The time an entity takes to pass through the system, in average.
- **Average time in move logic:** The amount of time an entity takes to travel from a location to the other, in average.
- **Average time waiting:** The amount of time an entity spent waiting for another entity or resource, in average.
- **Average time in operation:** The amount of time an entity spent being processed, in average.
- **Average time blocked:** The amount of time an entity had to wait for the following location of its path to be free, in average.

This exercise from the fourth lesson will be based on the Laboratory 2.6 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the concepts of locations, entities, arrivals, processes, and routings will be used.

The exercise is described by Harrel, Ghosh & Bowden (2012) as follows:

"At the Social Machine Shop gear blanks arriving to the shop wait in a queue (Incoming_Q) for processing on a turning center and a mill, in that order. A total of 100 gear blanks arrive at the rate of one every eight minutes. The processing times on the

turning center and mill are eight minutes and nine minutes, respectively. Develop a simulation model and run it."

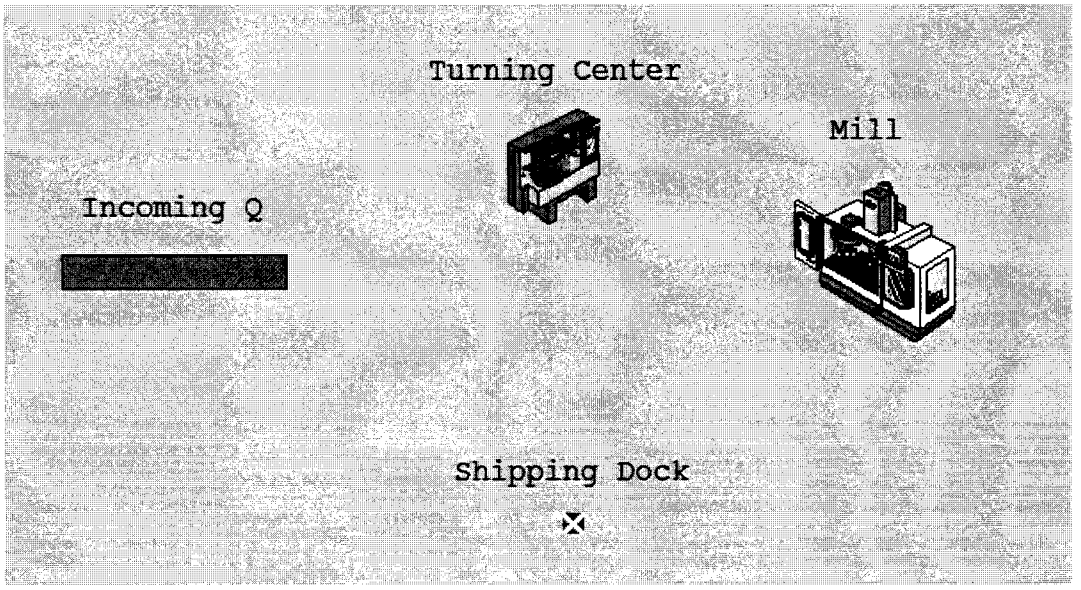
1. Creating a new model

    1.1. Select the menu "File" and then the option "New", and name your model as "**Social Machine Shop**"

2. Creating Locations

    2.1. To create the locations, first select the menu "**Build**" and then the option "**Locations**".

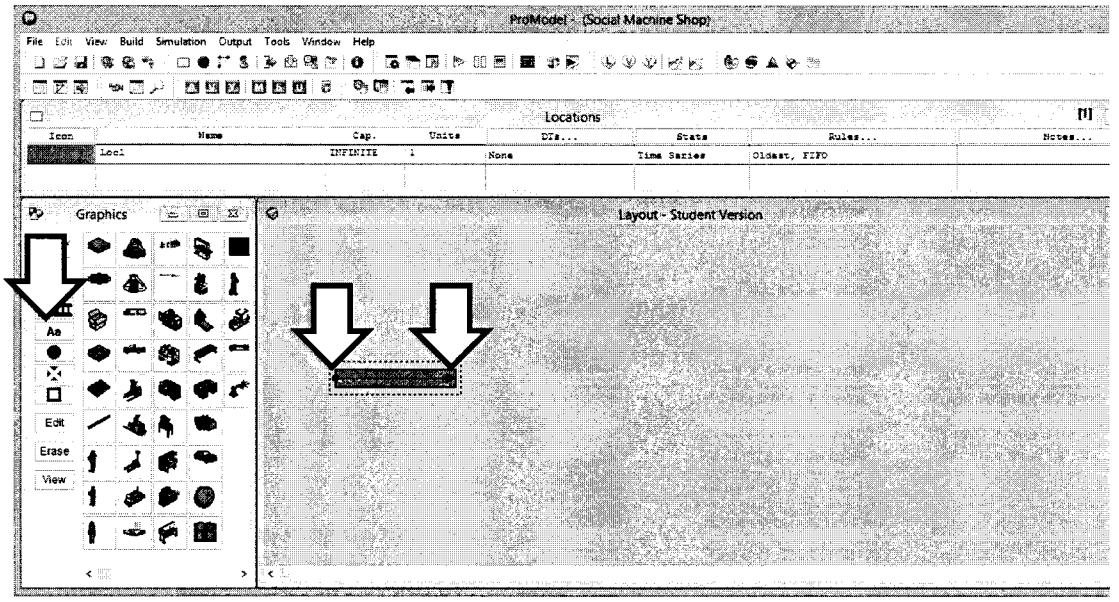
    2.2. The final model layout, should look like the following:



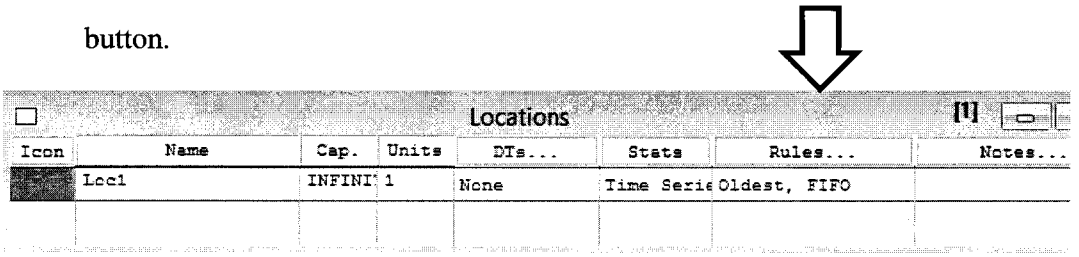
    2.3. For this model we will build four different locations with the goal to observe the "Blocking" phenomenon.

    2.4. The first location will be the incoming queue. In the Graphic window select the third icon on the first column (the one that looks like a ladder on its side) (1),

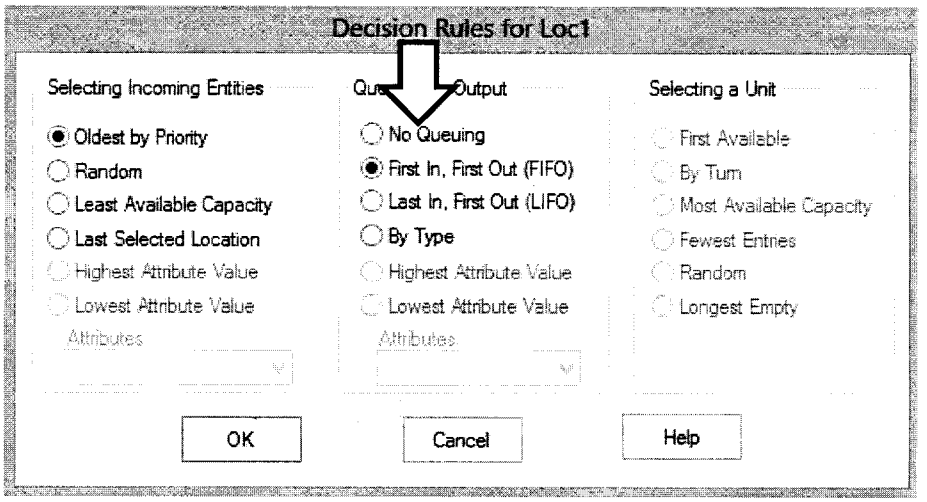
left click on the layout window to place the start of the queue (2) and then right click on a second point of the layout to indicate the end of the queue (3).



2.5. In order to observe the blocking event closer, we will have to make a few alterations on our queue. First, on the "Locations" table click on the "Rules" button.

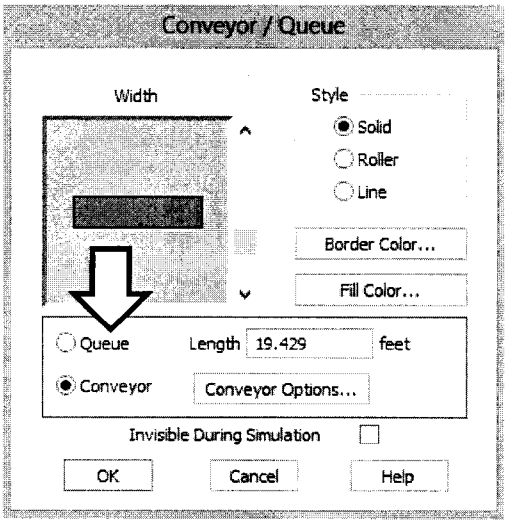


2.6. On the rules window, select the option "No Queue". And click Ok.

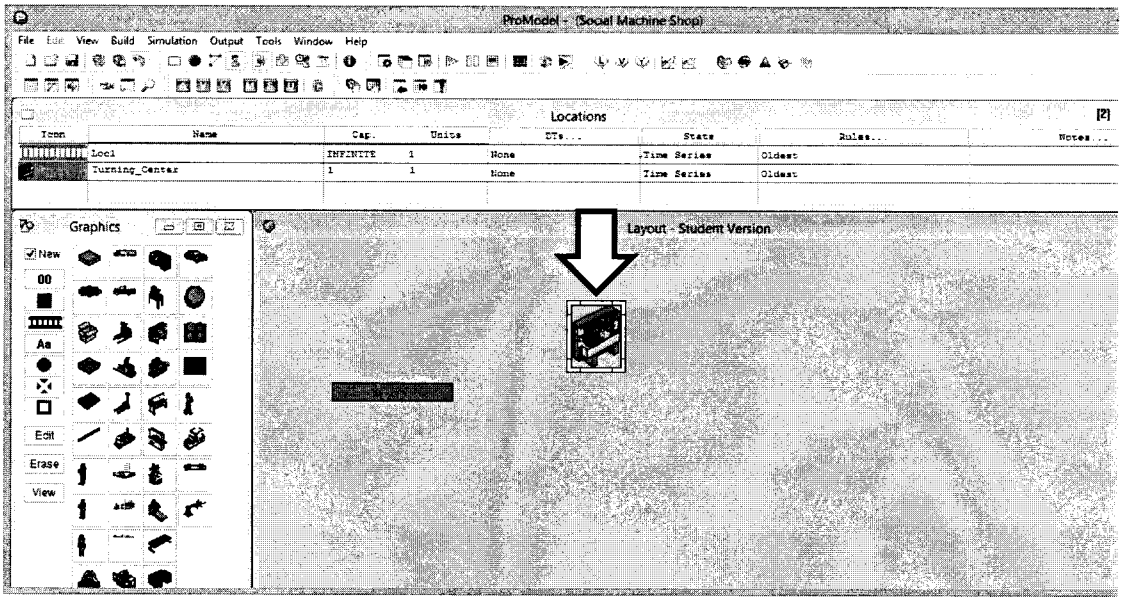


2.7. Right click on the queue graphic on the layout, and select the option "**Edit Graphic**".

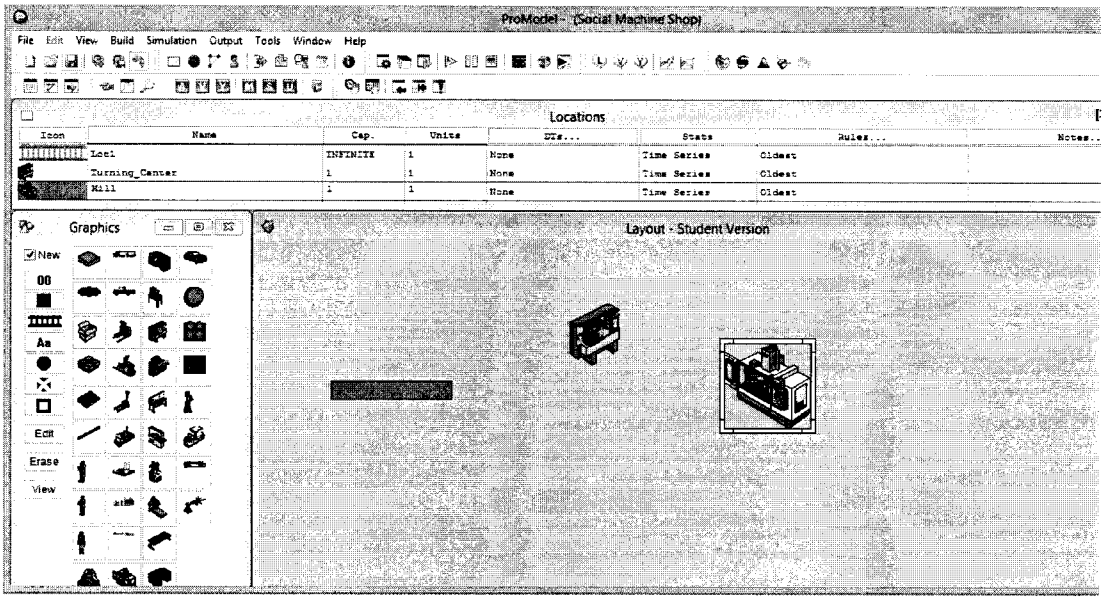
2.8. On the "Conveyor/Queue" window, select the option "**Queue**", as shown on the image below. Click on the button "Ok".



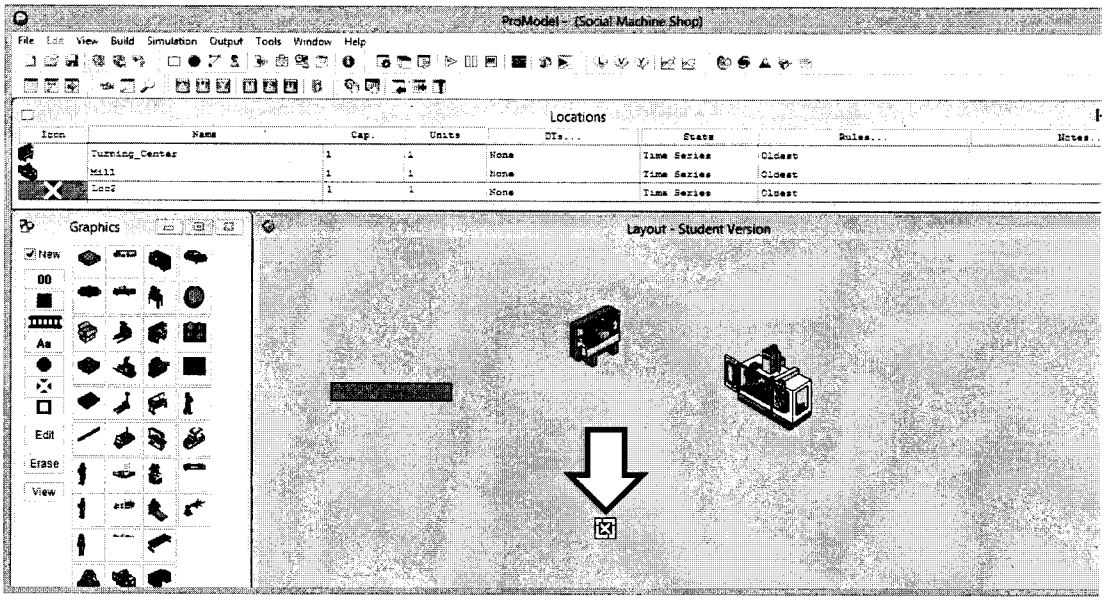
2.9. For the next location, select the third icon on the fourth column (Turning Center). Place it on the layout as shown on the image below.



2.10. For the third location, select the icon "Mill" from the Graphics window (tenth icon on the third column) and then place it on the layout as shown on the image below.



2.11. The last location will be the Shipping Dock. Select the sixth icon of the first column and place it on the layout as shown on the image below.



2.12. Rename the location "Loc1" as "**Incoming_Q**", and the location "Loc2" as "**Shipping Dock**" on the Locations table.

2.13. Place the name of the locations on the layout. Uncheck the "New" option on the Graphics window, then click on one location, click on the "Aa" button and click on the layout. Repeat the process for all the locations.

3. Creating entities

3.1. For this model we will make use of one entity: "**Gear Blank**".

3.2. To create the entity, select the menu "**Build**" and click on the option "**Entities**".

3.3. Select the second icon of the first column (The purple gear).

3.4. Rename it on the Entities window as "**Gear Blank**".

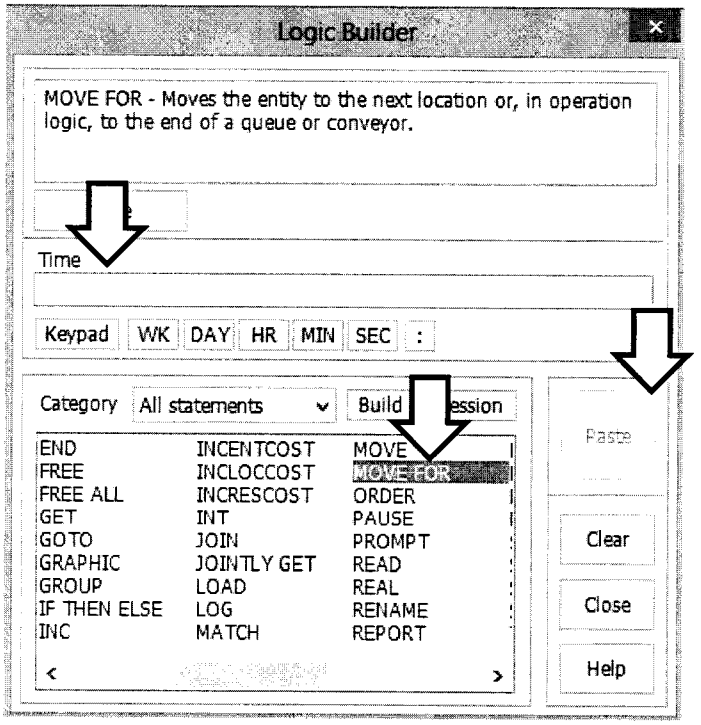
4. Creating processes

4.1. The entities in this model will arrive on the Incoming Q, then will be processed on the Turning Center, on the Mill, and then will be moved to the Shipping Dock, where they will leave the system.

4.2. To start the creation of the processes, click on the menu "**Build**" and select the option "**Processing**".

4.3. For the first process, select the "**Gear Blank**" for the entity, and the "**Incoming Q**" for the location. Open the operation window and bring up the logic builder (click on the hammer icon).

4.4. On the logic builder, select the function "**MOVE FOR**" (1), type in the value **0** (2), and hit "**Paste**" (3). This will ensure that the entities do not spend any time moving on this queue, therefore if an entity is waiting on the queue it will be considered as being blocked. Close the logic builder and the operation windows.

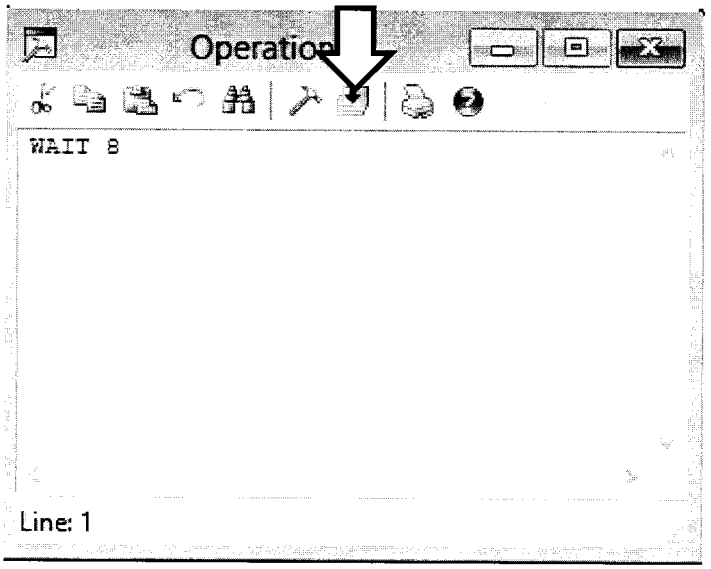


4.5. On the Routing table, select the "**Blank Gear**" as the output and the "**Turning Center**" as the destination.

4.6. Add a new row on the Process window (select the last row and hit the enter key).

4.7. On the new row, select the "**Blank Gear**" as the entity and the "**Turning Center**" as the location. Open the operation window, and input the command "**WAIT 8**" (this can be done using the logic builder as was explained in the past lessons or you can just type in the command if you feel comfortable on doing so.)

4.8. If you chose to type in the command rather than using the logic builder, it is very important that you verify if you used the correct construction and syntaxes. ProModel can tell you if your command is correct or not, just click on the "**Compile**" button (1) (the one to the right of the hammer). If your command has a correct syntax, the software will display "Compiled Successfully".



4.9. If you chose to type any of the following commands, it is VERY important that you compiled all of them before moving on, this will help you to quickly identify eventual errors in your model once it grows more complex.

4.10. On the routing window, select the "**Blank Gear**" as the output and the "**Mill**" as the destination.

4.11. Add a new row on your Process table. Select the "**Blank Gear**" as the entity and the "**Mill**" as the location. On the operation window, insert the command "**WAIT 9**".

4.12. On the Routing table, select the "**Gear Blank**" as the output and the "**Shipping Desk**" as the destination.

4.13. Add a new row to your Process table. Select the "**Blank Gear**" as the entity and the "**Shipping Dock**" as the location.

4.14. On the Routing table, select the "**Blank Gear**" as the output and the "**EXIT**" as the destination.

4.15. The Process and Routing tables should look like the following.

Process		
Entity	Location	Operation
Gear_Blank	Incoming_Q	MOVE FOR 0
Gear_Blank	Turning_Center	WAIT8
Gear_Blank	Mill	WAIT9
Gear_Blank	Shipping_Dock	

Routing				
Blk	Output	Destination	Rule	Move Logic
1	Gear_Blank	Turning_Center	FIRST 1	
1	Gear_Blank	Mill	FIRST 1	
1	Gear_Blank	Shipping_Dock	FIRST 1	
1	Gear_Blank	EXIT	FIRST 1	

5. Creating Arrivals

5.1. To create the arrivals, select the menu "**Build**" and the option "**Arrivals**".

5.2. On the Arrivals table, select the "**Gear Blank**" as the entity.

5.3. Select the "**Incoming Q**" as the location.

5.4. Input the value **1** as the Qty. Each, indicating that one entity will arrive at a time.

5.5. Input the value **0** for the First Time.

5.6. Input the value **100** for the Occurrences, meaning that 100 entities will arrive in the system.

5.7. On the frequency field, insert the value **8** (meaning that an entity will arrive each 8 minutes).

6. Defining Simulation Options, Saving, and Running the Model

6.1. Save your model.

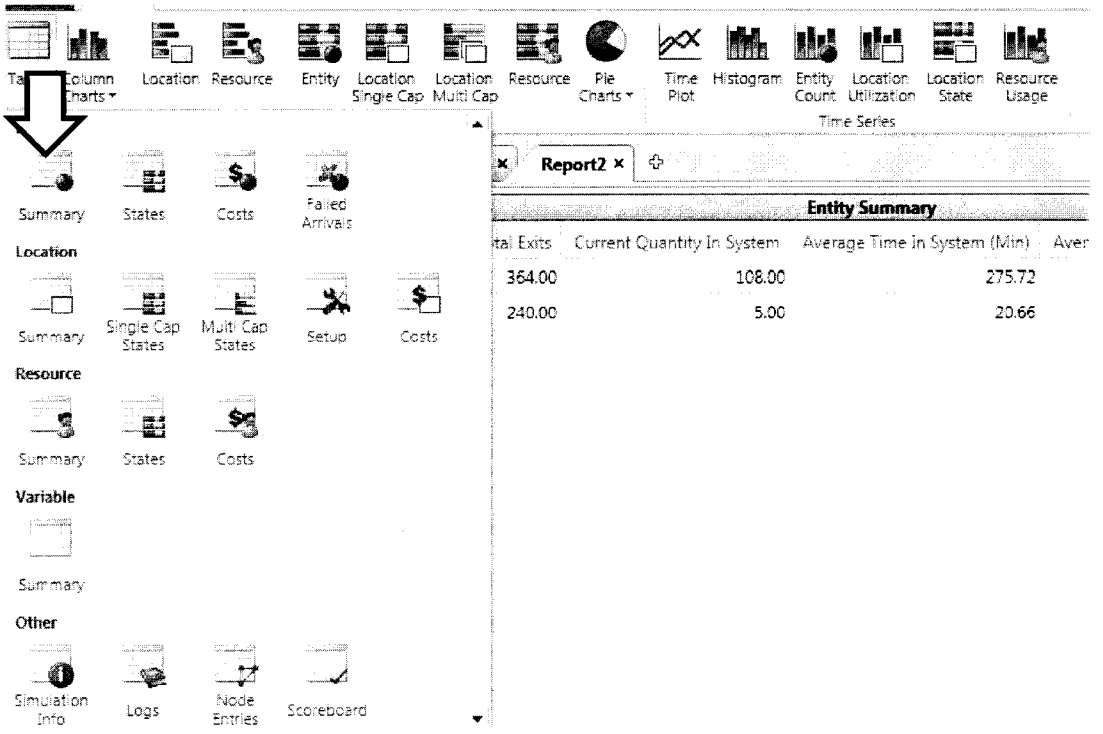
6.2. Run your model (Menu Simulation, option Run).

6.3. After your model finishes running, select the option to see the results.

7. Analyzing the results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. Analyze the Entity Summary Table. Click on the "Table" button, and under the section "Entity" select the option "Summary".



7.3. On the last column of the table it is possible to analyze the effect of "Blocking" (refer to the lab 2.6 on your textbook for a more detailed explanation about this phenomenon).

Entity Summary

Name	Total Exits	Current Quantity In System	Average Time In System (Min)	Average Time In Move Logic (Min)	Average Time Waiting (Min)	Average Time In Operation (Min)	Average Time Blocked (Min)
Gear	100.00	0.00	66.50	0.00	0.00	17.00	49.50

7.4. Can you identify what is causing the Blocking effect? (Hint: Observe the Locations Summary Table).

LESSON 5

This exercise from the fifth lesson will be based on the Laboratory 4.1 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concepts of Multiple Locations, and Multiple Entity Types.

The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"In one department at Pomona Electronics, three different printed circuit boards are assembled. Each board is routed through three assembly areas. The routing order is different for each of the boards. Further, the time to assemble a board depends on the board type and the operation. The simulation model is intended to determine the time to complete 500 boards of each type."

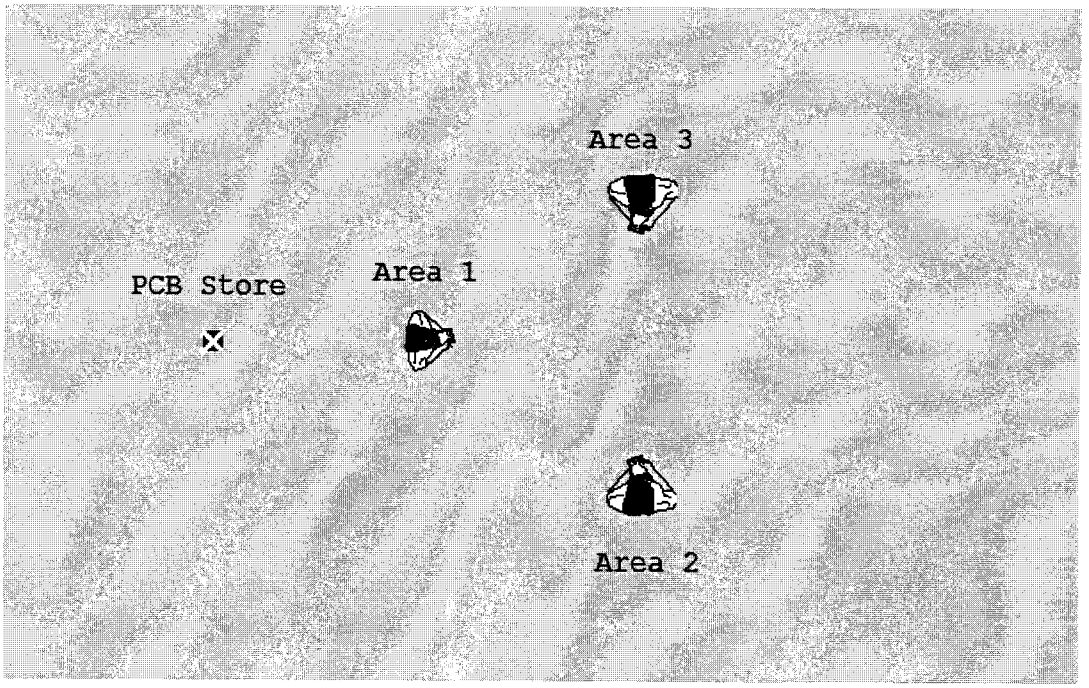
"Define three locations (area1, area2, and area3) where assembly work is done and another location, PCB_Store, where all the printed circuit boards are stored for future assembly. Assume each of the assembly areas has infinite capacity (...) Define three entities PCB1, PCB2, and PCB3. (...) Assume all 1,500 boards are in stock when the assembly operations begin. The process and routing tables"

The following table shows the process times for the different circuit boards on different locations.

Routing and Assembly Time for the Printed Circuit Boards

Printed Circuit Board 1		**Printed Circuit Board 2**		**Printed Circuit Board 3**	
Area	Mean Time	Area	Mean Time	Area	Mean Time
1	10	2	5	3	12
2	12	1	6	2	14
3	15	3	8	1	15

The following image shows the final layout of this model.



1. Creating a new model

   1.1. Select the menu "File" and then the option "New".

   1.2. On the General Information window, name your model "**Pomona Electronics**" (on the "Title" textbox).

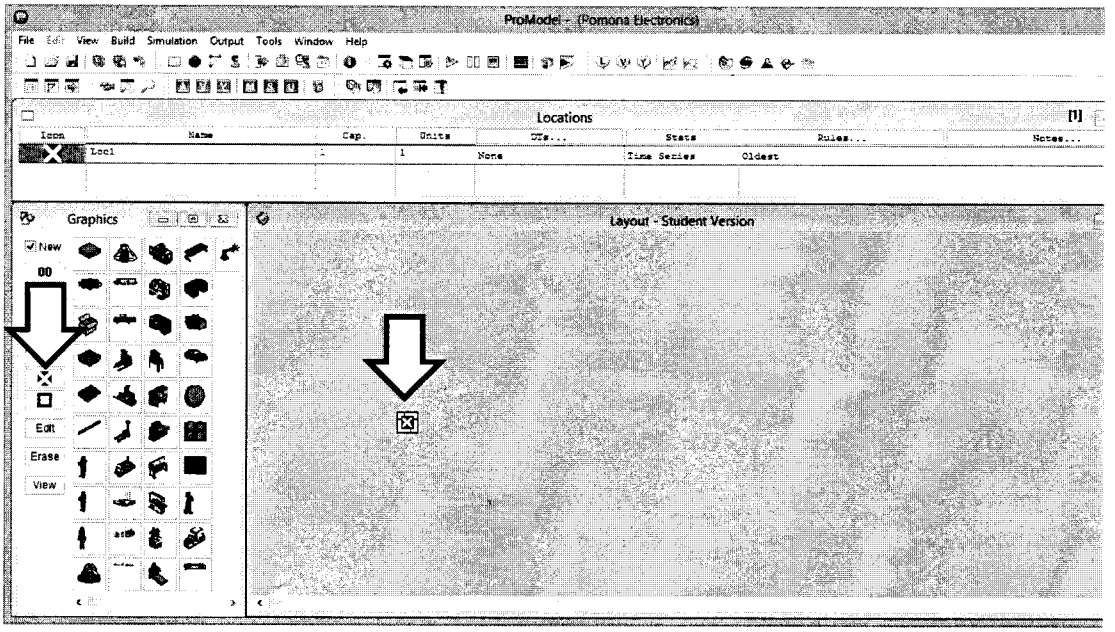
   1.3. Hit "**OK**".

2. Creating Locations

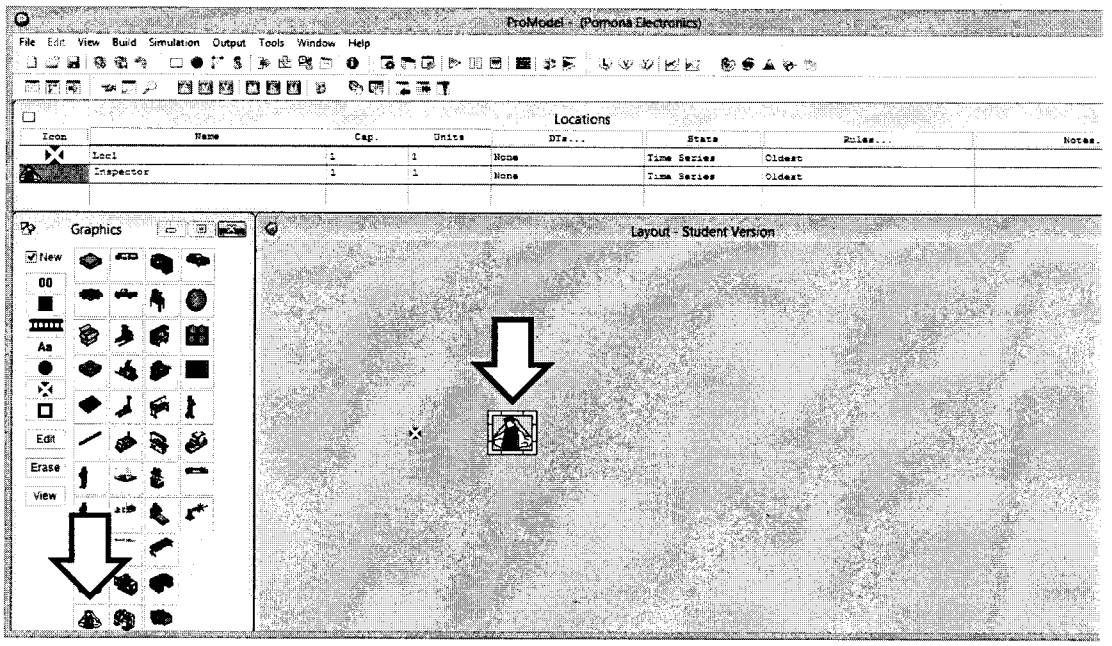
   2.1. For this exercise, four different locations will be created: PCB Store, Area 1, Area 2, and Area 3.

   2.2. To begin the locations building process select the menu "Build" and then the option "Locations".

2.3. To build the first location, select the sixth icon on the first column of the "Graphic Window" (1), and place it on the layout using the left button of your mouse (2) as shown on the image below.

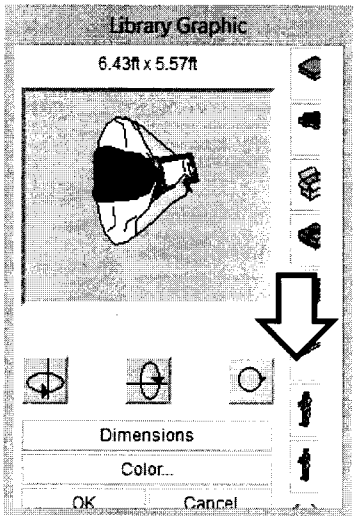


2.4. For the second location select the last icon of the second row on the "Graphic Window" (1) and position it on the layout (2)



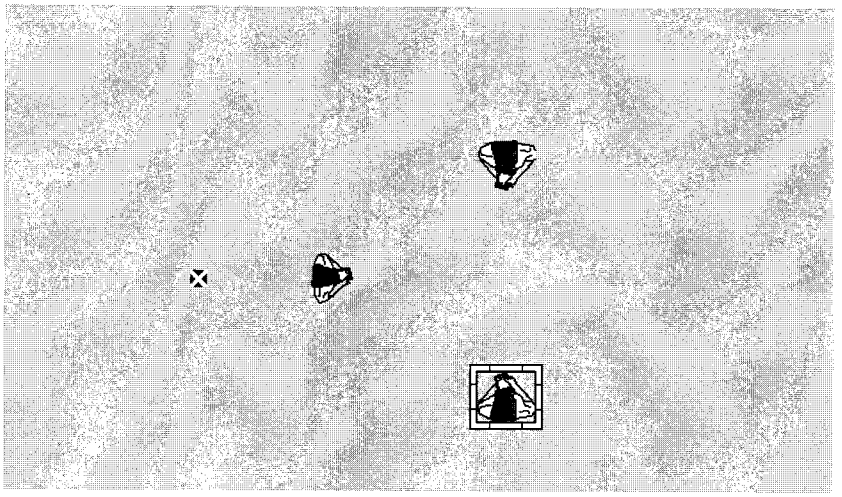
2.5. To make sure that the location looks identical as the one shown in the model layout at the beginning of the exercise it will be necessary to rotate the location until it is facing the right direction.

2.6. Right-Click on the location with your mouse and select the option "**Edit Graphic**"; on the Library Graphic window click on the third square button (1) until your image is facing right.



2.7. To create the next two locations (Area 2 and Area 3), the same process used for the last location will be used and the only difference is the direction faced by them. If you have questions, the detailed location construction process is explained on the companion video for this lesson.

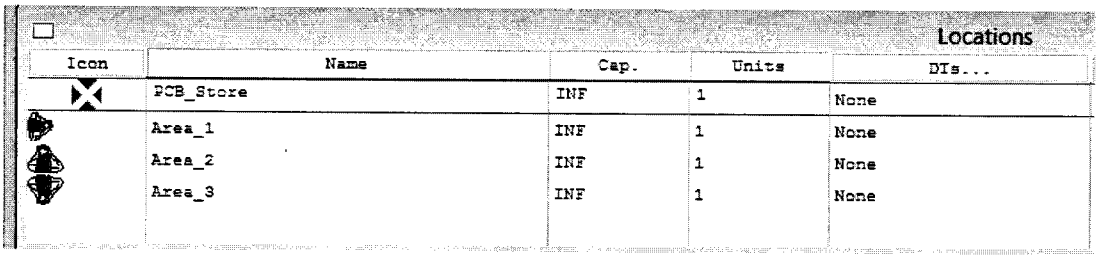
2.8. Once all the four locations are built, your layout should look like the following.



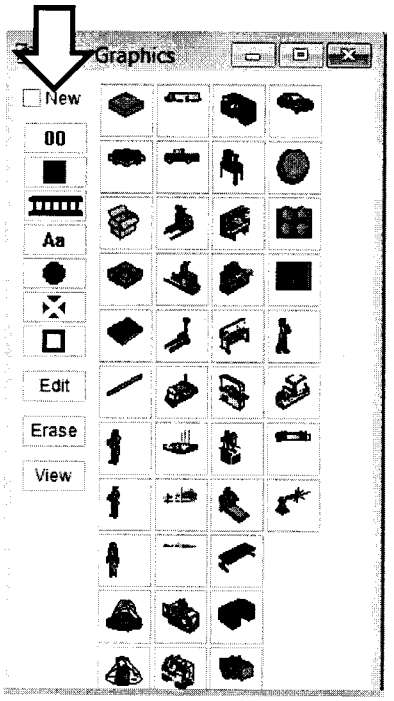
2.9. Next, rename the locations according to the model description and change their capacity (Cap.) "**INF**". To do so, on the "Locations" table, change the name of the locations according to the following:

Current Name	New Name
Loc1	PCB Store
Inspector	Area 1
Inspector2	Area 2
Inspector3	Area 3

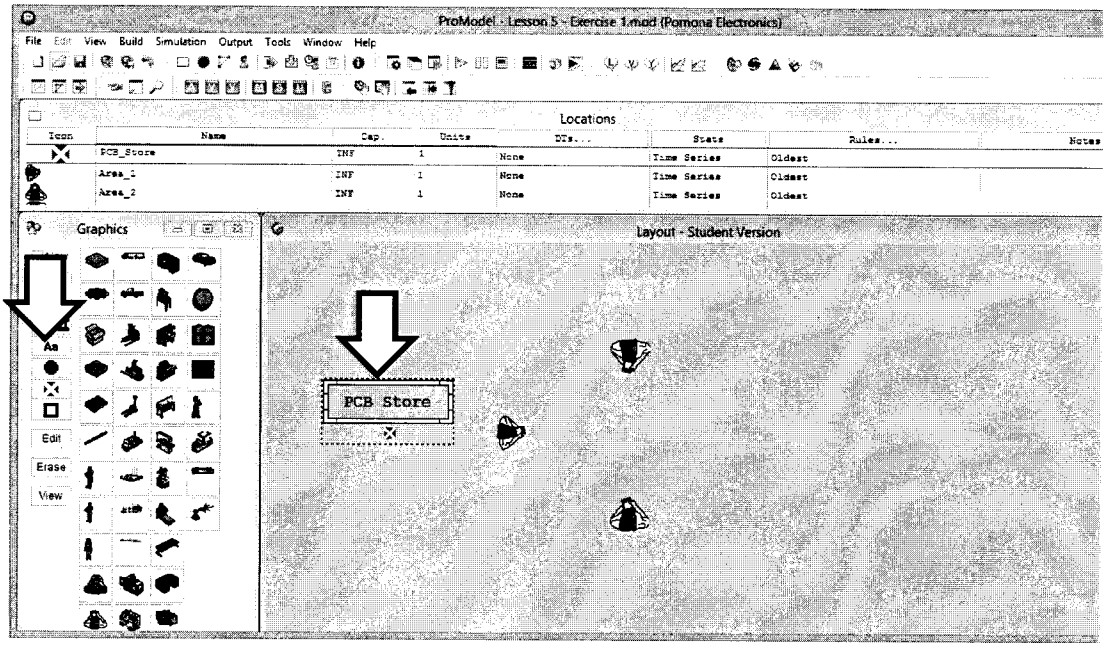
2.10. Your location table should look like the following.



2.11. Next, insert the location names. Uncheck the "New" option on the "Graphics" window (1).



2.12. Click on the location "PCB Store" on the Location Table (1), click on the "Aa" button on the Graphics Window (2), and finally click on the layout to place the name (3).



2.13. The detailed process of inserting the locations name on the layout is explained with more details on the video. Follow the steps on item 2.12 and insert the name for the other locations on the layout.

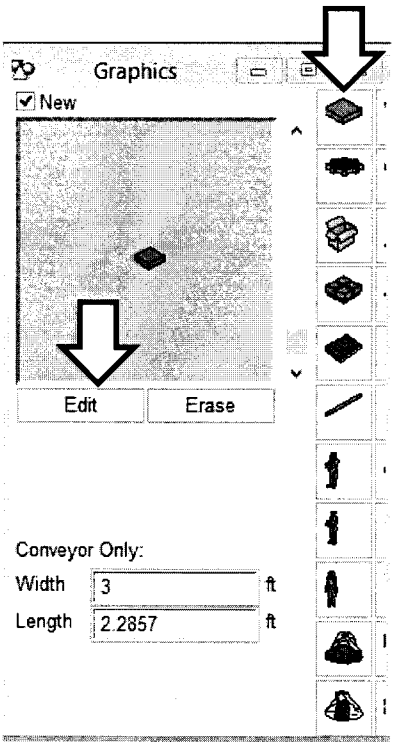
3. Creating Entities

3.1. For this model three different entities will be used: PCB1, PCB2, and PCB3.

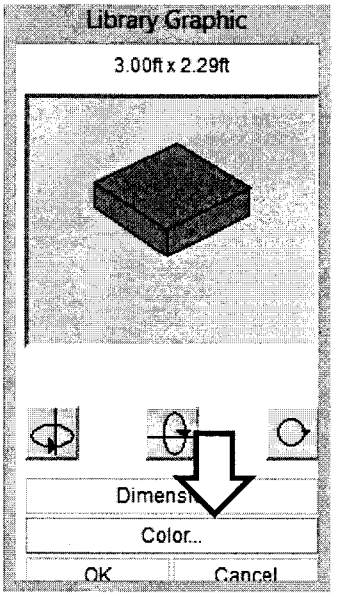
3.2. To start building the entities, select the menu "Build" and the option "Entities".

3.3. Since all the entities are circuit boards, we will use the same graphic with different colors to represent them.

3.4. Click on the first icon of the first column on the Graphics Window, in order to create the first entity (1) and then click on the button "Edit".



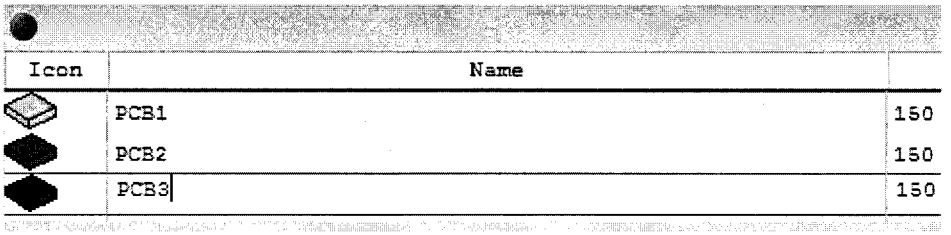
3.5. To differentiate the entities we will use different colors. On the Library Graphic window, click on the button "Color…" and pick a color for your first entity (1).



3.6. Create two additional entities: Repeat steps 3.4 and 3.5; also make sure that they have different colors.

3.7. Rename your entities on the "Entities" Table as PCB1, PCB2, and PCB3 respectively.

3.8. The Entities Table should look similar to the following.



Icon	Name	
	PCB1	150
	PCB2	150
	PCB3	150

4. Creating Processes

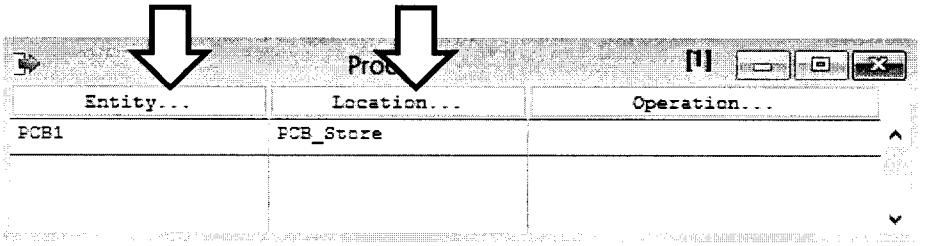
4.1. The idea is that the entities will enter the model on the location "PCB Store", then will move to the Area 1, to the Area 2, to the Area 3, and finally will leave the model. The entities will suffer some sort of processing in the locations Area 1, Area 2, and Area 3. The processing times for each location and entity are shown on the table below.

Routing and Assembly Time for the Printed Circuit Boards

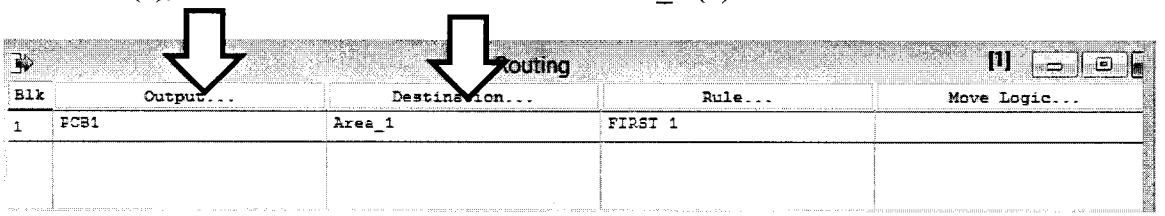
Printed Circuit Board 1		**Printed Circuit Board 2**		**Printed Circuit Board 3**	
Area	Mean Time	Area	Mean Time	Area	Mean Time
1	10	2	5	3	12
2	12	1	6	2	14
3	15	3	8	1	15

4.2. First we will create the processes that involve the entity PCB1. Select the menu "Build" and then the option "Processing".

4.3. On the "Process" table, click on the first row. Click on the button "Entity" and select the entity **PCB1** (1), click on the button "Location" and select **PCB_Store** (2).

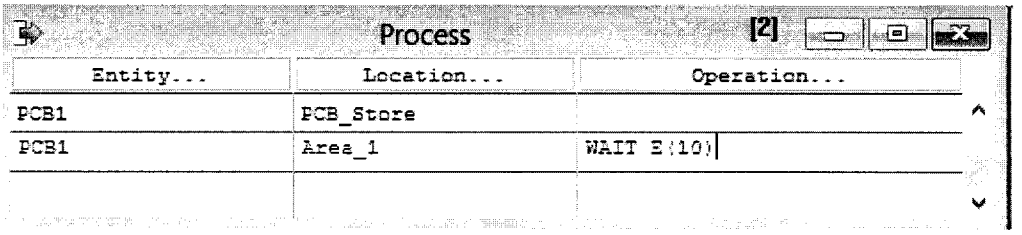


4.4. On the "Routing Table": click on the button "Output" and select the entity **PCB1** (1), click on "Destination" and select **Area_1** (2).

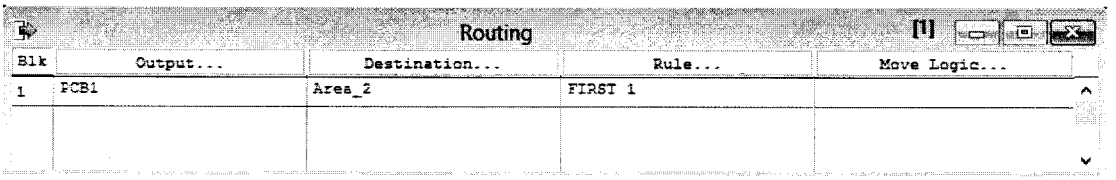


4.5. Back on the Process table, select the first row and hit the Enter key to add a new row. On the new row, select **PCB1** for the entity (click on the entity button) and select **Area_1** for the location.

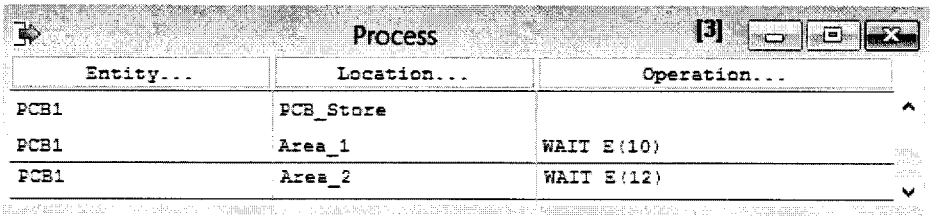
4.6. Next, open the "Operation" window (click on the operation button on the Process table). Here we will tell ProModel that the entity PCB1 will be processed on the location Area_1 for a period equal to an exponential distribution with mean of 10 minutes. To do it, type in the command "**WAIT E(10)**" (Without the ""). It is also possible to use the logic builder (Hammer Icon) if you prefer. The second row of your process table should look like the following.



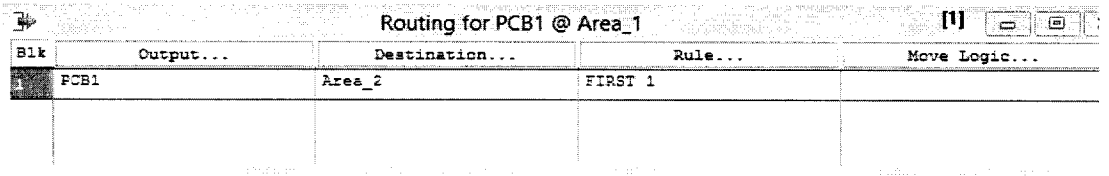
4.7. Move to the Routing table. Select the **PCB1** for as the Output and the location **Area_2** as the destination.



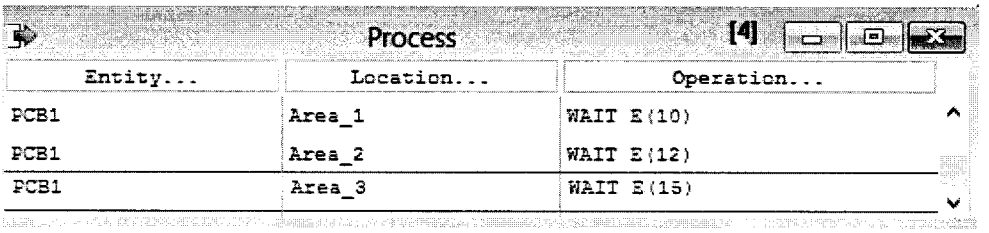
4.8. Add a new line to the Process Table (Select its last row and hit the enter key). Select the **PCB1** as the Entity, and **Area_2** as the Location. Open the Operation Window and type in the command **WAIT E(12)** (Meaning that the entity will be processed for a period of time equal to an exponential distribution with mean 12).



4.9. On the Routing Table, select the **PCB1** as the Output, and the location **Area_3** as the Destination.

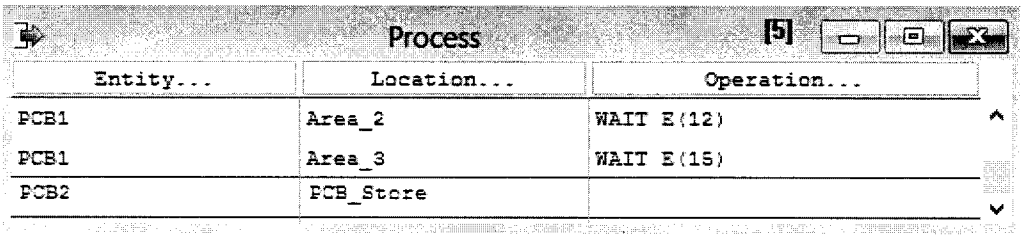


4.10. Add a new row to the Process Table. Select the Entity **PCB1**, and the Location **Area_3**. On the Operation Window, insert the command **WAIT E(15)** .

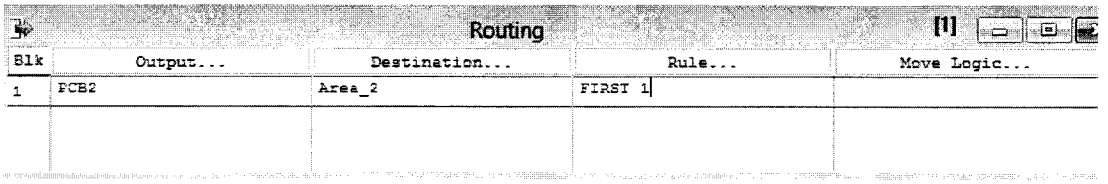


4.11. On the Routing Table, select the **PCB1** as the Output, and the **EXIT** as the Destination. This concludes the processing logic for the entity PCB1, now we will program similar processing logics to PCB2.

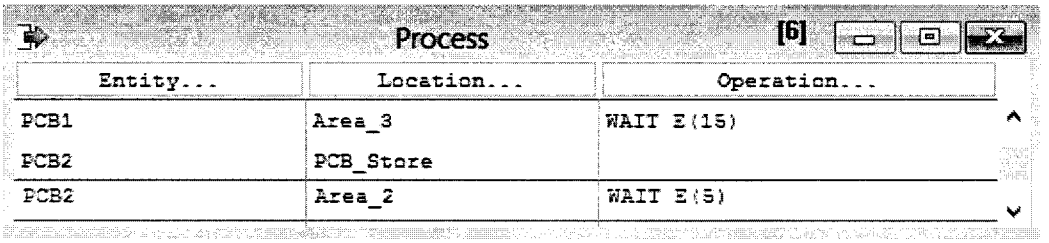
4.12. Add a new row to your Process Table. Select **PCB2** as the Entity and **PCB_Store** as the location.



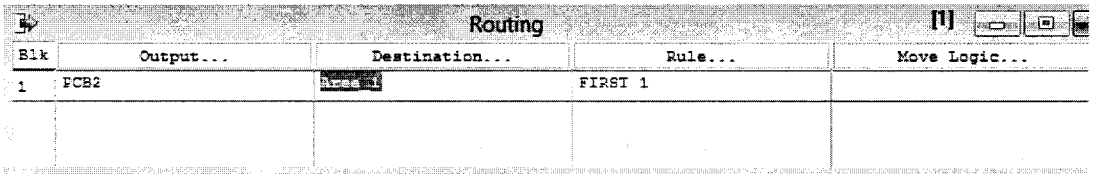
4.13. On the Routing Table, select **PCB2** as the Output, and **Area_2** as the Destination.



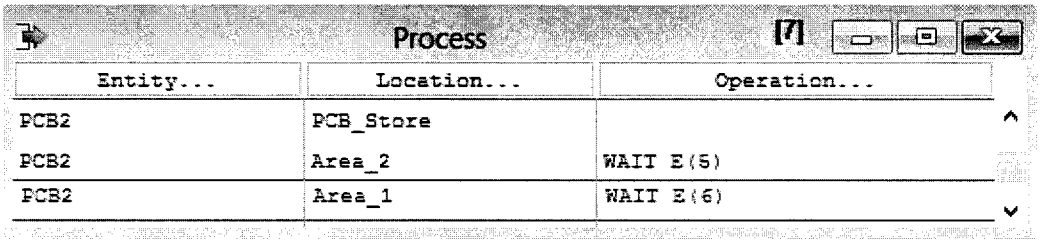
4.14. Add a new row to your Process Table. Select **PCB2** as the Entity, and **Area_2** as the Location. On the Operation Window insert the command **WAIT E(5)** – this tells ProModel that the entity PCB2 will be processed on the location Area_1 for a time equal to an exponential distribution with mean equal to 5.



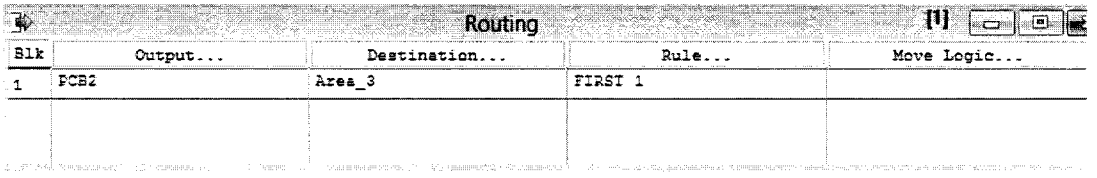
4.15. On the Routing Table, select **PCB2** as the Output and **Area_1** as the Destination.



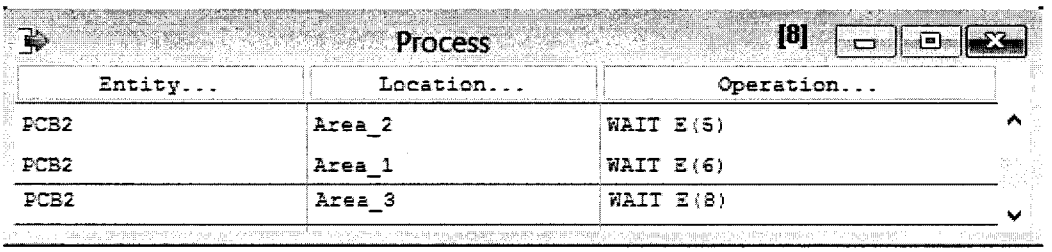
4.16. Add a new Row to your Process Table. Select the **PCB2** as the Entity and **Area_1** as the Location. On the Operation Window type in **WAIT E(6)**.



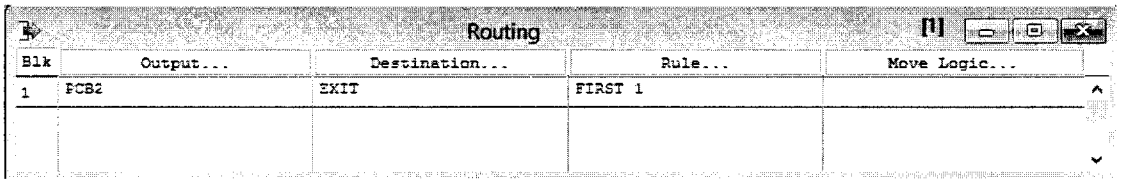
4.17. On the Routing Table, select the **PCB2** as the Output and the **Area_3** as the Destination.



4.18. Add a new row to your Process Table. Select the **PCB2** as the Entity and the **Area_3** as the Location. On the Operation Window, type the command **WAIT E(8)**.



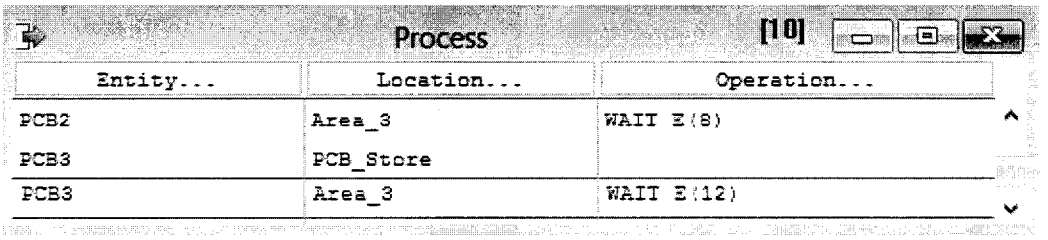
4.19. On the Routing Table select the **PCB2** as the Output, and the **EXIT** as the Destination. This concludes the processing of the entity PCB2.



4.20. Add a new row to the Process Table. Select **PCB3** as the Entity and **PCB_Store** as the Location.

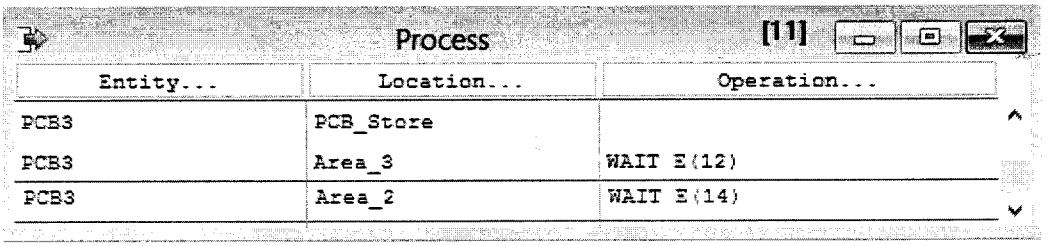
4.21. On the Routing Table, select **PCB3** as the Output and **Area_3** as the Destination.

4.22. Add a new row to the Process Table. Select **PCB3** as the Entity and **Area_3** as the Location. On the Operation Window type in the command **WAIT E(12)**.



4.23. On the Routing Table. Select **PCB3** as the Output and **Area_2** as the Destination.

4.24. Create a new row on the Process Table. Select **PCB3** as the Entity, and **Area_2** as the Location. On the Operation Window insert the command **WAIT E(14)** .



4.25. On the Routing Window. Select **PCB3** as the Output and **Area_1** as the Destination.

4.26. Add a new row to the Process Window. Use **PCB3** as the Entity and **Area_1** as the Location. On the Operation Window, type the command **WAIT E(15)** .

4.27. On the Routing Window select the **PCB3** as the Output and **EXIT** as the Destination. This concludes the Processing Logic of the model. If you have any questions, a more dynamic and complete explanation is available on the video companion.

4.28. The final Process and Routing Tables should look like the following.

Process		
Entity	**Location**	**Operation**
PCB1	PCB_Store	
PCB1	Area_1	WAIT E(10)
PCB1	Area_2	WAIT E(12)
PCB1	Area_3	WAIT E(15)
PCB2	PCB_Store	
PCB2	Area_2	WAIT E(5)
PCB2	Area_1	WAIT E(6)
PCB2	Area_3	WAIT E(7)
PCB3	PCB_Store	
PCB3	Area_3	WAIT E(12)
PCB3	Area_2	WAIT E(14)
PCB3	Area_1	WAIT E(15)

Routing				
Blk	**Output**	**Destination**	**Rule**	**Move Logic**
1	PCB1	Area_1	FIRST 1	1
1	PCB1	Area_2	FIRST 1	1
1	PCB1	Area_3	FIRST 1	1
1	PCB1	EXIT	FIRST 1	1
1	PCB2	Area_2	FIRST 1	1
1	PCB2	Area_1	FIRST 1	1
1	PCB2	Area_3	FIRST 1	1
1	PCB2	EXIT	FIRST 1	1
1	PCB3	Area_3	FIRST 1	1
1	PCB3	Area_2	FIRST 1	1
1	PCB3	Area_1	FIRST 1	1
1	PCB3	EXIT	FIRST 1	1

5. Creating Arrivals

5.1. Once three entities are being used in this model, it will be necessary to create three different entries for the arrival table. In order to do so, select the menu Build, and the option Arrivals.

5.2. To create the first entry, click on the first row of the "Arrivals Table"

5.3. For the Entity, select **PCB1** (1), for the Location select **PCB_Store** (2), for the Qty Each input the value **500** (3), for the First Time insert the value **0** (4), for Occurrences insert the value **1** (5), and for Frequency input the value **0** (6).

5.4. Add a new row to the Arrivals Table and create an entry for the entity **PCB2** with the same values used for the first row.

5.5. Create a new row on the Arrivals Table and repeat the process for the entity **PCB3**.

5.6. The arrivals table should look like the following.

Arrivals [3]

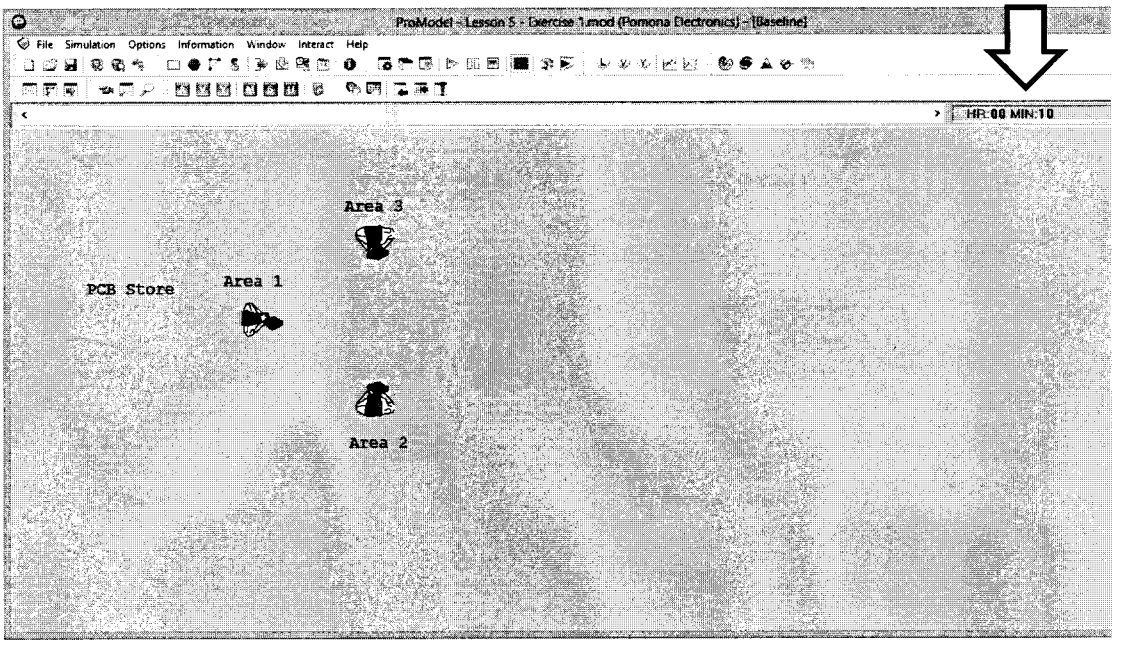
Entity...	Location...	Qty Each...	First Time...	Occurrences	Frequency	Logic...
PCB1	PCB_Store	500	0	1	0	
PCB2	PCB_Store	500	0	1	0	
PCB3	PCB_Store	500	0	1	0	

6. Defining Simulation Options, Saving, and Running the Model

6.1. Save your model (Menu File, Option Save).

6.2. Run your model. Select the menu Simulation, and the option Run.

6.3. How long did your model take to finish running (Simulation Time, not real time – check image below to see where the simulation time is shown).



6.4. After your model finished running the time displayed on the clock should be equal (or very close to) 2 hours and 27 minutes.

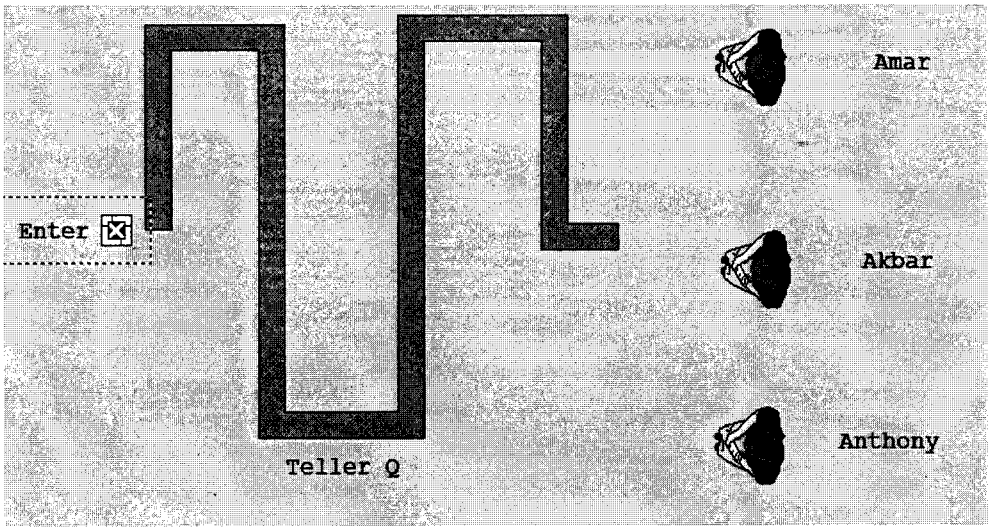
LESSON 6

This exercise from the sixth lesson will be based on the Laboratory 4.4 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concepts of Routing Rules.

The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"Amar, Akbar, and Anthony are three tellers in the local branch of Bank of India. (...) Assume that customers arrive at the bank according to a uniform distribution (mean of five minutes and half-width of four minutes). All the tellers service the customers according to another uniform distribution (mean of 10 minutes and half width of 6 minutes). However, the customers prefer Amar to Akbar, and Akbar over Anthony. If the teller of choice is busy, the customers chose the first available teller. Simulate the system for 200 customer service completions. Estimate the teller's utilization (percentage of time busy)."

The authors also inform that the locations used for this model will be defined as Akbar, Anthony, Amar, Teller_Q, and Enter. The teller queue (Teller_Q) is 100 feet long. Your final layout should look like the following image.



1. Creating a new model

   1.1. Select the menu "File" and then the option "New".

   1.2. On the General Information window, name your model "**Bank of India**" (on the "Title" textbox).

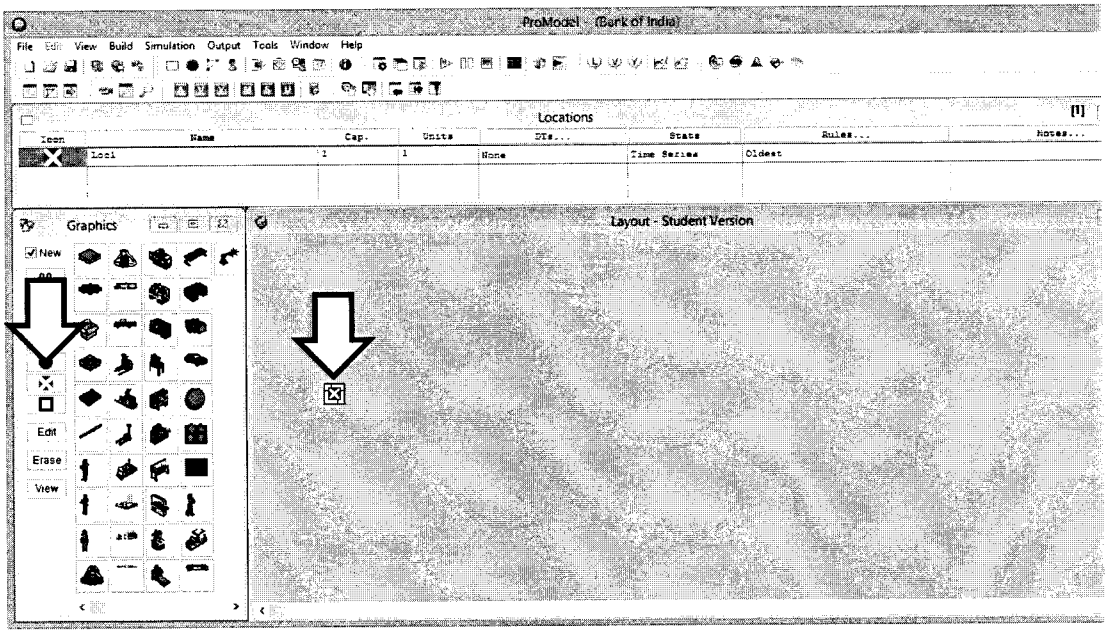
   1.3. Hit "**OK**".

2. Creating Locations

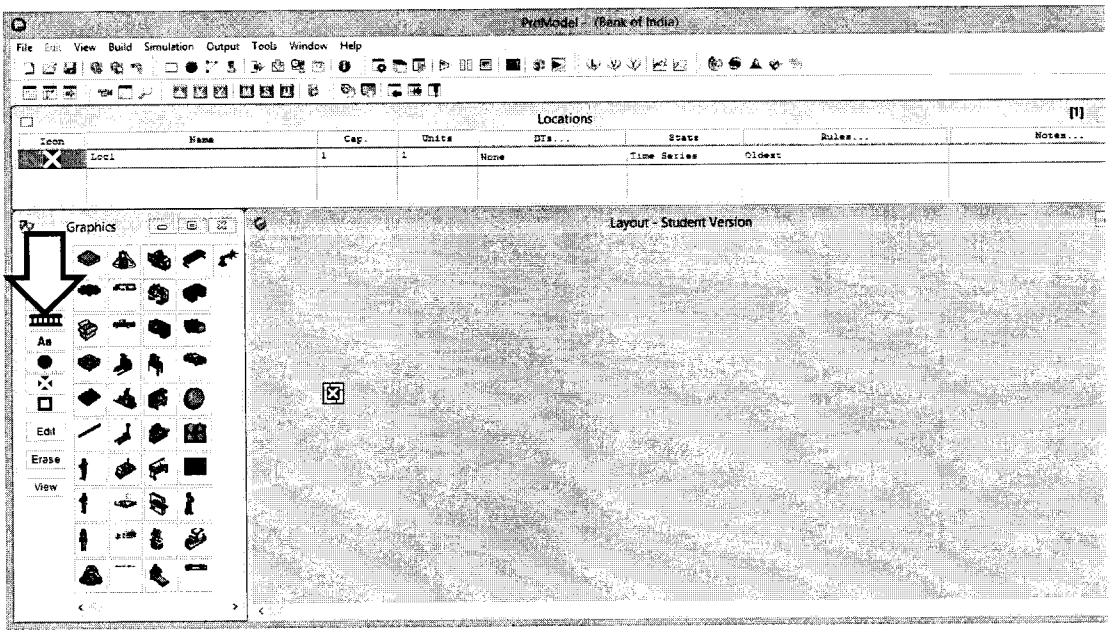
   2.1. For this exercise, five different locations will be created: Enter, Teller_Q, Amar, Akbar, and Anthony.

   2.2. To begin the locations building process select the menu "Build" and then the option "Locations".

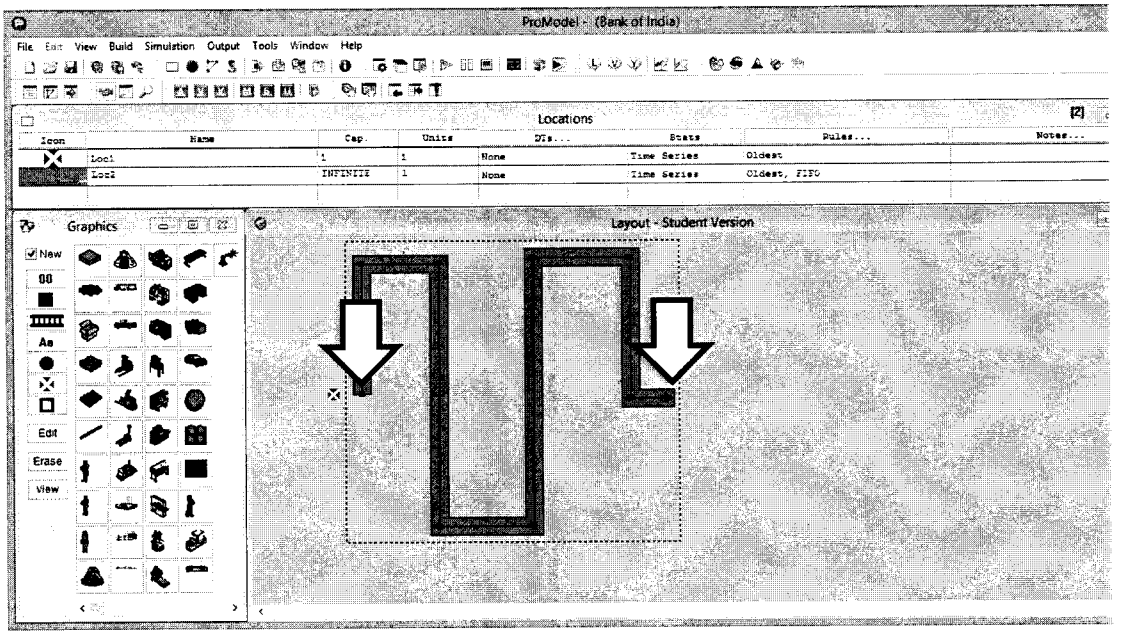
   2.3. To build the first location: select the sixth icon on the first column of the "Graphic Window" (1), and place it on the layout using the left button of your mouse (2) as shown on the image below.



2.4. The second location to be created will be the "Teller Q". The creation of the location involves a little more than just selecting an icon and placing it on the layout. First, select the third icon on the first column of the Graphics window.

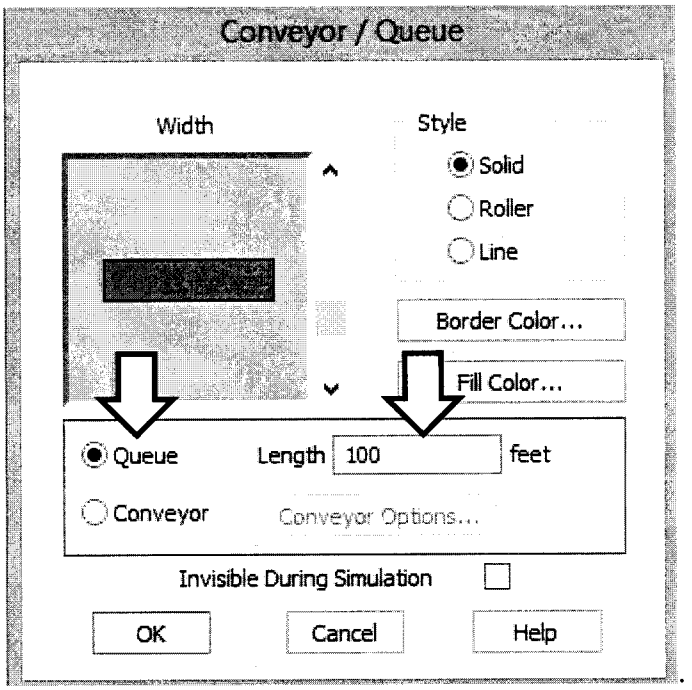


2.5. Next, click with the left button of your mouse where the Queue will start (1). Add the corners of the queue, use your left mouse button until your queue resembles the one shown on the initial layout image. To finish your queue, click with the right button of your mouse where the queue will end (2). Do not worry if your queue does not look exactly the same as the one used in this example.

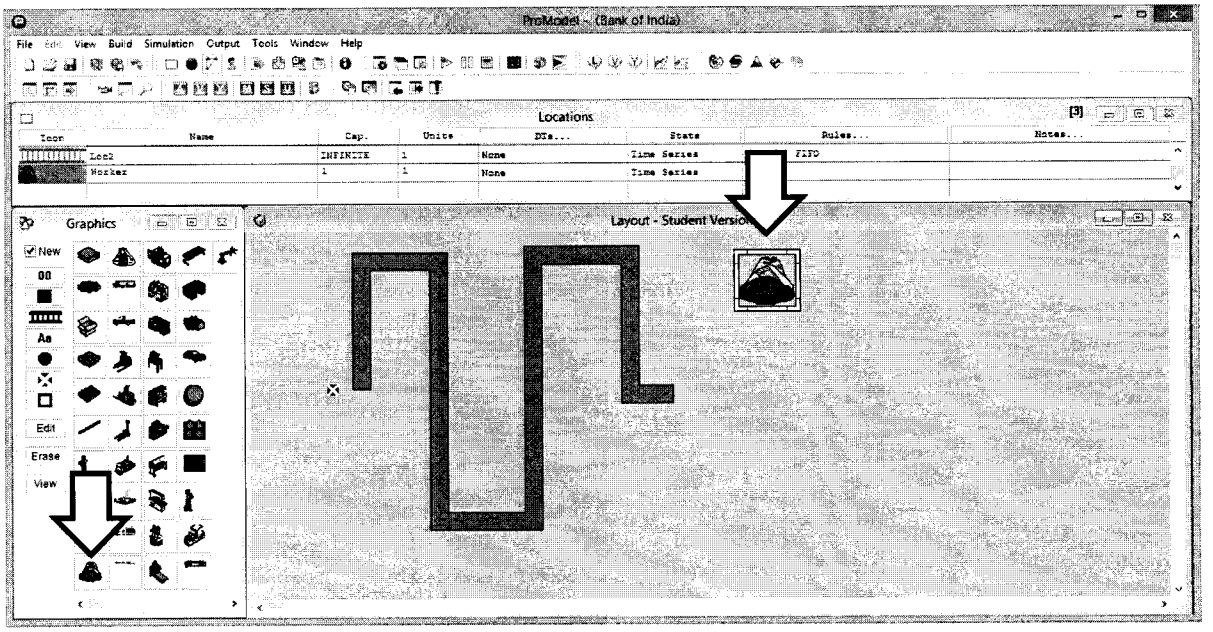


2.6. When you create this type of location, ProModel will always assume that it is a Conveyor. In order to inform ProModel that this location is a Queue with a length of 100 feet, right click on the location that was just placed on the layout and select the option "Edit Graphic" from the menu.

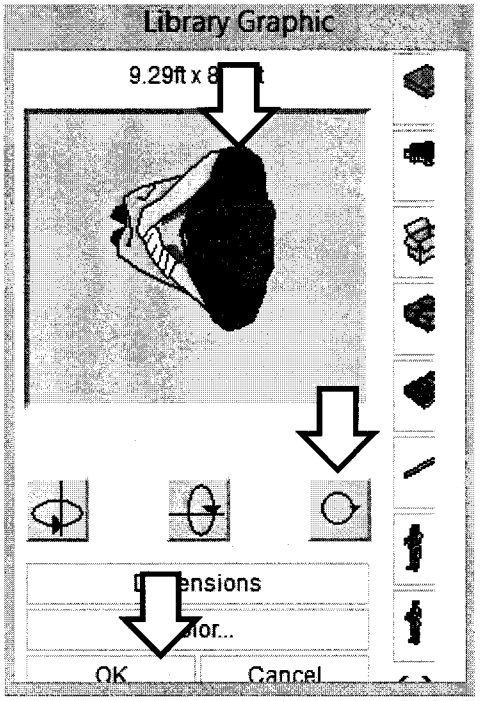
2.7. On the new Conveyor/Queue window, select the option "Queue" (1) and change the length value to 100 (2)



2.8. Now the final three locations will be added. Select the tenth icon on the second column of the Graphics window (1) and place it on the layout (2)

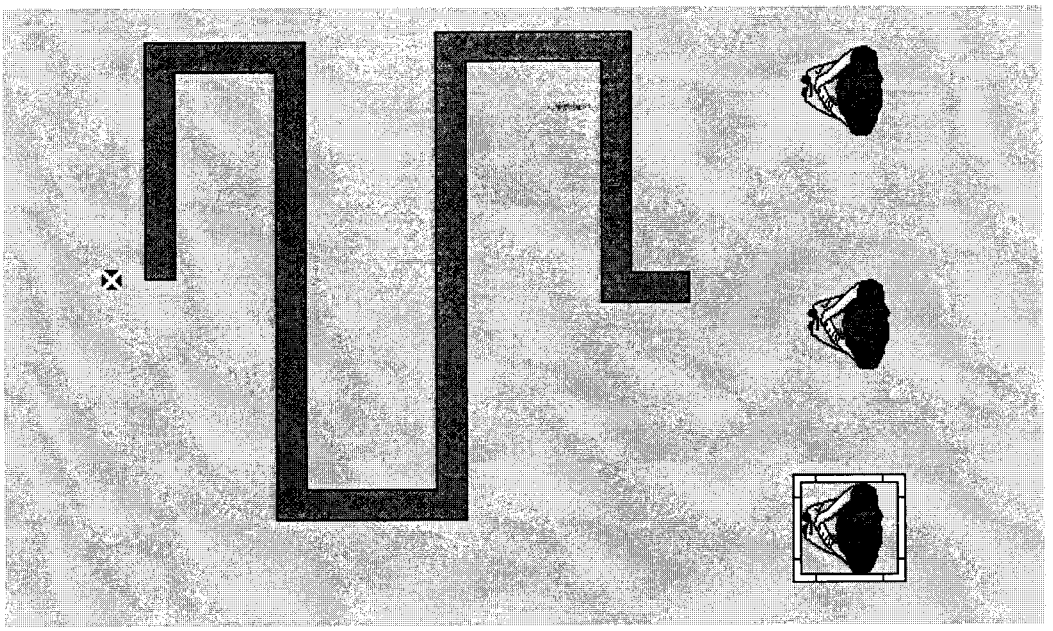


2.9. Rotate the Graphic so it is facing the Queue: right-click on the location icon and select the option "Edit Graphic". On the Library Graphic window, click on the third rotate button (1) three times until the location is facing left (2). Click Ok to close the window (3)



2.10. Repeat steps 2.7 and 2.8 to create two additional Tellers. Feel free to change their colors or icons if you would like. This step will be shown in details on the companion video.

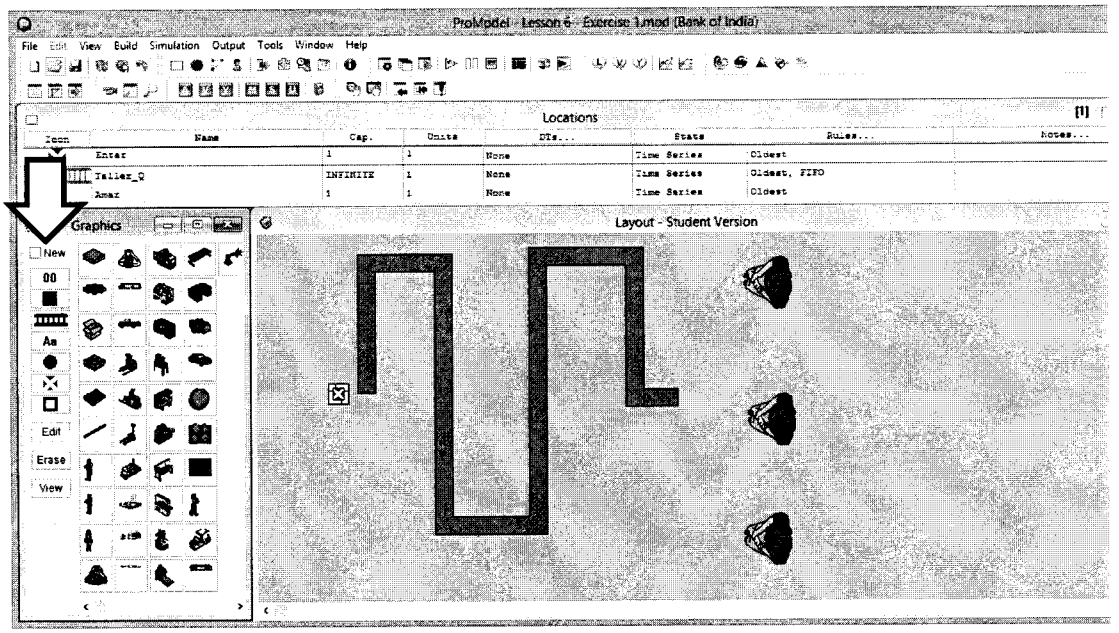
2.11. Your layout should look similar to the following image.



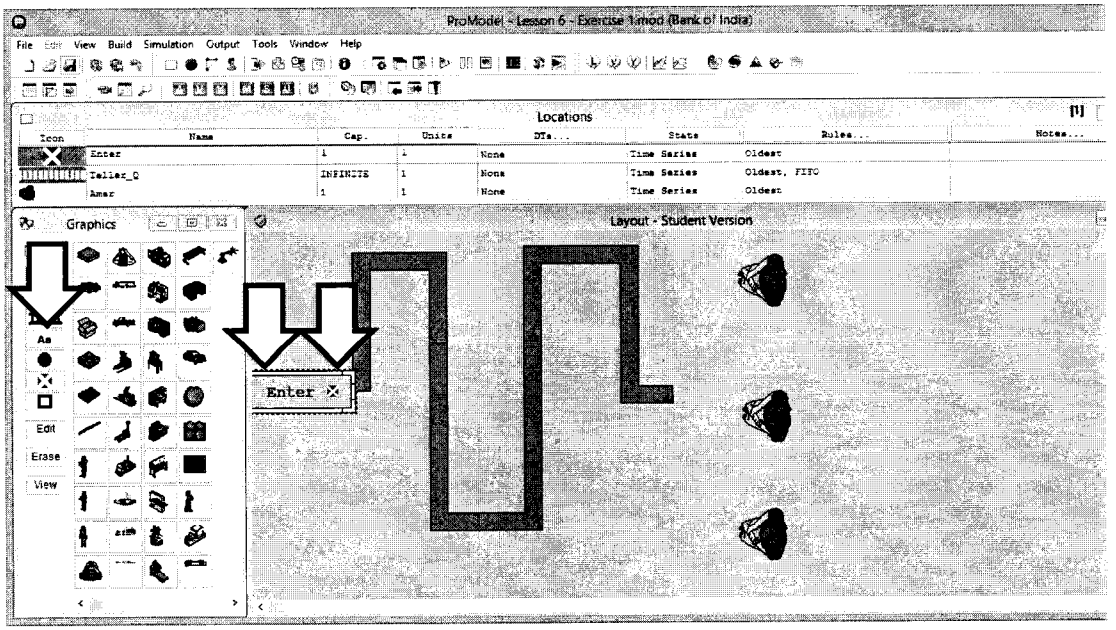
2.12. On the Locations table, rename your locations following the list below. Notice that if you used different icons on the creation of the model, some of the Original Names may be different than the ones shown on the list.

Original Name	New Name
Loc1	Enter
Loc2	Teller_Q
Worker (top of the layout)	Amar
Worker2 (between the two tellers)	Akbar
Worker3 (bottom of the layout)	Anthony

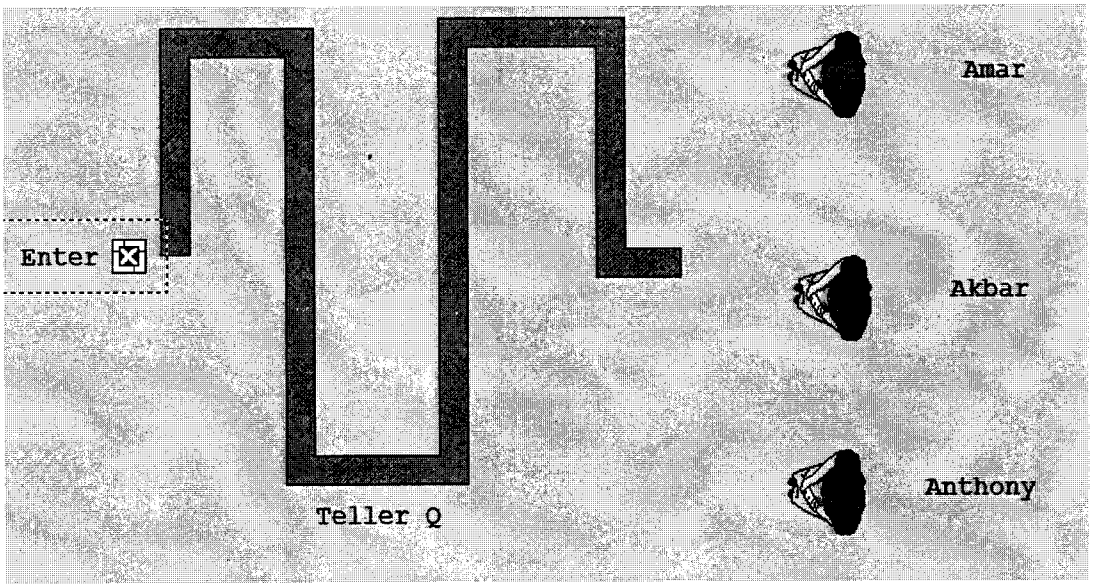
2.13. Insert the locations' names on the layout. To do so uncheck the option "New" on the Graphics window.



2.14. Click on one location on the layout (1), click on the button "Aa" on the Graphics window (2), and click on the layout to insert the location name (3).



2.15. Repeat step 2.14 and insert the names of all the other locations on the layout. Your final layout should resemble the following. It is important that the teller names are shown in the same order.

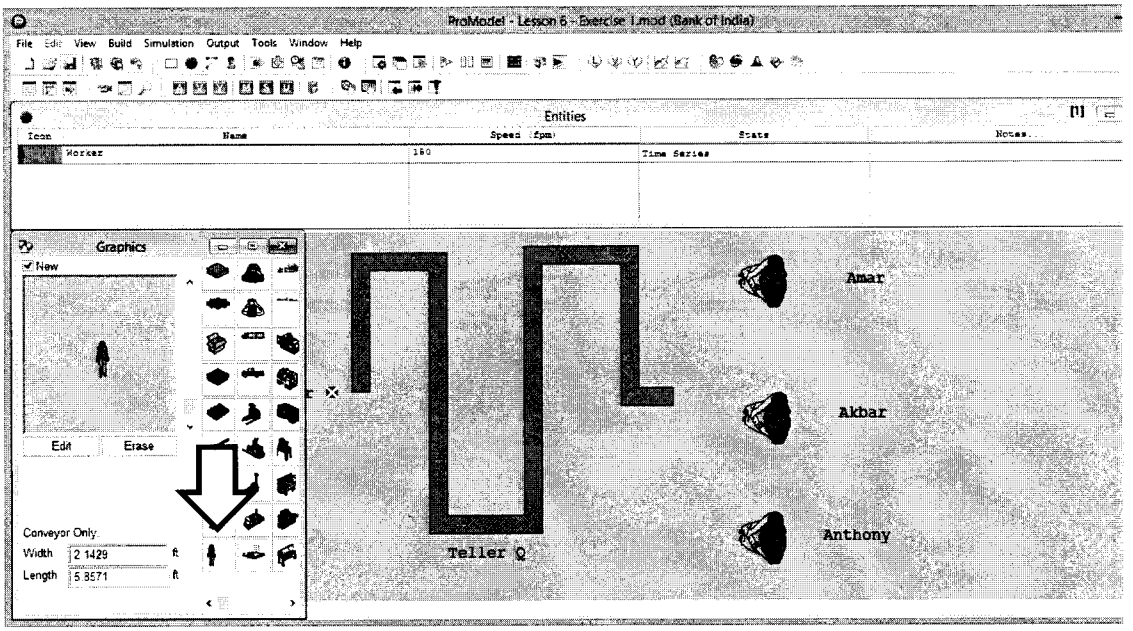


3. Creating Entities

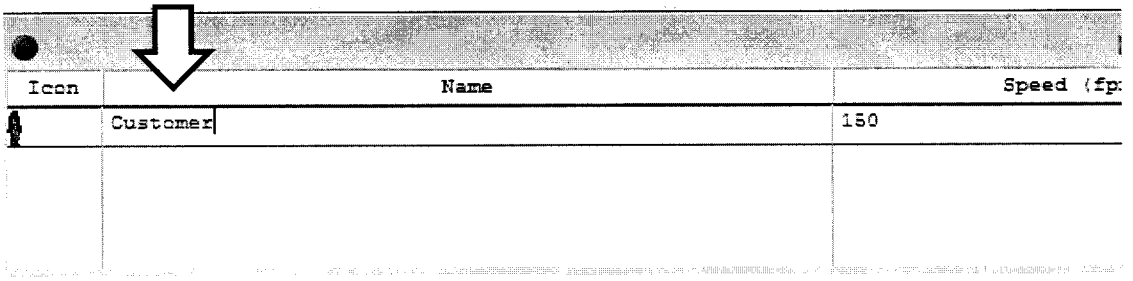
3.1. This model will make use of only one entity: Customers.

3.2. To start building the entities, select the menu "Build" and the option "Entities".

3.3. Select the ninth icon of the first row on the Graphics Window (1).



3.4. On the Entities table, rename your entity to **Customer** (1).

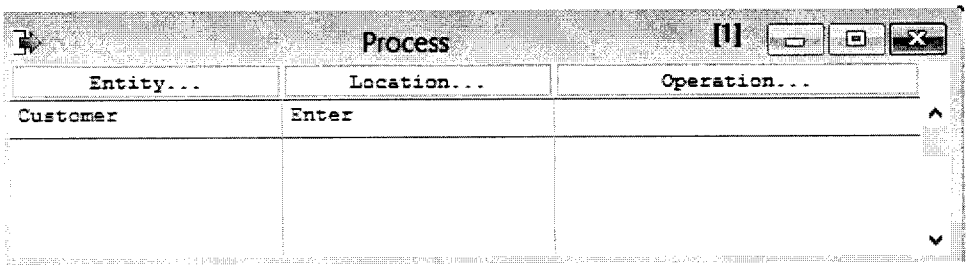


4. Creating Processes

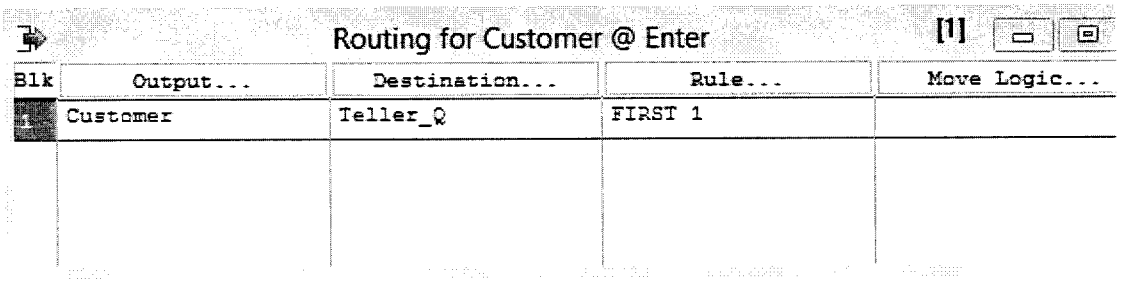
4.1. For this model, the entities will enter the system on the location Enter and will move to the queue Teller_Q. After this location, the entities will be processed by one of the tellers (Amar, Akbar, or Anthony), and then leave the system. It is also important to remember that the entities will select their tellers based on a specific preference rule: they will try to go to Amar, but if he is busy then they will try to go to Akbar; if Akmar is busy they will try to go to Anthony, and if he is also busy they will wait in line until one of them is available.

4.2. To create the processes that involve the entity Customer. Select the menu "Build" and then the option "Processing".

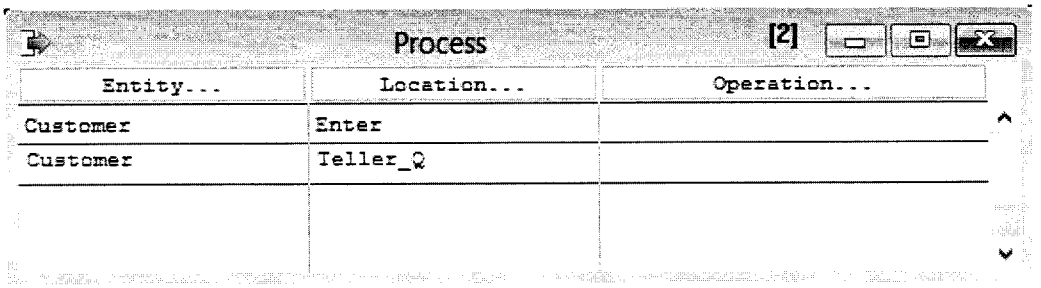
4.3. Select the first line of the Process table. Select the Customer as the Entity, and Enter as the Location.



4.4. On the Routing Table, select the Customer as the Output, and the Teller_Q as the Destination.



4.5. Back on the Process Table, create a new row (select the first row and hit the enter key) and select the Customer as the Entity and the Teller_Q as the Location.



4.6. This step is where we will define the order in which the entities (Customers) will select a destination (Tellers) based on a pre-defined preference. On the Routing Table, select the Customer as the Output, and Amar as the Destination.

Routing [1]

Blk	Output...	Destination...	Rule...	Move Logic...
1	Customer	Amar	FIRST 1	

4.7. Add a new Row to the Routing Table (hit the enter key). On the second row, select the Customer as the Output, and Akbar as the Destination.

Routing [2]

Blk	Output...	Destination...	Rule...	Move Logic...
1	Customer	Amar	FIRST 1	
	Customer	Akbar	FIRST	

4.8. Add a third row to the Routing Window; then select the Customer as the Output and Anthony as the Destination.

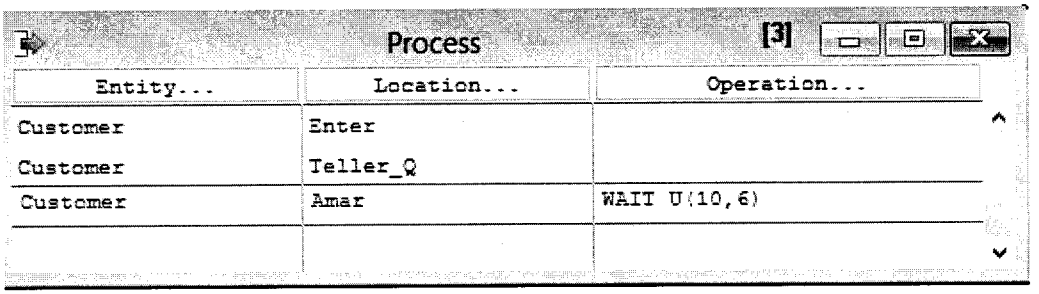
Routing [3]

Blk	Output...	Destination...	Rule...	Move Logic...
1	Customer	Amar	FIRST 1	
	Customer	Akbar	FIRST	
	Customer	Anthony	FIRST	

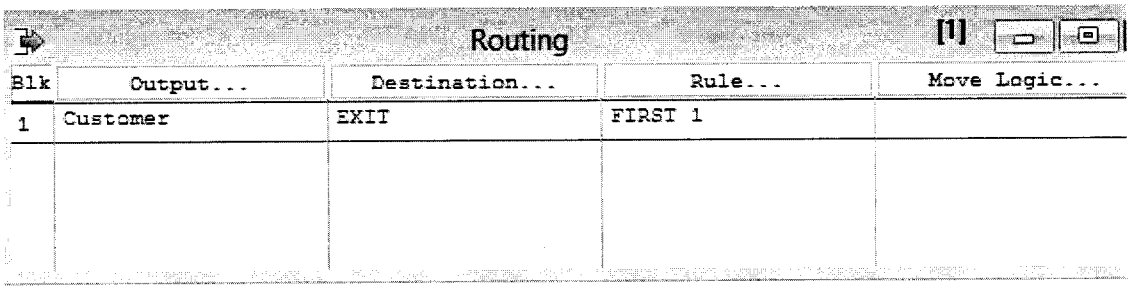
4.9. When the Routing Rule (3rd column of the Routing Table) is "First", that means that the entity will first try to select the first destination of the routing table, if it

the location is busy it will try to select the second one and so forth. Many other routing rules are available and their descriptions can be found along with the description of this exercise on the textbook used for this class.

4.10. Once all the entities are being routed to three tellers, it is time to program the processes in each of them. Add a new row to the Process Table, select the Customer as the Entity, Amar as the Location, and double-click the operation cell (this will open the Operation window). On the Operation window type in the command "WAIT U(10,6)". This informs ProModel that the processing time on the teller is equal to a uniform distribution with mean of 10 minutes and half width of 6 minutes.

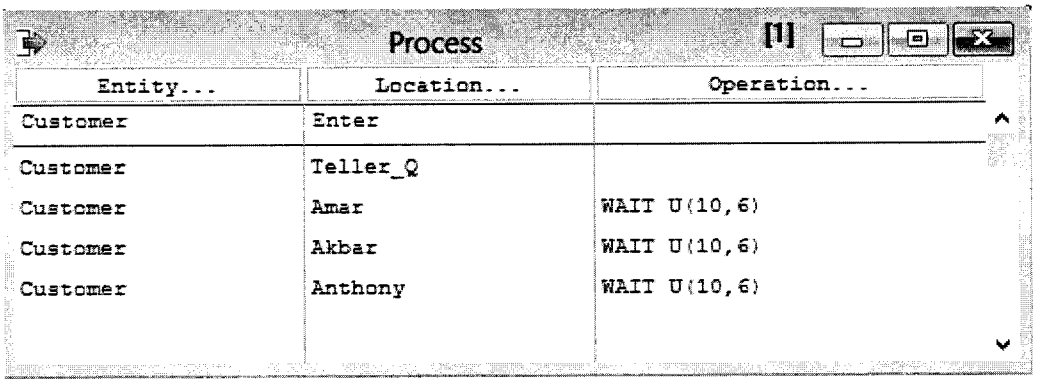


4.11. On the Routing Window, select the Customer as the Output, and EXIT as the Destination.



4.12. Once the Processing Time, and Routing Options are the same for all the Tellers. Repeat Steps 4.10 and 4.11 for the other two tellers (Remember to select the

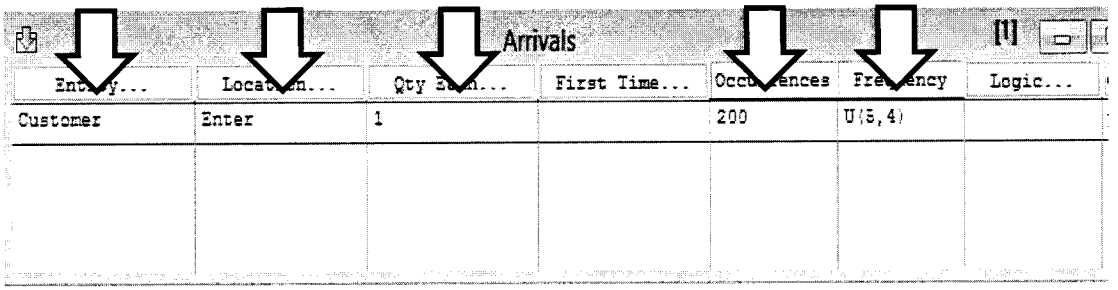
other two tellers as the Locations for the processes). The Process Table should look like the following.



5. Creating Arrivals

5.1. Select the menu Build, and the option Arrivals.

5.2. Select the Customer for the Entity (1), the Enter for the Location (2), 1 for Qty Each (3), 200 for the Occurencies (4), and type in U(5,4) for the frequency (5).



6. Defining Simulation Options, Saving, and Running the Model

6.1. Save your model (Menu File, Option Save).

6.2. Run your model. Select the menu Simulation, and the option Run.

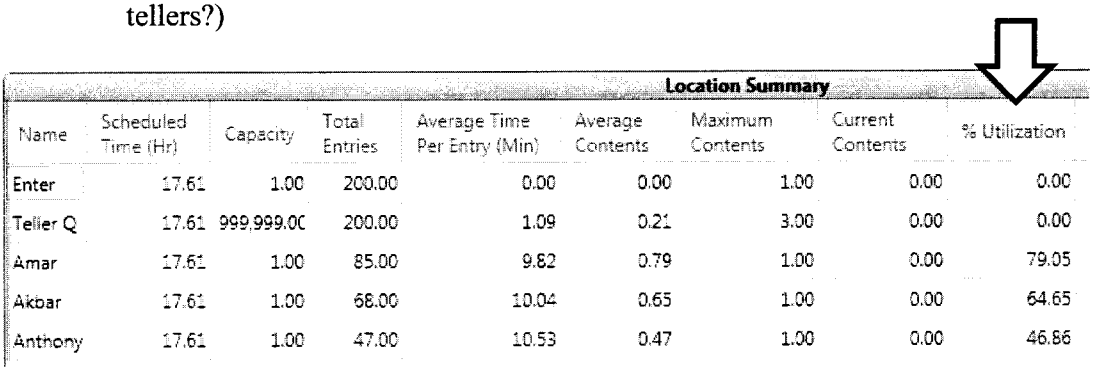
6.3. After your model finishes running, select the option to see the results.

6.4. What was the utilization of the tellers?

7. Analyzing the Results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. To find out the utilization of the tellers, click on the button "Tables", and under the section "Locations" select the option "Summary". The column "Utilization" has the answers from the questions of this lesson (What was the utilization of the tellers?)



Location Summary

Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	Maximum Contents	Current Contents	% Utilization
Enter	17.61	1.00	200.00	0.00	0.00	1.00	0.00	0.00
Teller Q	17.61	999,999.00	200.00	1.09	0.21	3.00	0.00	0.00
Amar	17.61	1.00	85.00	9.82	0.79	1.00	0.00	79.05
Akbar	17.61	1.00	68.00	10.04	0.65	1.00	0.00	64.65
Anthony	17.61	1.00	47.00	10.53	0.47	1.00	0.00	46.86

7.3. Why do the utilization of the tellers shows such pattern? (Amar with the highest utilization, followed by Akbar, and Anthony)

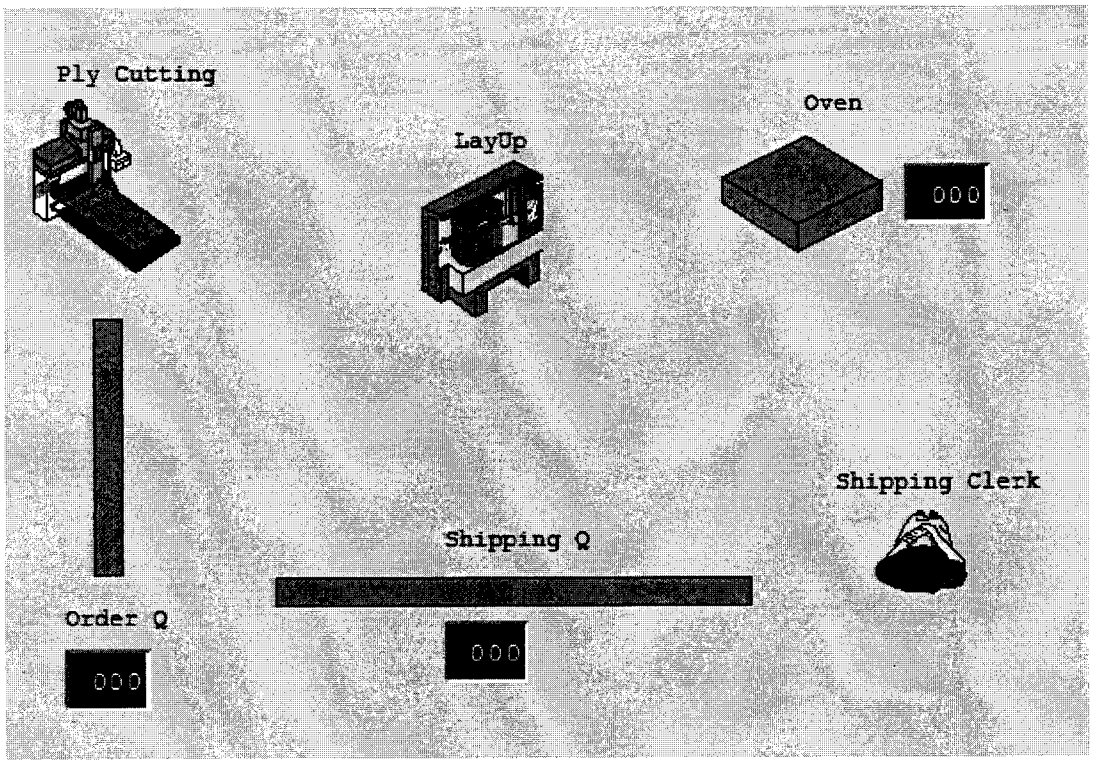
LESSON 7

This exercise from the seventh lesson will be based on the Laboratory 4.7.1 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concepts of Temporary Batch, where entities are batched together and can be ungrouped later retaining their original characteristics.

The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"El Segundo Composites receive orders for aerospace parts that go through cutting, lay-up, and bonding operations. The bonding operation is done in an autoclave in batches of five parts. The processing times for these operations are uniform(20,5), uniform(30,10) and uniform(100,10) minutes. After bonding, the parts go to the shipment clerk individually. The shipment clerk takes normal(20,5) minutes to pack and ship the parts. The orders are received on average once every hour, exponentially distributed. It takes an average of 15 minutes to transport these parts from one machine to another. Figure out the amount of WIP in the shop. Simulate for six months or 1,000 working hours."

The locations that will be used for this model are: Ply_Cutting, LayUp, Oven, Order_Q, Ship_Clerk, and Ship_Q. For this lesson we will also use the concept of variables (Lab 4.5 from the textbook) and the final layout of the system is shown on the image below.



1. Creating a new model

    1.1. Select the menu "File" and then the option "New".

    1.2. On the General Information window, name your model "**El Segundo Composites Part 1**" (on the "Title" text box).

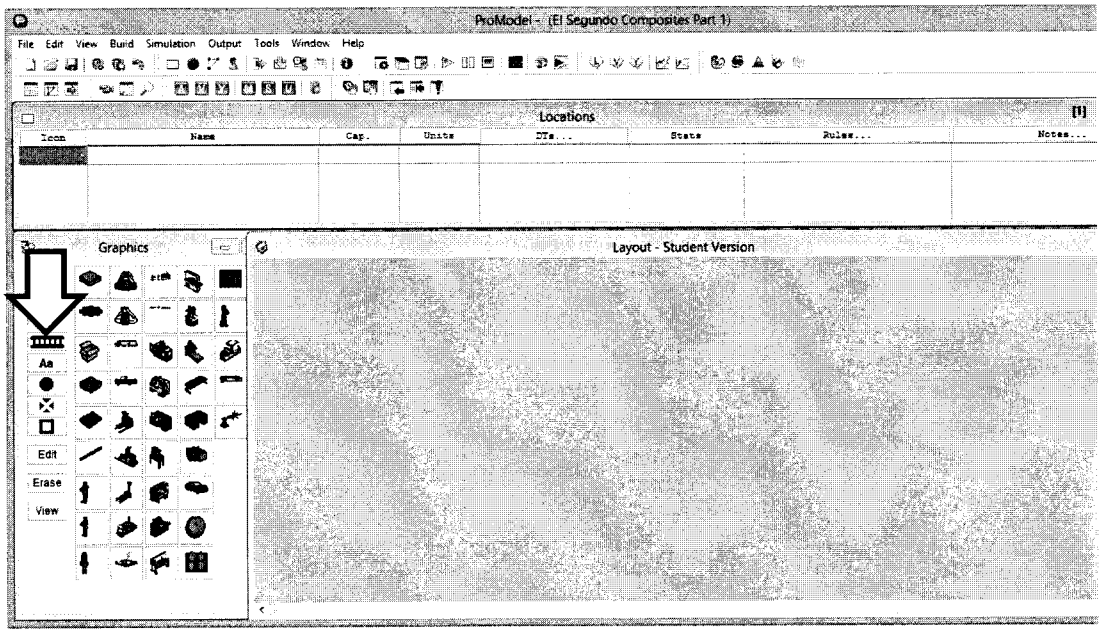
    1.3. Hit "**OK**".

2. Creating Locations

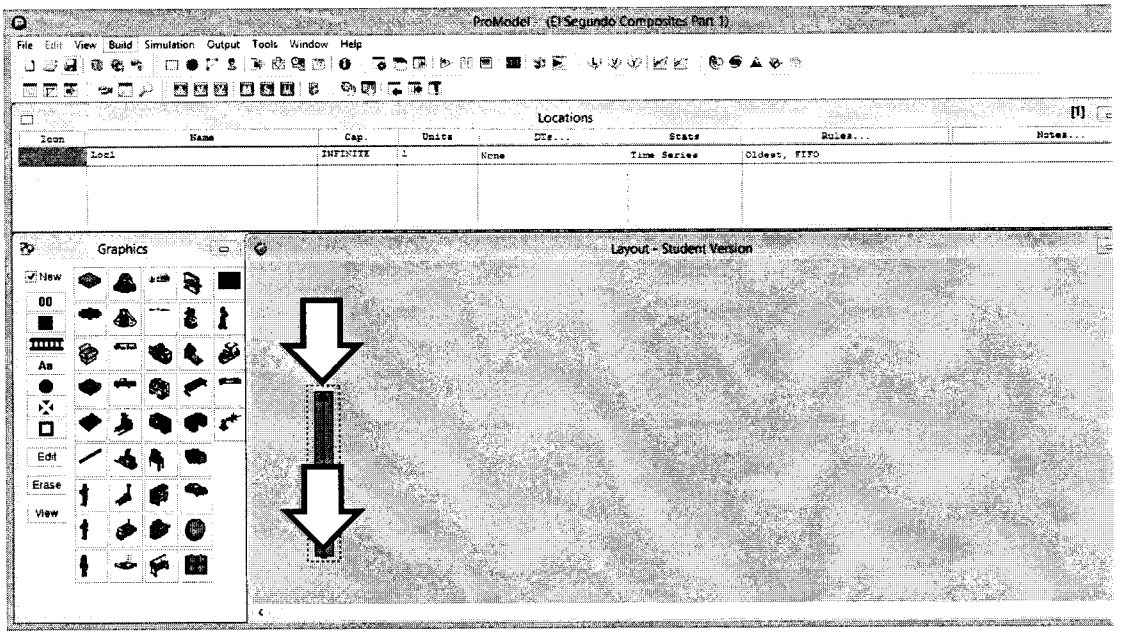
    2.1. For this exercise, six different locations will be created: Ply_Cutting, LayUp, Oven, Order_Q, Ship_Clerk, and Ship_Q.

    2.2. To begin the locations building process select the menu "Build" and then the option "Locations".

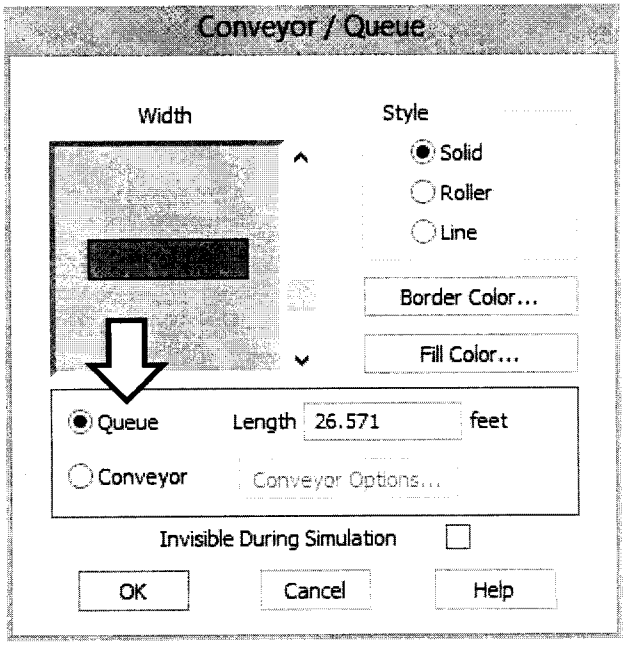
2.3. The first location to be created will be the "Order_Q". The creation of the location involves a little more than just selecting an icon and placing it on the layout. First, select the third icon on the first column of the Graphics window.



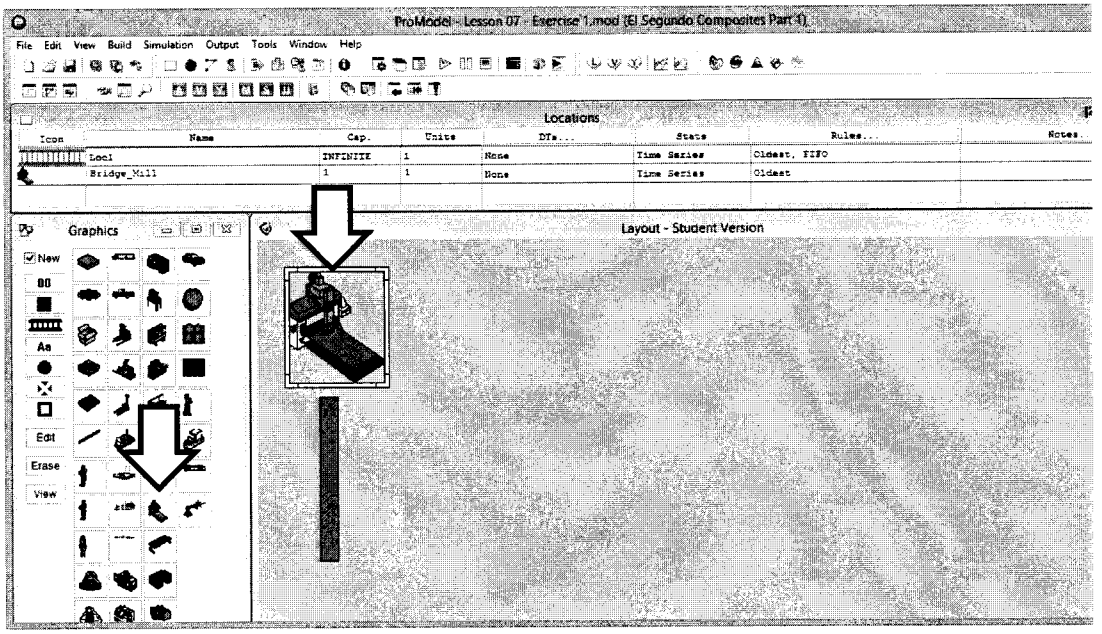
2.4. Next, click with the left button of your mouse where the Queue will start (1) and to finish your queue, click with the right button of your mouse where the queue will end (2).



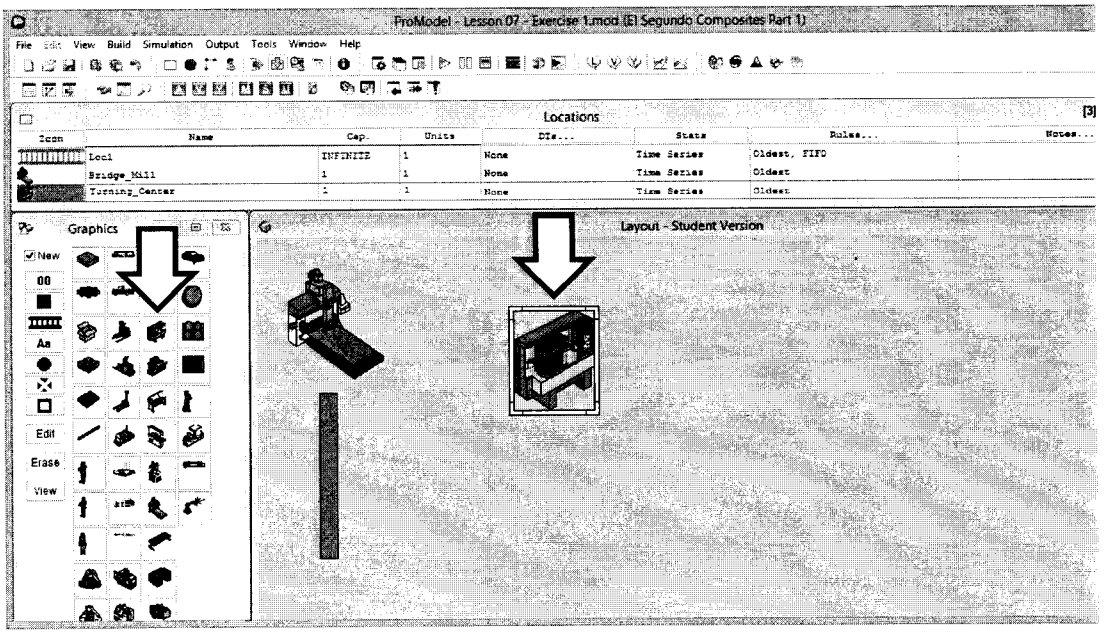
2.5. Now it is necessary to inform ProModel that this location is a Queue and not a Conveyor. Right click on the location that was just placed on the layout and select the option "Edit Graphic" from the menu. On the new Conveyor/Queue window, select the option "Queue".



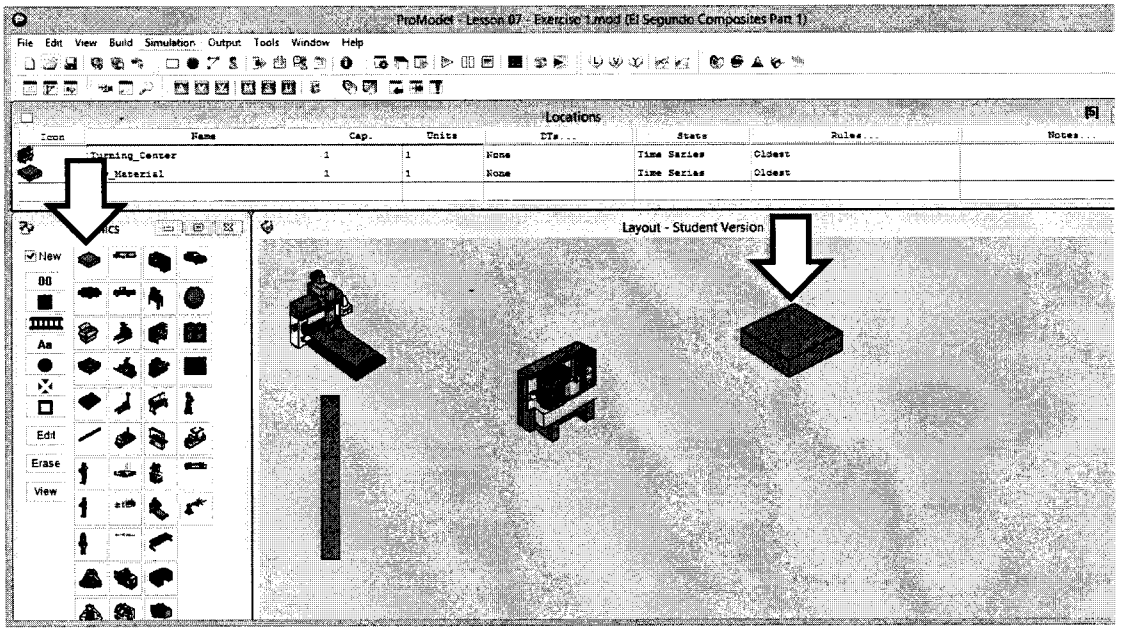
2.6. The next location will be the Ply_Cutting. Select the eight on the fourth column (1) and place it on the layout (2).



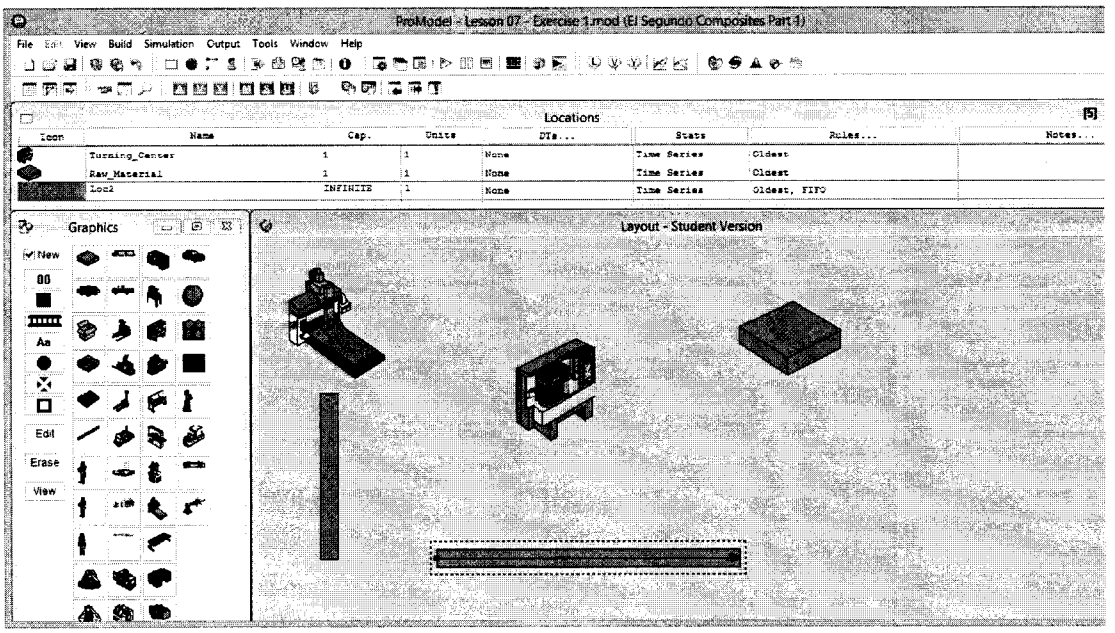
2.7. Next, add the location LayUp. Select the third icon on the fourth column (1) and place it on the layout (2).



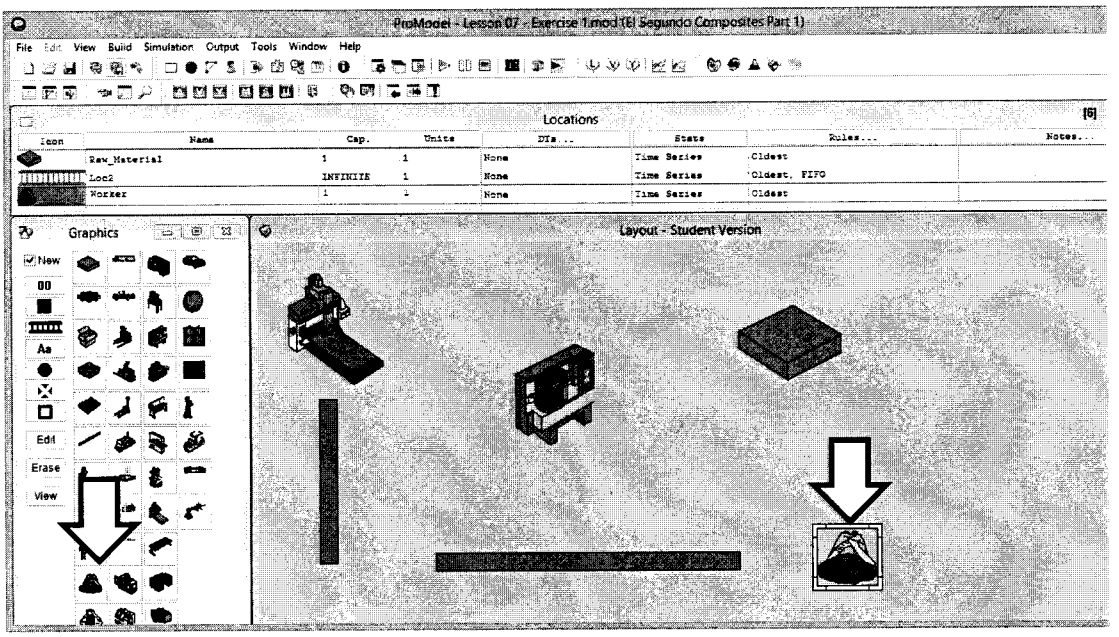
2.8. The next location will be the Oven. Select the first icon on the second column (1) and place it on the layout (2).



2.9. Now add the location Ship_Q. As the name suggests this location is a queue, so follow the steps 2.3, 2.4, and 2.5 to create a location that looks like the one in the image below.

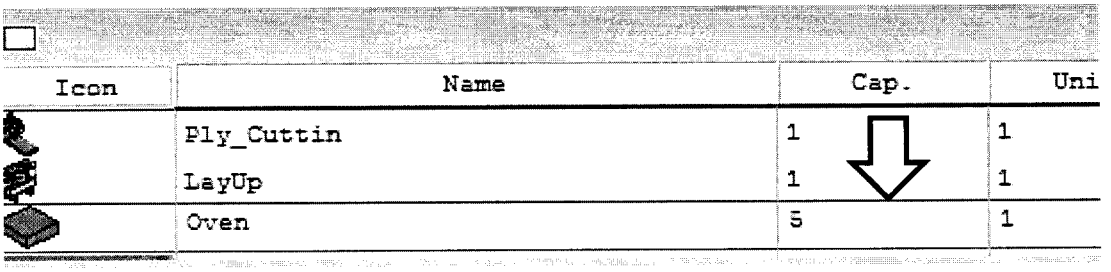


2.10. The last location of this model will be the Ship_Clerk. Select the tenth icon of the second row (1) and place it on the layout (2).



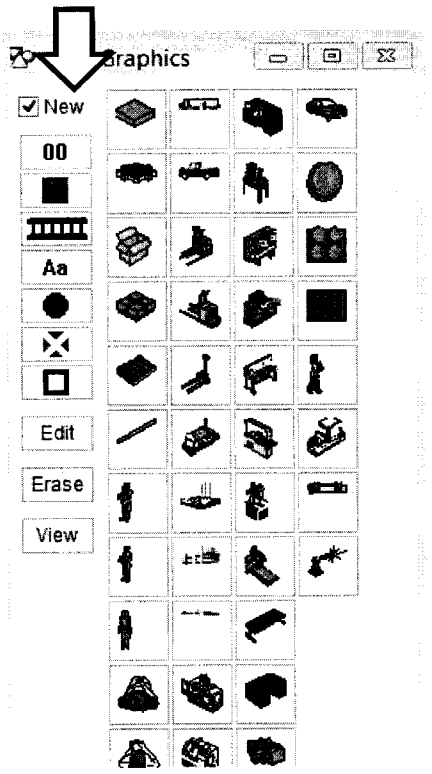
2.11. If you have not done it yet, now it is time to rename your locations. Follow the order in which they were created, and on the Locations Table rename your locations to Order_Q, Ply_Cutting, LayUp, Oven, Ship_Q, and Ship_Clerk respectively.

2.12. On the Locations Table, change the Oven Capacity to 5.

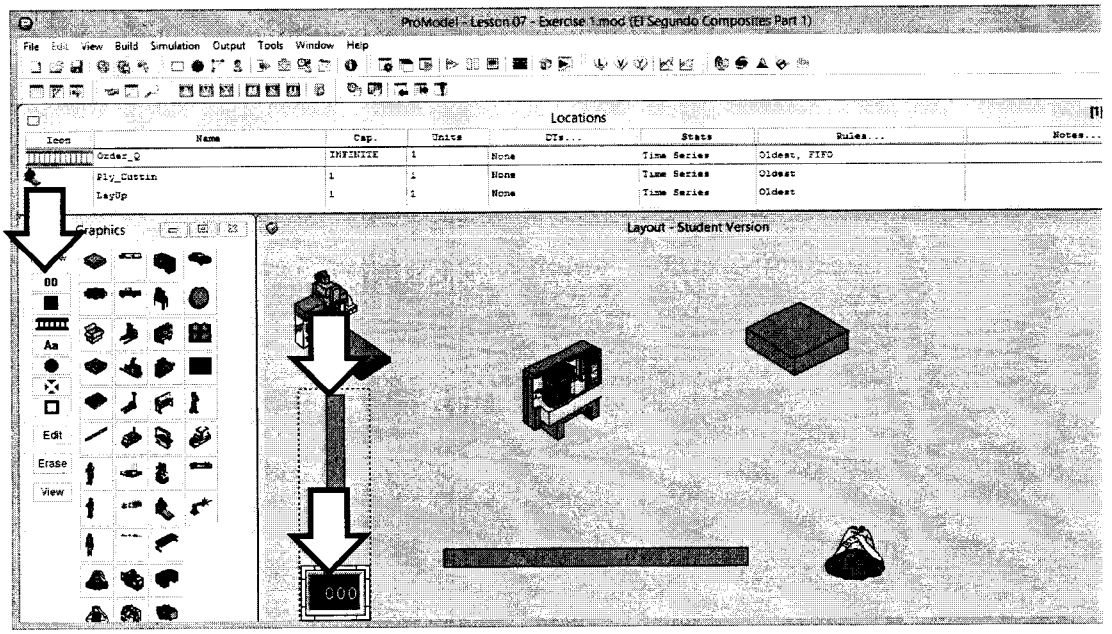


Icon	Name	Cap.	Uni
	Ply_Cuttin	1	1
	LayUp	1	1
	Oven	5	1

2.13. The next step will be to insert a few counters in the model. First uncheck the "New" option on the Graphics Window.

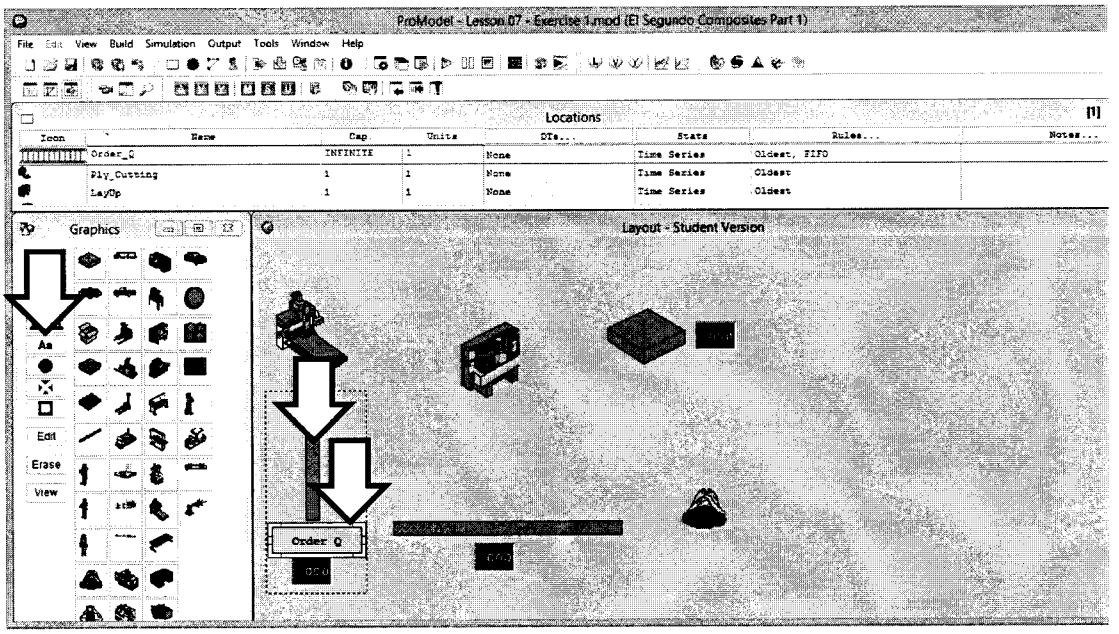


2.14. Select the Location "Order_Q" (1), click on the first button of the first column (2) and click on the layout (3) to place the counter.

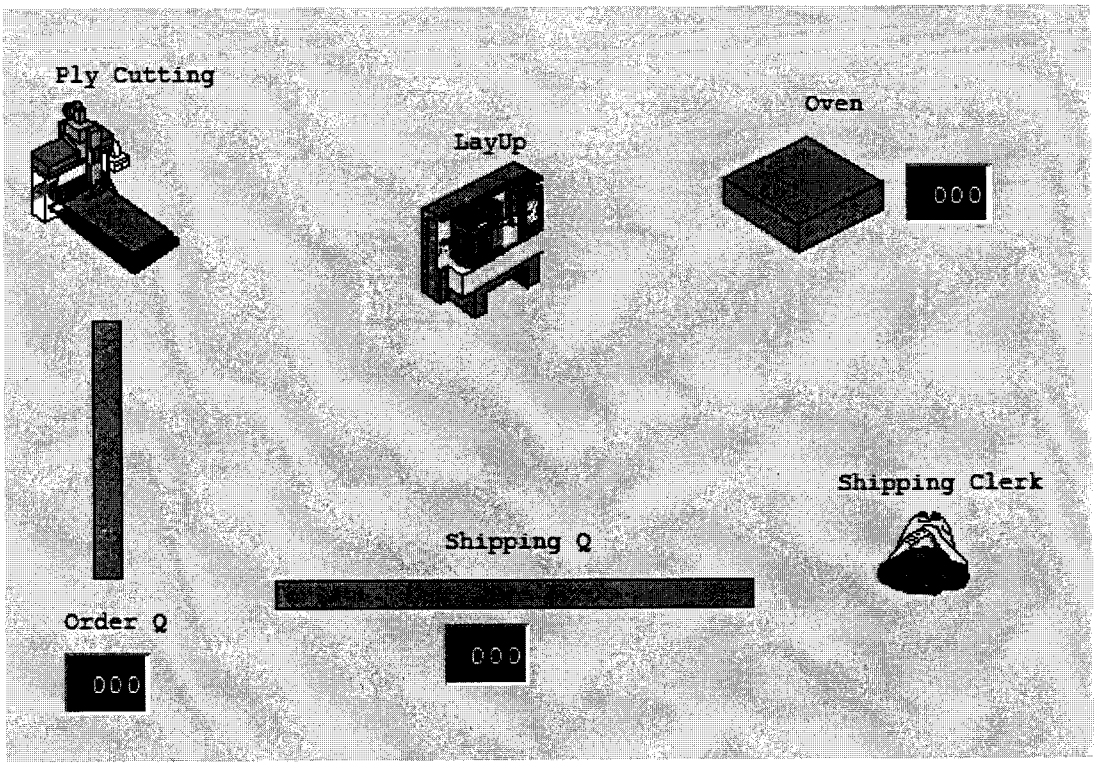


2.15. Repeat the step 2.14 for the locations "Oven" and "Ship_Q".

2.16. Next, insert the location names. Select the location "Order_Q" (1), click on the fourth icon of the first row (2), and click on the layout to place the location name (3).



2.17. Repeat the last step for all the other locations: Your layout should resemble the following image (make sure that all the shown elements are present).



2.18. At this point, your Locations table should look like the following.

Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Order_Q	INFINIT	1	None	Time Series	Oldest, FIFO	
	Ply_Cutting	1	1	None	Time Series	Oldest	
	LayUp	1	1	None	Time Series	Oldest	
	Oven	5	1	None	Time Series	Oldest	
	Shipping_Q	INFINIT	1	None	Time Series	Oldest, FIFO	
	Shipping_Clerk	1	1	None	Time Series	Oldest	

2.19. It is very important that you only have 6 locations on your model. If you have more than six, consider deleting the extra ones. This can be done by selecting the row you wish to erase and clicking on the menu "Edit" and selecting the

option "Delete". BE VERY CAREFUL: ProModel DOES NOT HAVE AN "UNDO" FUNCTION.

3. Creating Entities

3.1. This model will make use of two entities: Raw_Material, and Batch. The second being used to represent a group of "Raw Material" entities.

3.2. To start building the entities, select the menu "Build" and the option "Entities".

3.3. To create the first entity, select the second icon of the first row of the Graphics Window (a gear), and to create the second entity click on the third icon of the first row (an open box).

3.4. On the Entities Table, rename the first entity as "Raw Material" and the second one as "Batch".

3.5. Your Entities Table should look similar to the following (feel free to use different icons).

Entities [2]

Icon	Name	Speed (fpm)	Stats	Notes...
	Raw_Material	150	Time Series	
	Batch	150	Time Series	

4. Creating Processes

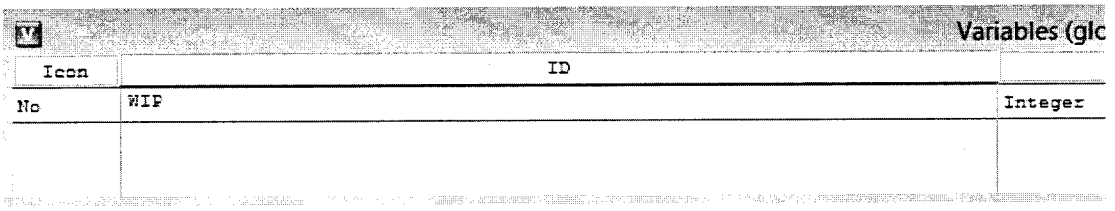
4.1. In this model, the entities will arrive on the location "Order Q" and move to the "Ply Cutting" as soon as it is available; they will then follow to the LayUp, and to the Oven where they will be grouped in a Batch of 5 entities to be processed. After this last location, the entities will be ungrouped and move to the location

"Ship Q" where they will wait until the "Ship Clerk" is available, and after being processed in this last location the entities will leave the system.

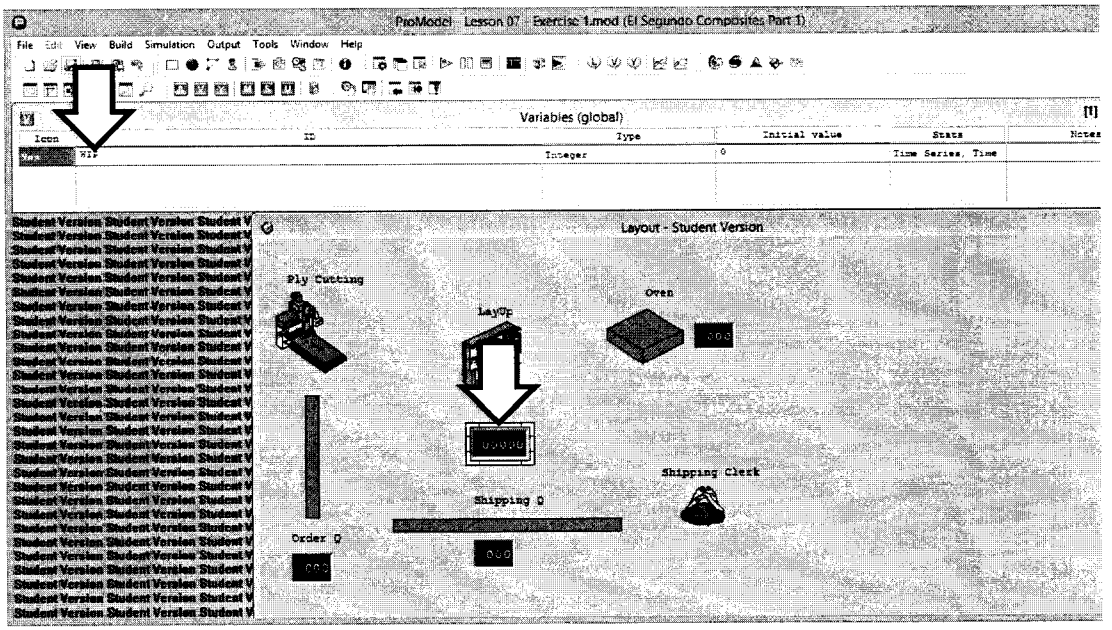
4.2. Variables will be used for this model (as seen on Lab 4.5).

4.3. First of all, start by creating the variable. Select the menu "Build" and the option "Variables (Global)".

4.4. On the Variables table, input WIP as the ID value.

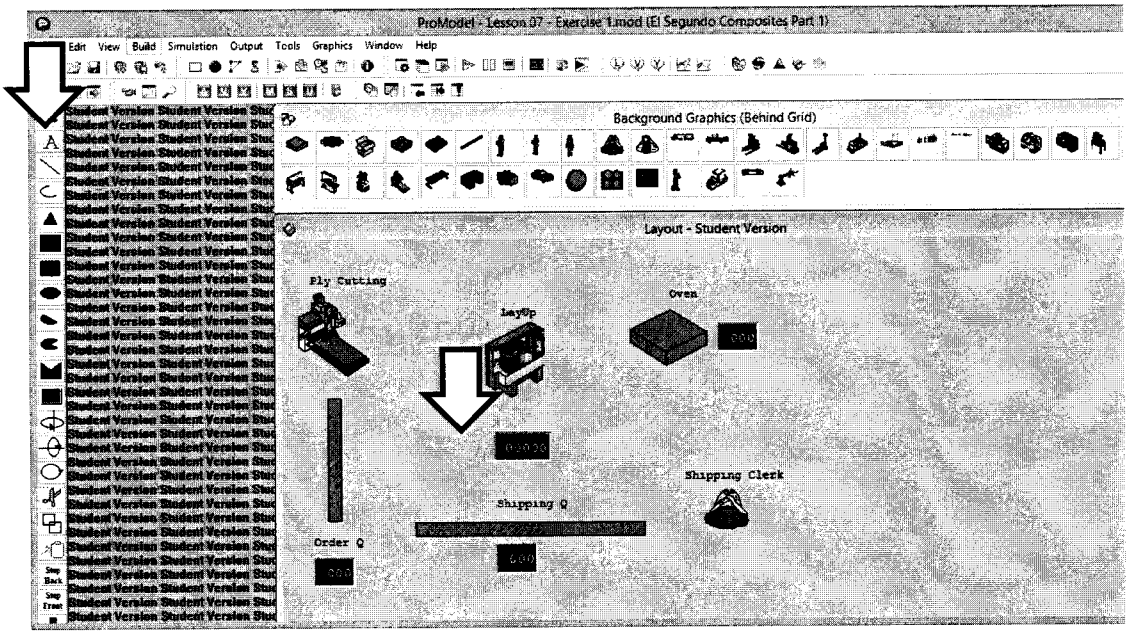


4.5. Next, click on the Variable ID (1) and click on the layout (2) to insert a counter that will display the variable value during the simulation.

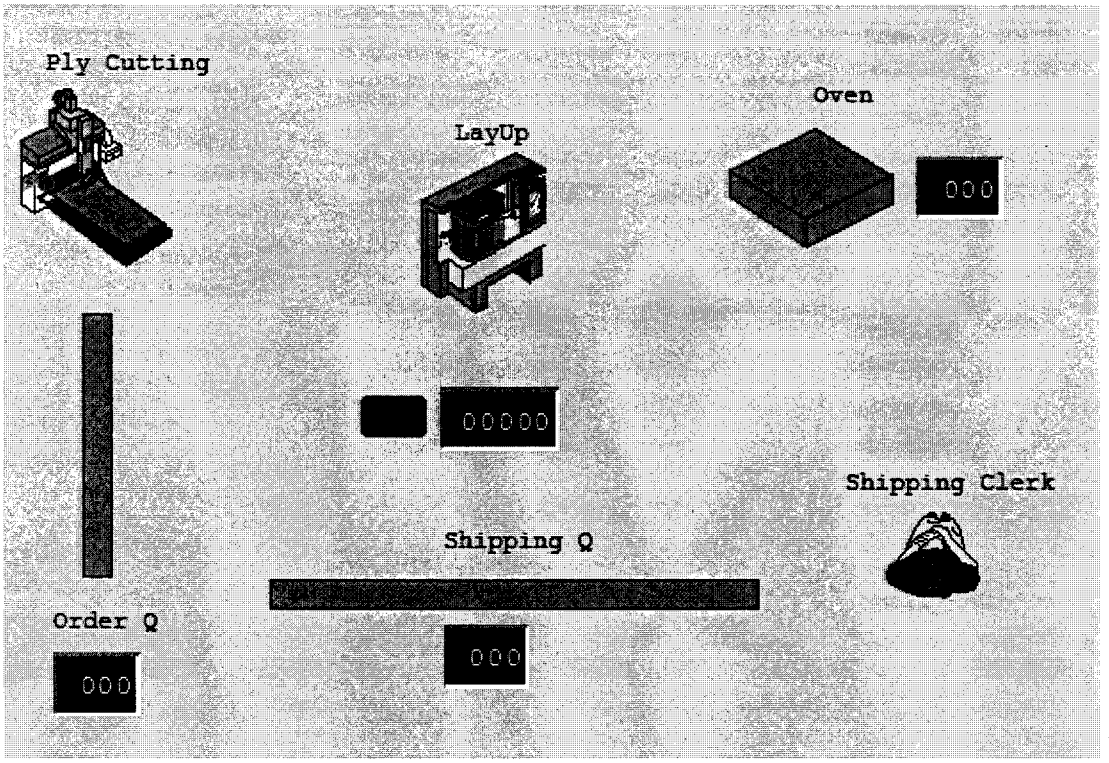


4.6. But that counter does not show any identification on the model layout, so next insert the variable name on the layout. Select the menu "Build", "Background Graphics", "Behind the Grid".

4.7. Select the first icon on the column on the left side of the screen (1) and click on the layout on the left side of the WIP Variable counter (2).

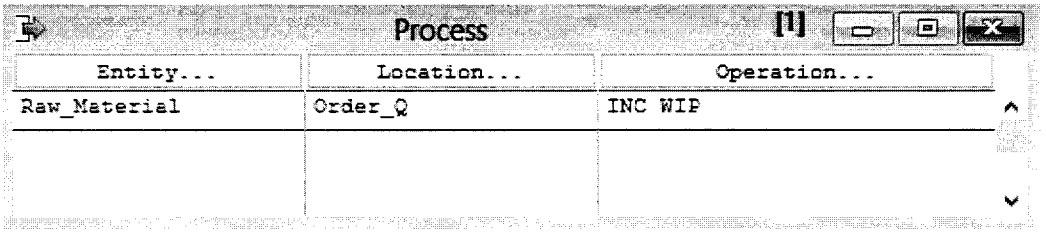


4.8. In the window "Text Options" type WIP and hit the button OK. Your layout should contain the elements shown on the following image.



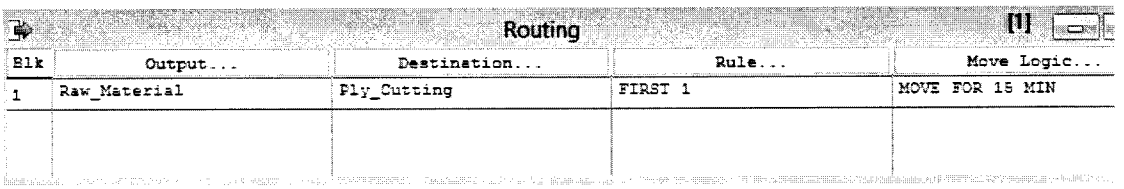
4.9. To start creating the processes, select the menu "Build" and then "Processing".

4.10. On the Process Table, select the "Raw Material" as the Entity, and "Order Q" as the location. Double click on the Operation field and on the Operation Window type the command "INC WIP" (This will tell ProModel to Increase the value of the variable WIP).

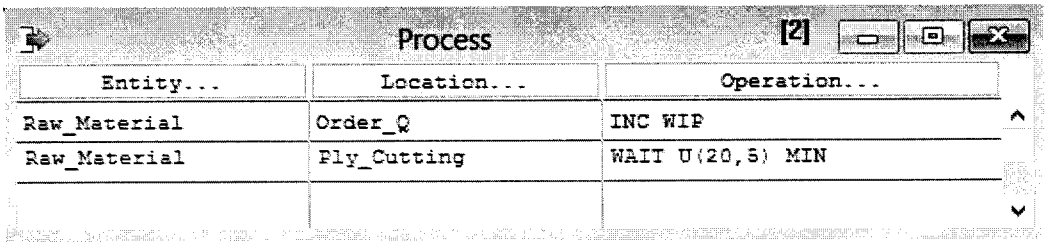


4.11. On the Routing Window. Select the "Raw Material" as the Output, the "Ply Cutting" as the Destination, and on the Move Logic field type the command

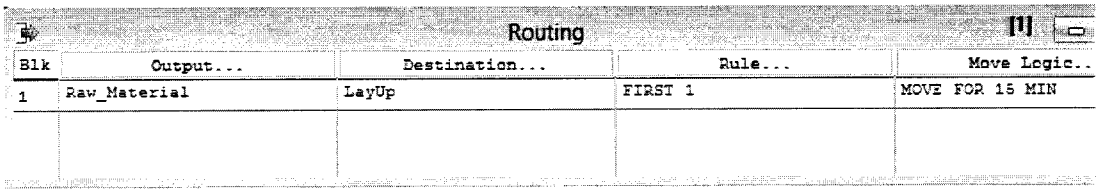
"MOVE FOR 15 MIN" (meaning that the entity will take 15 minutes to be moved to the Ply Cutting location).



4.12. Add a new row to the Process Table (select the last row of the table and hit the enter key). Select the "Raw Material" as the entity and the "Ply Cutting" as the location. Double-click the Operation field, and type in the command "Wait U(20,5) MIN".



4.13. On the Routing Table, select the "Raw Material" as the Output, and the "LayUp" as the Destination. On the Move Logic Field type in the command "MOVE FOR 15 MIN".



4.14. Add a new row to the Process Table. Select the "Raw Material" as the Entity and the "LayUp" as the Location. Double-click the Operation field, and type in the command "WAIT U(30,10) MIN".

Process [3]

Entity...	Location...	Operation...
Raw_Material	Order_Q	INC WIP
Raw_Material	Ply_Cutting	WAIT U(20,5) MIN
Raw_Material	LayUp	WAIT U(30,10) MIN

4.15. On the Routing Table, select the "Raw Material" as the Output and the "Oven" as the Destination. On the Move Logic field, insert the command "MOVE FOR 15 MIN".

Routing [1]

Blk	Output...	Destination...	Rule...	Move Logic...
1	Raw_Material	Oven	FIRST 1	MOVE FOR 15 MIN

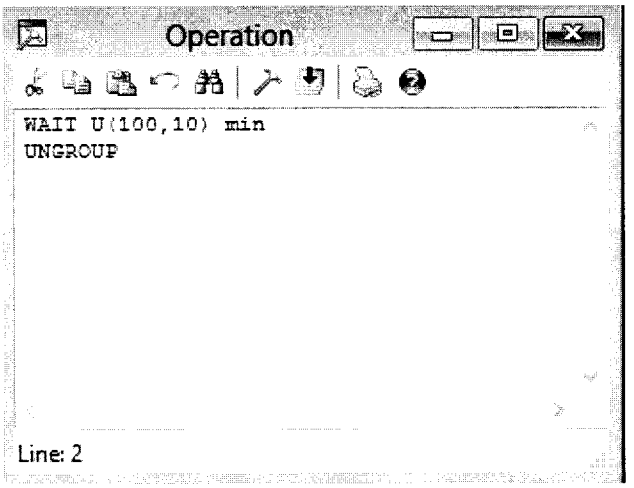
4.16. Add a new row to the Process Table. Select the "Raw Material" for the entity and the "Oven" for the location. Double click the Operation cell. On the Operation window type the command "Group 5 as Batch" – This tells ProModel to combine 5 units of the entity "Raw Material" into a temporary entity called "Batch" (created earlier).

Process [2]

Entity...	Location...	Operation...
Raw_Material	Ply_Cutting	WAIT U(20,5) MIN
Raw_Material	LayUp	WAIT U(30,10) MIN
Raw_Material	Oven	GROUP 5 AS BATCH

4.17. Since we now have the entity "Batch" on the location "Oven", it is necessary to create a row on the Process table that will address the process involving this location and new entity. On the new row, select "Batch" as the entity and "Oven" as the location. Double Click the Operation cell and insert the command "WAIT

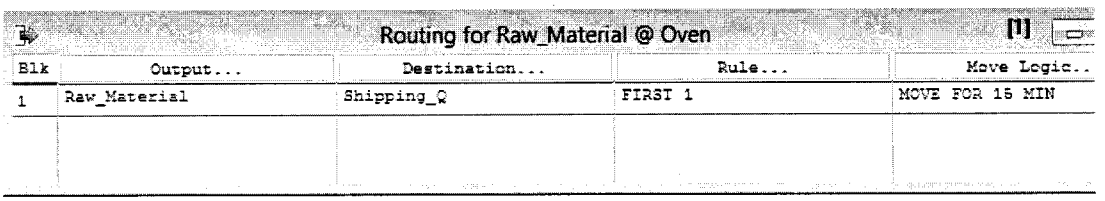
U(100,10) MIN" on the first line and the command "UNGROUP" on the second line.



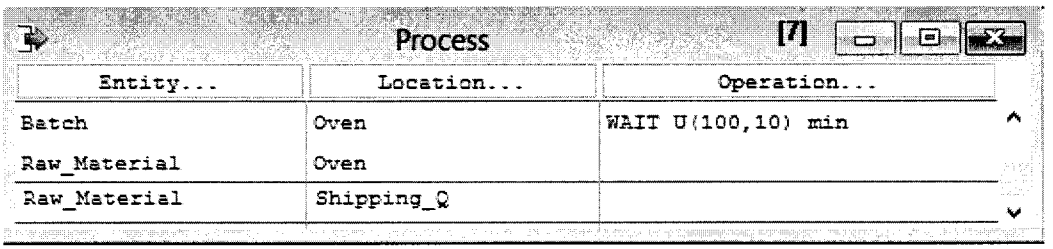
4.18. The command "UNGROUP" tells ProModel to separate the entity "Batch" into the entities "Raw Material" that composes it. Once we have the entity "Raw Material" on the location "Oven" again, it is necessary to create a new row at the Process table to tell ProModel what to do with it.

4.19. On the new row of the Process Table, select the "Raw Material" as the Entity and the "Oven" as the location. It will not be necessary to input anything on the Operation window this time.

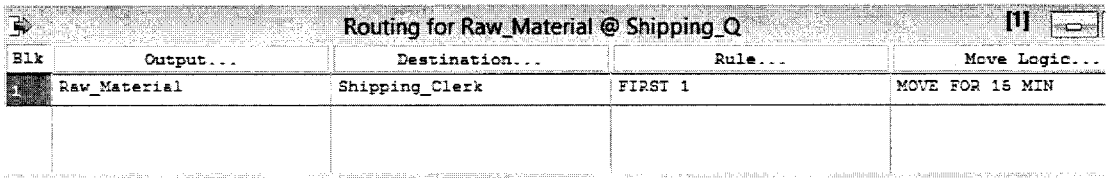
4.20. On the Routing Table, select the "Raw Material" as the Output, and the "Ship_Q" as the Destination. On the Moving Logic cell, insert the command "MOVE FOR 15 MIN"



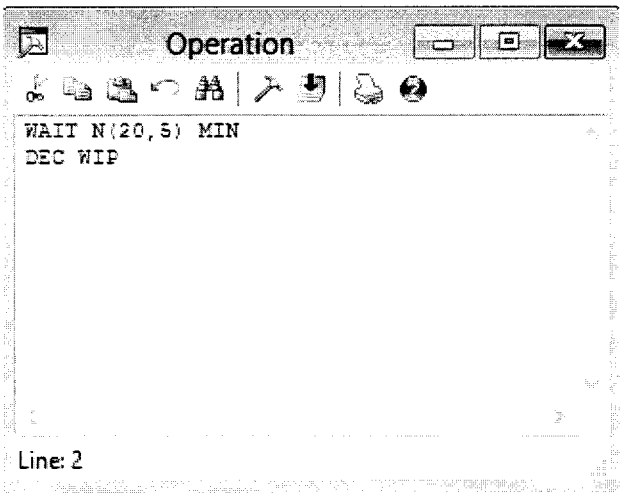
4.21. Add a new row to the Process Table. Select the "Raw Material" as the Entity and the "Ship Q" as the Location.



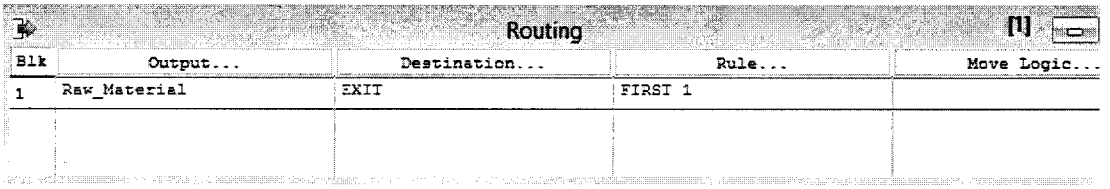
4.22. On the Routing Table select the "Raw Material" as the Output and the "Ship Clerk" as the Destination. On the Move Logic, type "MOVE FOR 15 MIN".



4.23. Add a new row to the Process Table. Select the "Raw Material" as the Entity and the "Ship Clerk" as the Location. On the Operation Window, insert the command "WAIT N(20,5) MIN" on the first line, and "DEC WIP" on the second one (as shown below).



4.24. On the Routing Table, select the "Raw Material" as the Output and "EXIT" as the Destination.



4.25. The Process and Routing Tables should be looking similar to the following.

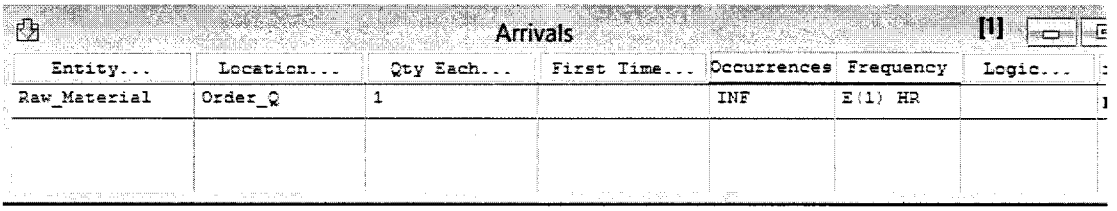
Process			Routing				
Entity	**Location**	**Operation**	**Blk**	**Output**	**Destination**	**Rule**	**Move Logic**
Raw_Material	Order_Q	INC WIP	1	Raw_Material	Ply_Cutting	FIRST 1	MOVE FOR 15 MIN
Raw_Material	Ply_Cutting	WAIT U(20,5) MIN	1	Raw_Material	LayUp	FIRST 1	MOVE FOR 15 MIN
Raw_Material	LayUp	WAIT U(30,10) MIN	1	Raw_Material	Oven	FIRST 1	MOVE FOR 15 MIN
Raw_Material	Oven	Group 5 as Batch					
Batch	Oven	WAIT U(100,10) MIN UNGROUP					
Raw_Material	Oven		1	Raw_Material	Ship_Q	FIRST 1	MOVE FOR 15 MIN
Raw_Material	Ship_Q		1	Raw_Material	Ship_Clerk	FIRST 1	MOVE FOR 15 MIN
Raw_Material	Ship_Clerk	WAIT N(20,5) MIN DEC WIP	1	Raw_Material	EXIT	FIRST 1	

5. Creating Arrivals

5.1. Select the menu Build, and the option Arrivals.

5.2. For this Exercise it is only necessary to create the arrival to one of the entities (Raw Material) once the entity "Batch" is created by a process in the model.

5.3. On the Arrival Table, select the "Raw Material" as the Entity, "Order Q" as the Location, "1" as the Qty Each, "INF" as the Occurrences, and "E(1) HR" as the Frequency. Your arrival table should resemble the following.

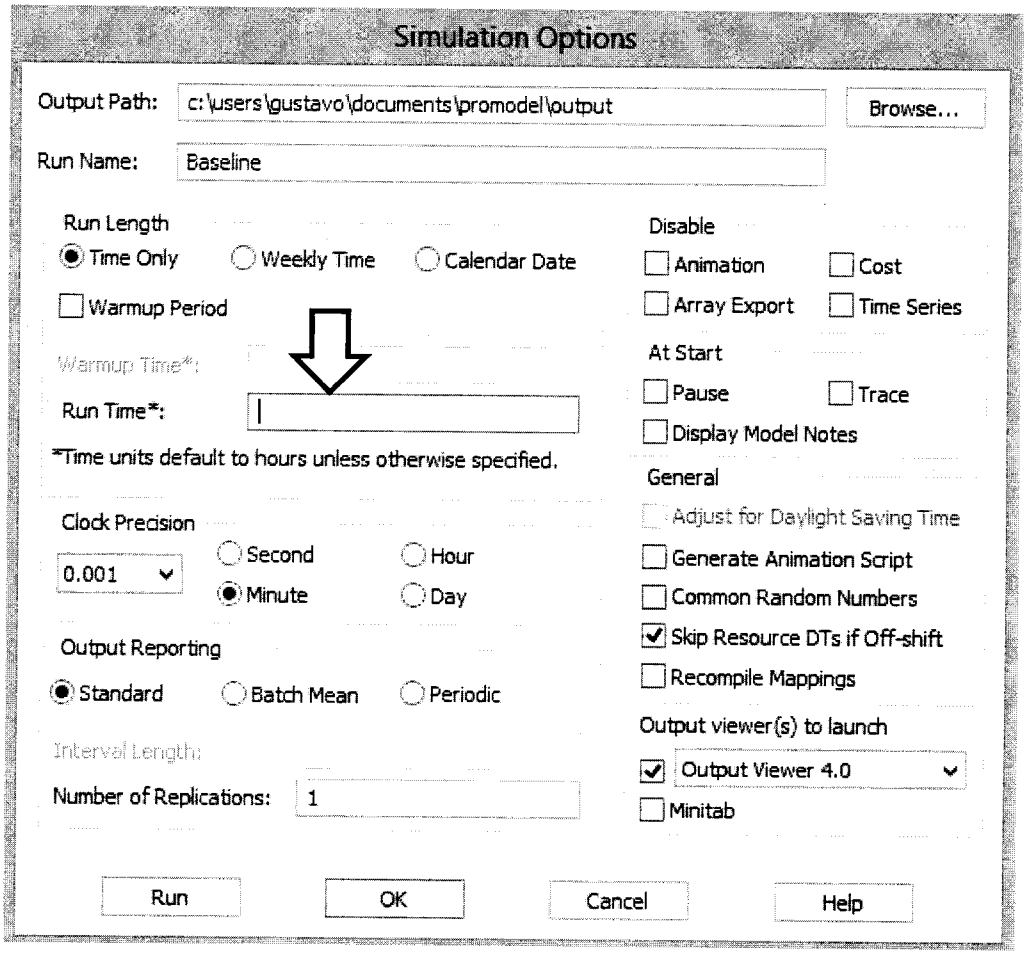


6. Defining Simulation Options, Saving, and Running the Model

6.1. Save your model (Menu File, Option Save).

6.2. Go to the menu Simulation, and select Options.

6.3. Change the "Run Time" value to 1000 (Meaning that the model will simulate a period of 1000 hours). Click on the Button OK to close the window.



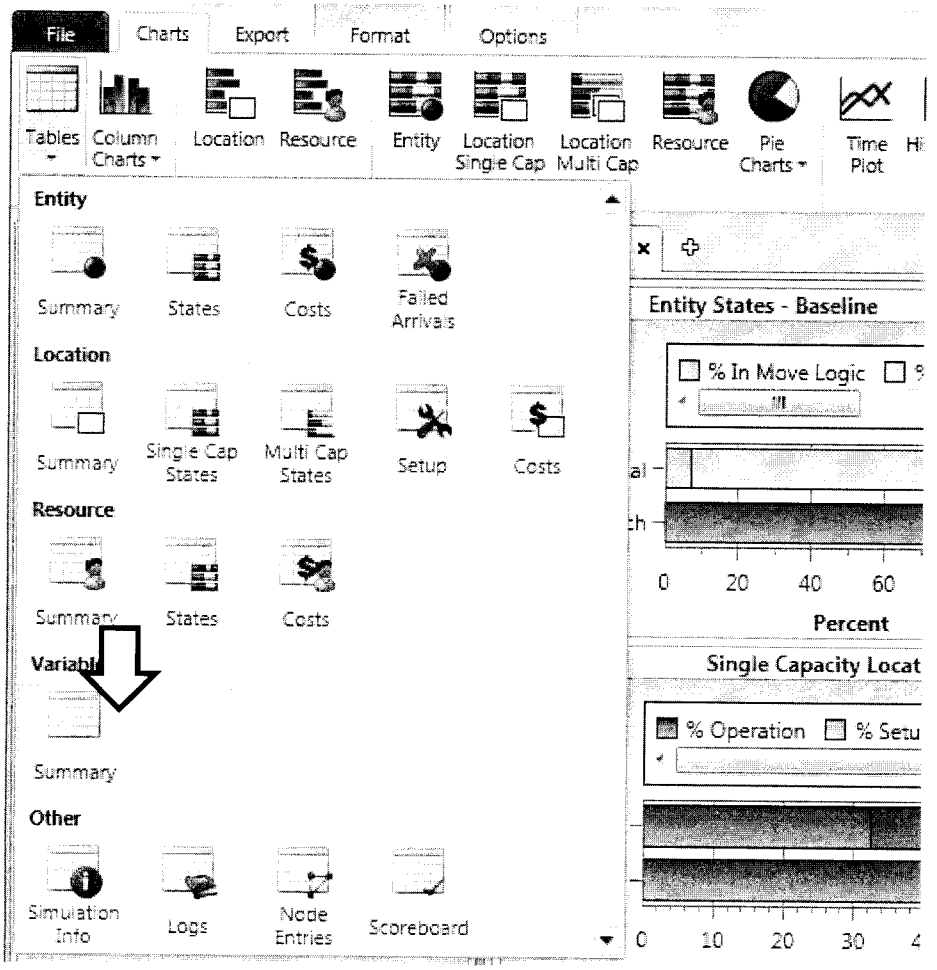
6.4. Run your model. Select the menu Simulation, and the option Run.

6.5. After your model finishes running, hit "OK" to view your results.

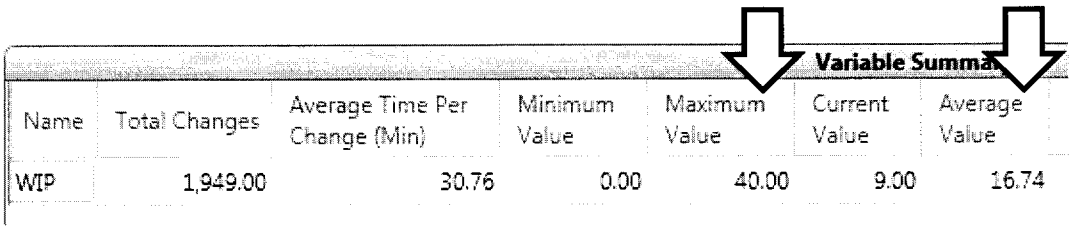
7. Analyzing the Results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

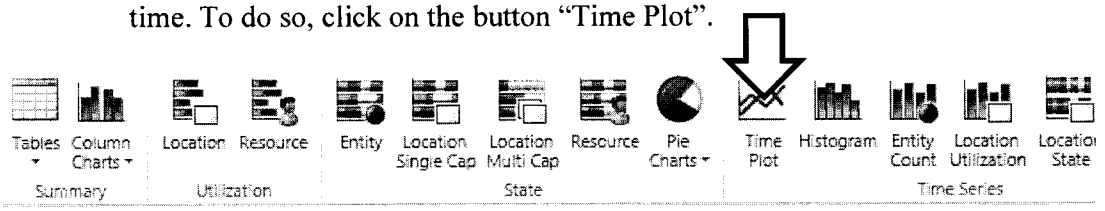
7.2. For this exercise it is necessary to inform the WIP behavior during the simulation period. To do so, click on the button "Tables", and under the section "Variables, select the option "Summary".



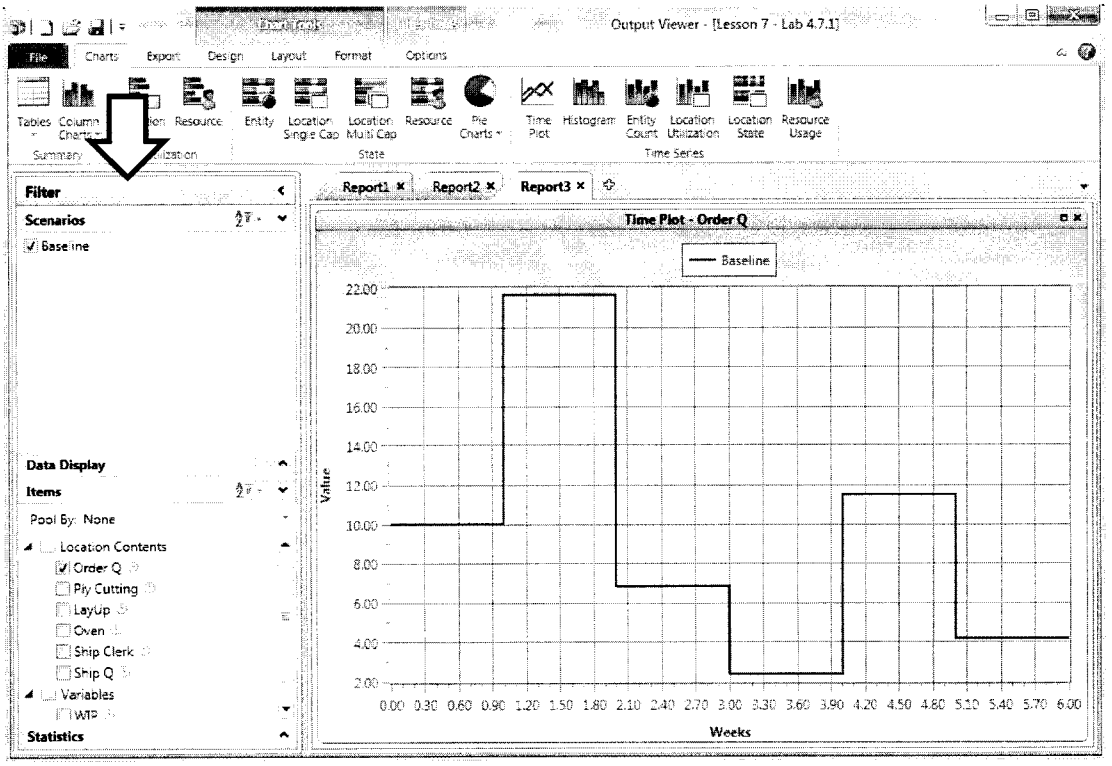
7.3. On the Variable Summary Output table, it is possible to observe the average and maximum value of the WIP variable.



7.4. It is also possible to observe the variation of this valuable versus the simulation time. To do so, click on the button "Time Plot".

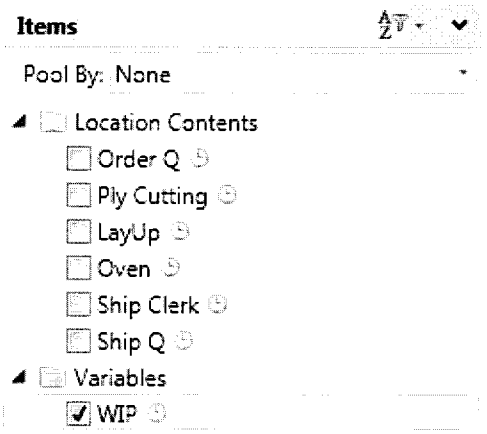


7.5. A time plot will be displayed. On the left side of the screen there is a menu side-bar where a few options can be modified.

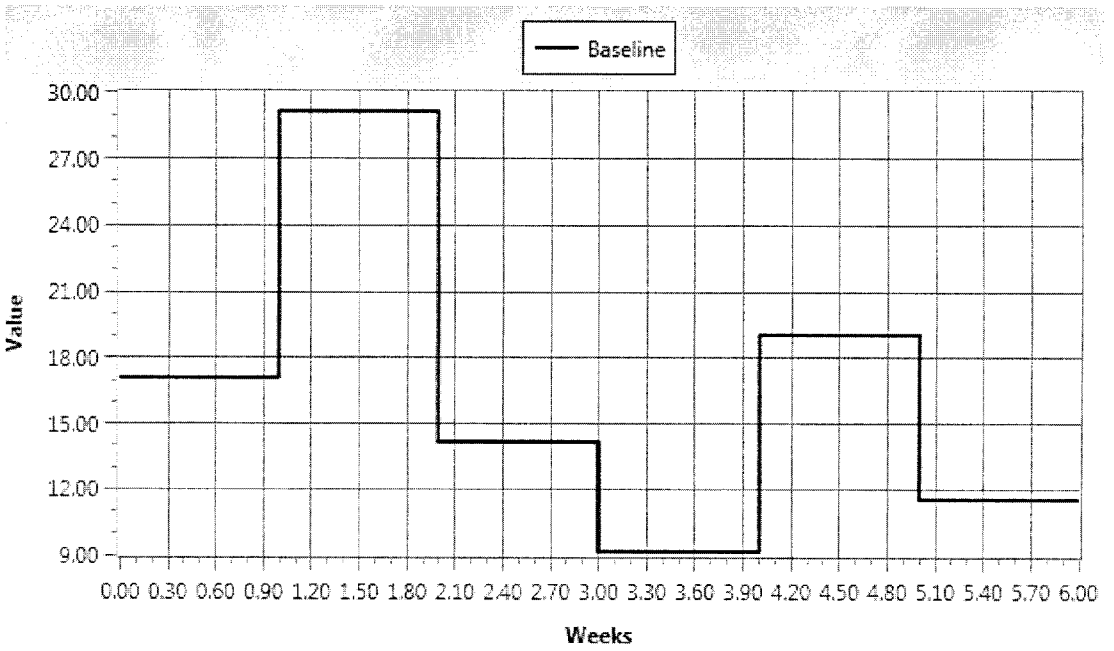


7.6. At the bottom of this side bar there is a section named "Items". In this section a few items of your model are displayed and the item "Order Q" should be

selected. In order to observe the WIP behavior versus time, make sure that the item WIP (under variables) is the only one selected.



7.7. The variation of the variable WIP will be displayed.



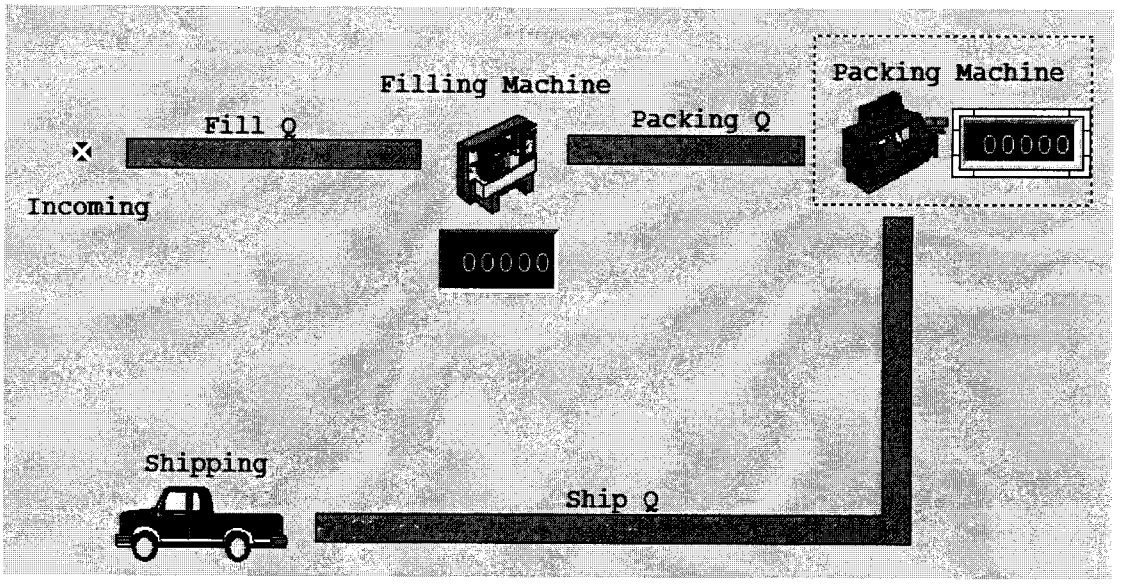
LESSON 8

This exercise from the eight lesson will be based on the Laboratory 4.7.2 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concepts of Permanent Batch, where entities are combined and cannot be ungrouped at a later point.

The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"At the Garden Reach plant of the Darjeeling Tea Company, the filling machine fills empty cans with 50 bags of the best Darjeeling tea at the rate of one can every 1 ± 0.5 seconds uniformly distributed. The teabags arrive to the packing line with a mean inter arrival time of one second exponentially distributed. The filled cans go to a packing machine where 20 cans are combined into one box. The packing operation takes uniform (20 ± 10) seconds. The boxes are shipped to the dealers. The facility runs 24 hours a day. Simulate for one day."

The locations used for this model are: Incoming, Fill Q, Filling Machine, Packing Q, Packing Machine, Ship Q, and Shipping. The final model layout should resemble the one presented on the image below.



1. Creating a new model

    1.1. Select the menu "File" and then the option "New".

    1.2. On the General Information window, name your model "**Darjeeling Tea Company**" (on the "Title" text box).

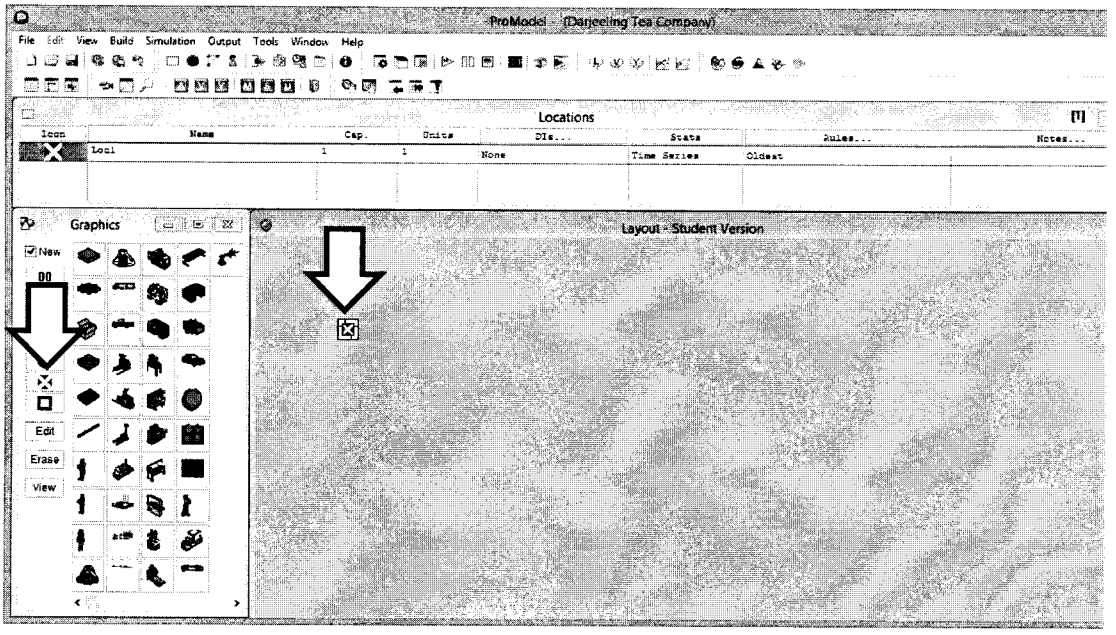
    1.3. Hit "**OK**".

2. Creating Locations

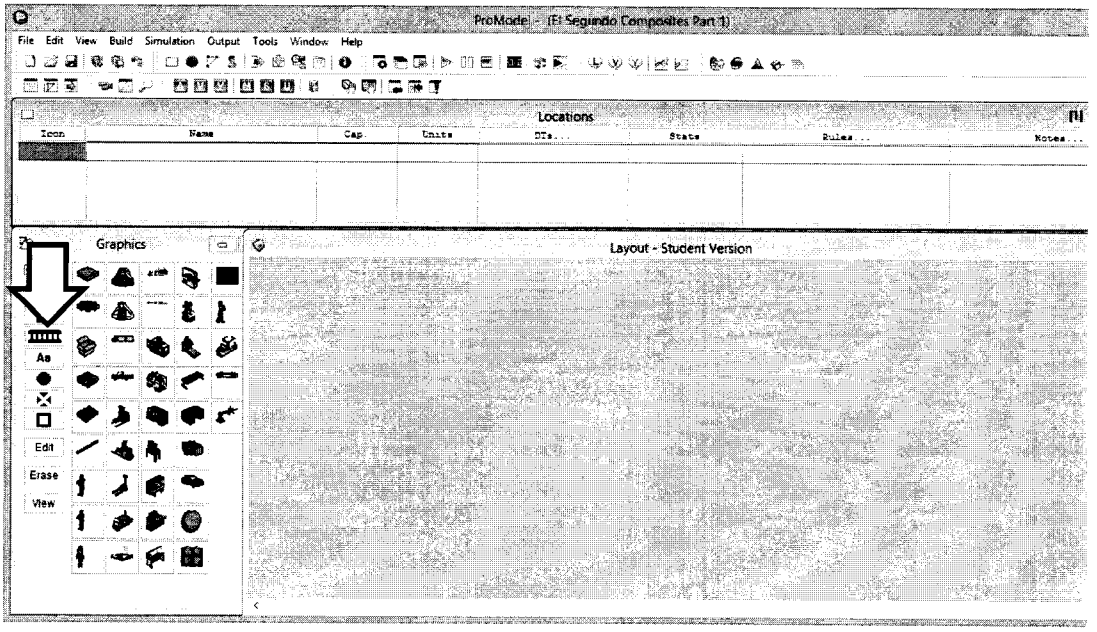
    2.1. For this exercise, seven different locations will be created: Incoming, Fill Q, Filling Machine, Packing Q, Packing Machine, Ship Q, and Shipping.

    2.2. To begin the locations building process select the menu "Build" and then the option "Locations".

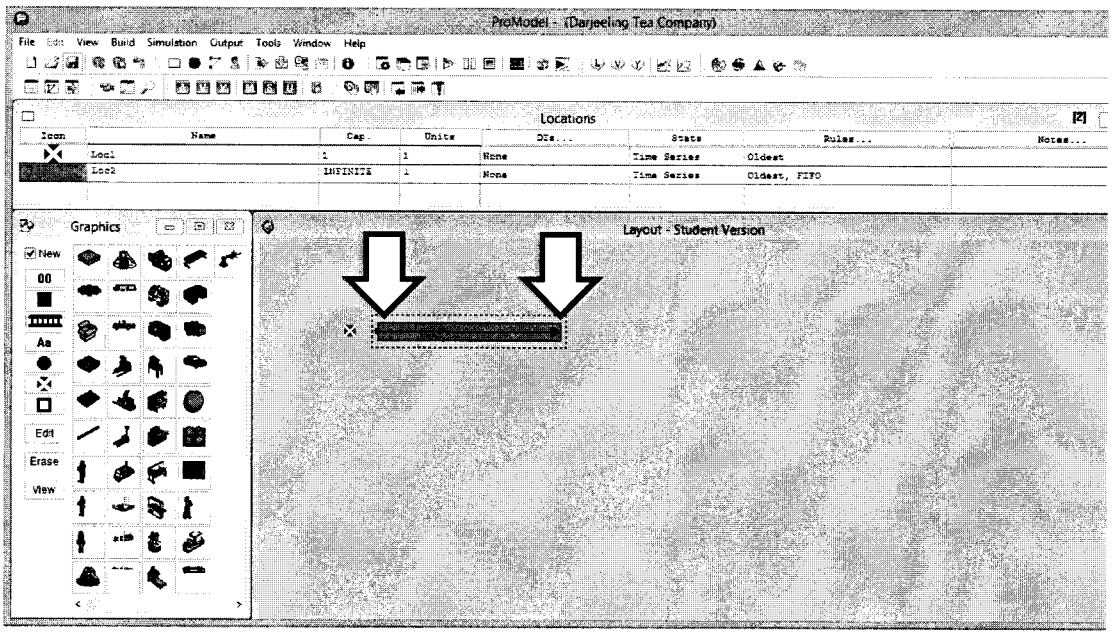
    2.3. The first location will be the "Incoming". Select the sixth icon on the first column (1) and place it on the layout (2).



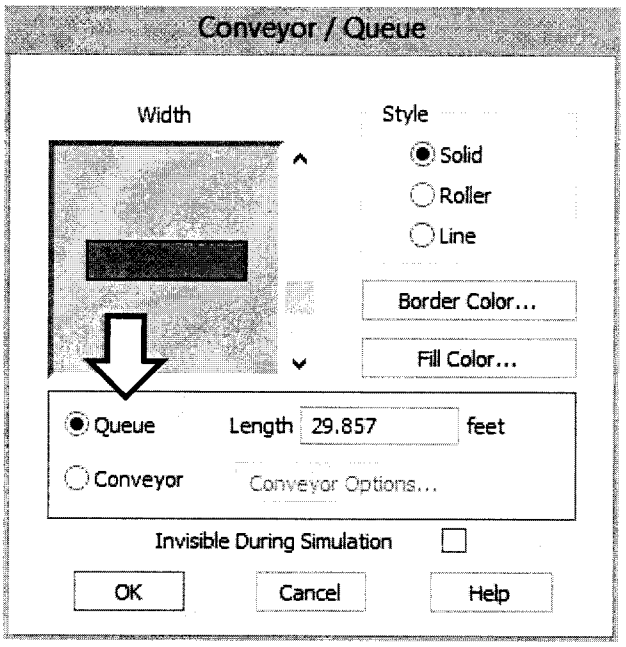
2.4. The next location to be created will be the "Fill Q". The creation of the location involves a little more than just selecting an icon and placing it on the layout. First, select the third icon on the first column of the Graphics window.



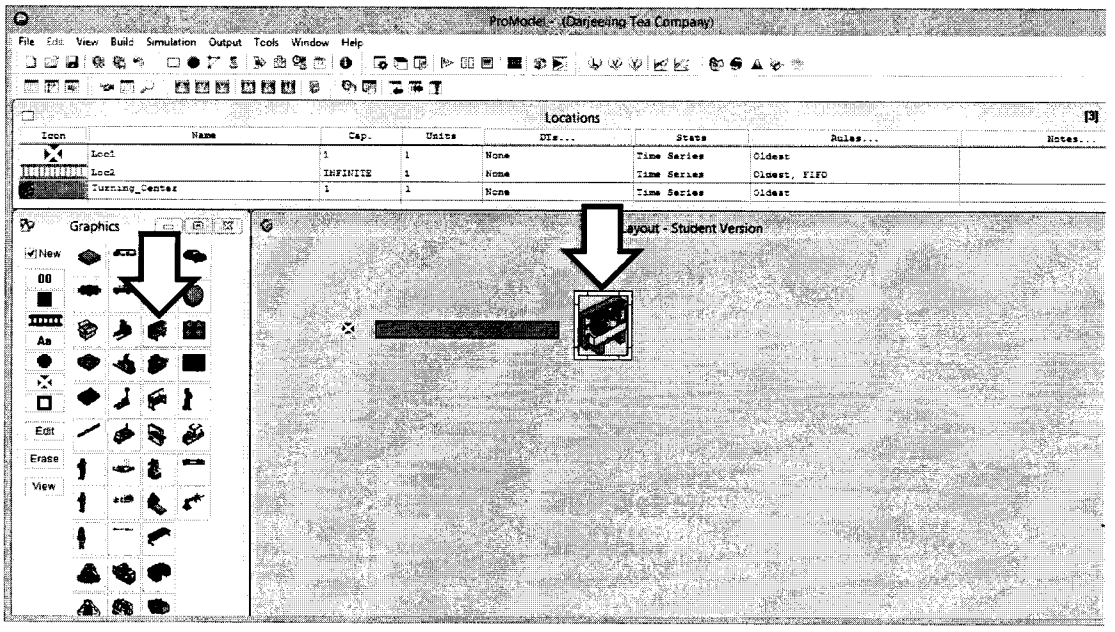
2.5. Next, click with the left button of your mouse where the Queue will start (1) and to finish your queue, click with the right button of your mouse where the queue will end (2).



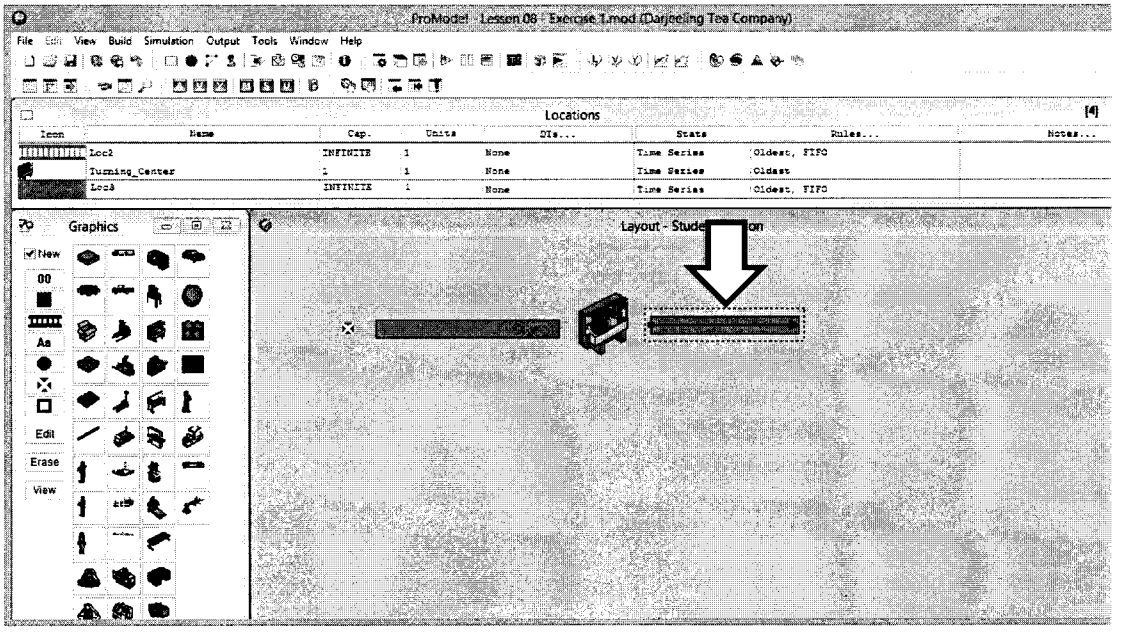
2.6. Now it is necessary to inform ProModel that this location is a Queue and not a Conveyor. Right click on the location that was just placed on the layout and select the option "Edit Graphic" from the menu. On the new Conveyor/Queue window, select the option "Queue".



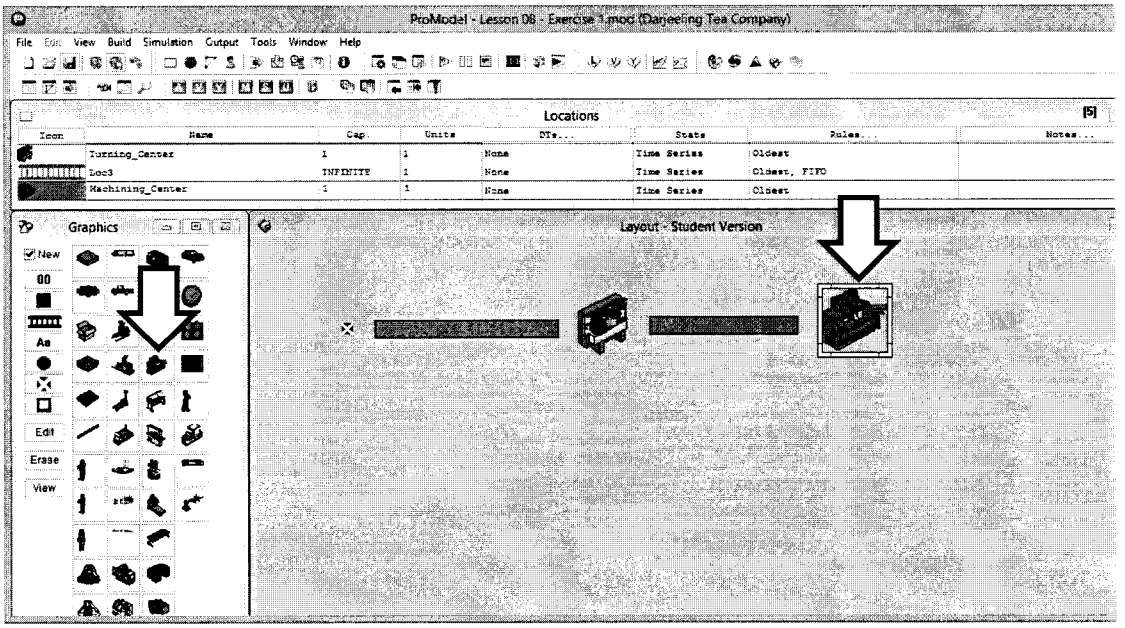
2.7. The third location to be created is the "Filling Machine". Select the third icon on the fourth column (1) and place it on the model layout (2).



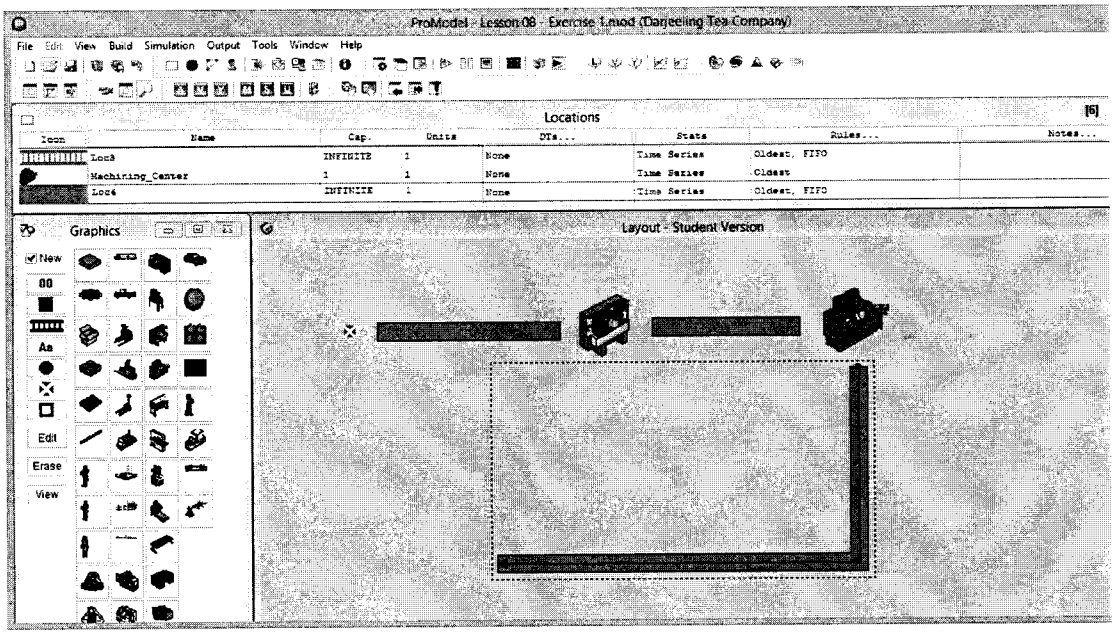
2.8. The next location will be the "Packing Q". Follow steps 2.4, 2.5 and 2.6 to create a Queue that looks like the one on the image below.



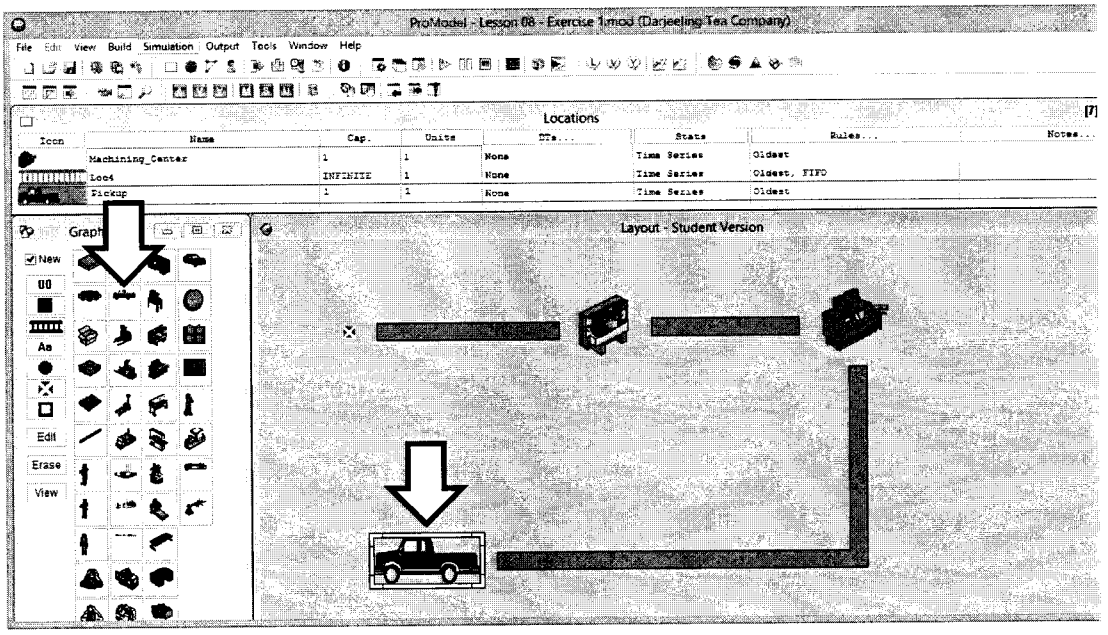
2.9. The fifth location will be the "Packing Machine". Select the fourth icon in the fourth column (1) and place it on the layout (2).



2.10. The next location will be the "Ship Q". Follow steps 2.4, 2.5 and 2.6 to create a Queue that looks like the one on the image below.



2.11. The final location of this model will be the "Shipping". Select the second icon on the third column (1) and place it on the layout (2).



2.12. If you have not done it yet, now it is time to rename your locations. Follow the order in which they were created, and on the Locations Table rename your

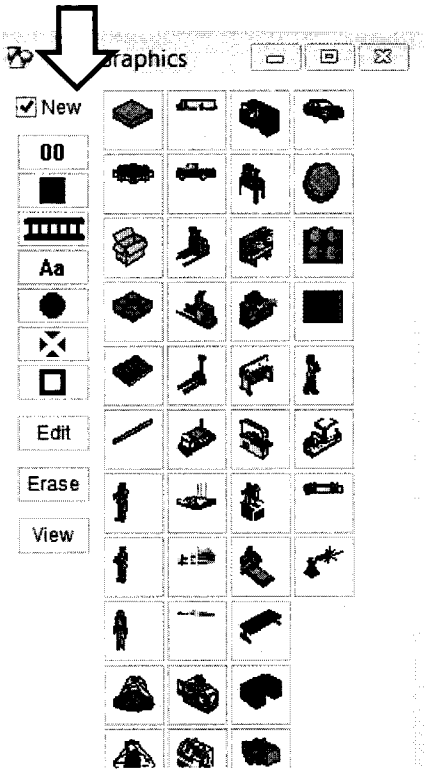
locations to Incoming, Fill Q, Filling Machine, Packing Q, Packing Machine, Ship Q, and Shipping.

2.13. On the Locations Table, change the Filling Machine Cap. to 50 and the Packing Machine Cap. to 20. At this point, your location table should look like the following.

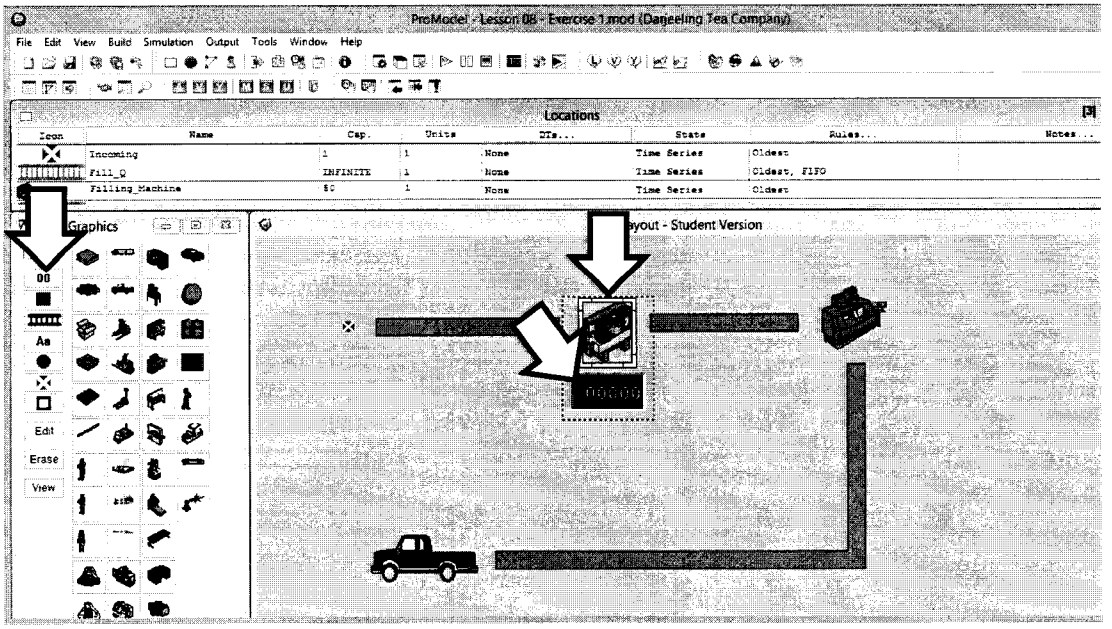
Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...
	Incoming	1	1	None	Time Series	Oldest
	Fill_Q	INFINITE	1	None	Time Series	Oldest, FIFO
	Filling_Machine	50	1	None	Time Series	Oldest
	Packing_Q	INFINITE	1	None	Time Series	Oldest, FIFO
	Packing_Machine	20	1	None	Time Series	Oldest
	Ship_Q	INFINITE	1	None	Time Series	Oldest, FIFO
	Shipping	1	1	None	Time Series	Oldest

2.14. The next step will be to insert a few counters in the model. First uncheck the "New" option on the Graphics Window.

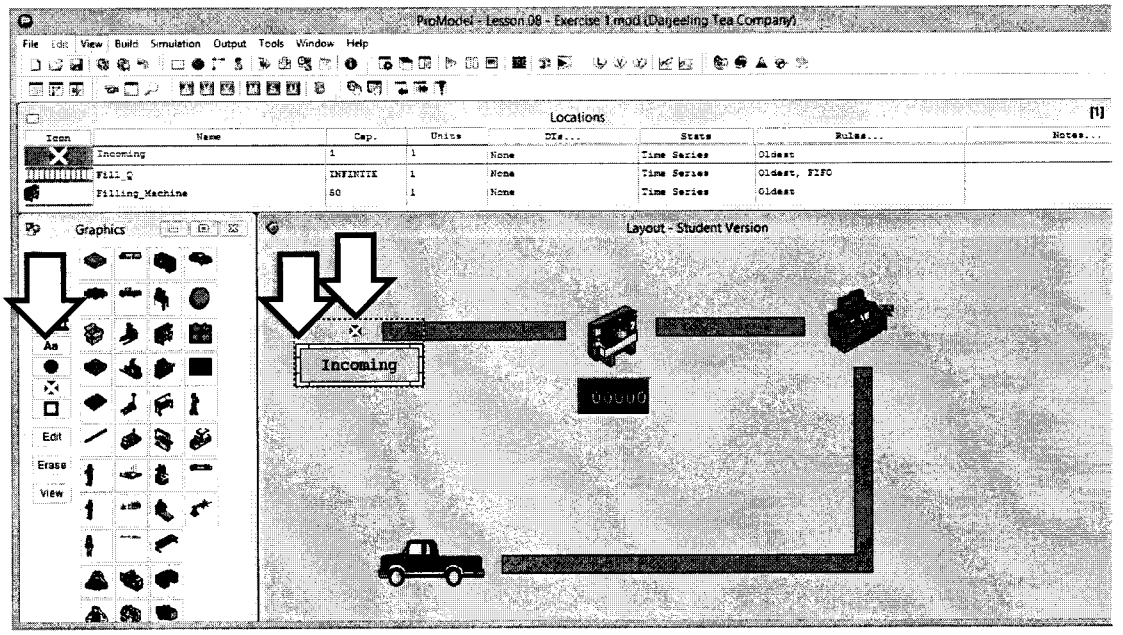


2.15. Select the Location "Filling Machine" (1), click on the first button of the first column (2) and click on the layout (3) to place the counter.



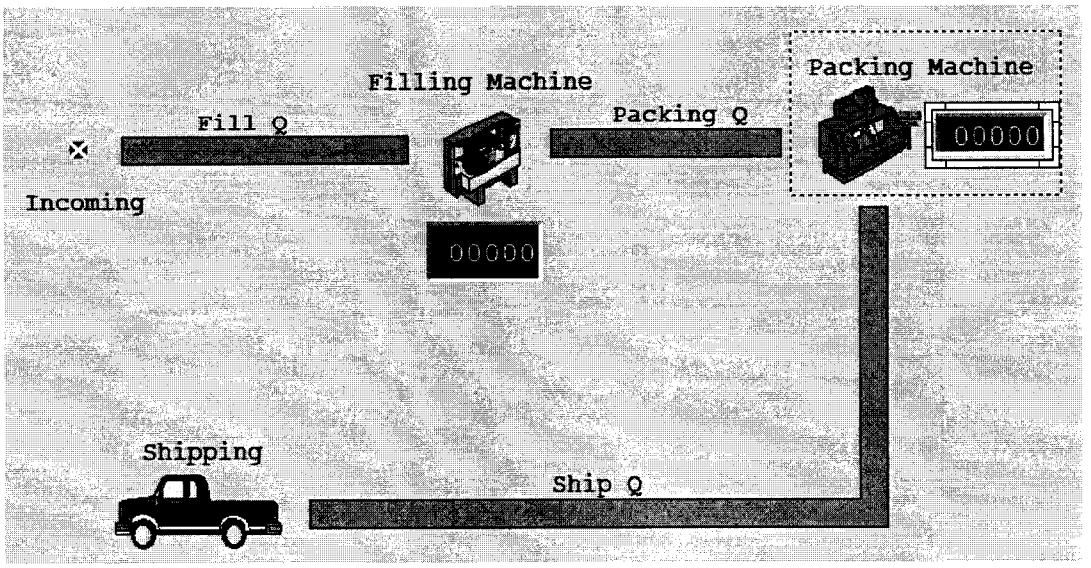
2.16. Repeat step 2.15 and insert a counter for the location "Packing Machine".

2.17. Now, insert the names of the locations on the layout. Select the location "Incoming" (1), click on the fourth button of the first row of the Graphics Window (2), and click on the layout (3).



2.18. Repeat the step 2.17 and insert the location names for all the other locations.

2.19. Your layout should contain the elements shown on the image below.



2.20. Your location table should look similar to the following.

Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...
	Incoming	1	1	None	Time Series	Oldest
	Fill_Q	INFINIT	1	None	Time Series	Oldest, FIFO
	Filling_Machine	50	1	None	Time Series	Oldest
	Packing_Q	INFINIT	1	None	Time Series	Oldest, FIFO
	Packing_Machine	20	1	None	Time Series	Oldest
	Ship_Q	INFINIT	1	None	Time Series	Oldest, FIFO
	Shipping	1	1	None	Time Series	Oldest

2.21. It is very important that you only have 6 locations on your model. If you have more than six, consider deleting the extra ones. This can be done by selecting the row you wish to erase and clicking on the menu "Edit" and selecting the option "Delete". BE VERY CAREFUL: ProModel DOES NOT HAVE AN "UNDO" FUNCTION.

3. Creating Entities

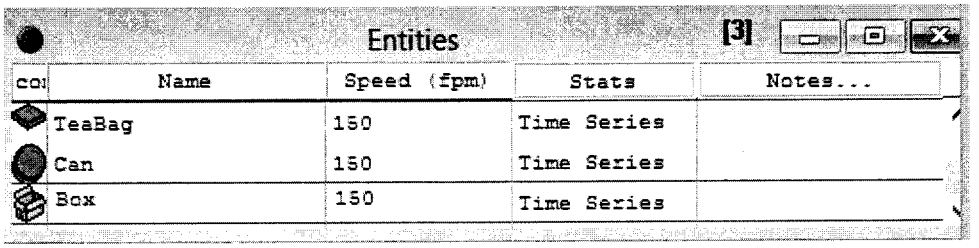
3.1. This model will make use of three entities: TeaBag, Can, and Box. The second being used to represent a group of "TeaBag" entities, and the third a group of "Can" entities.

3.2. To start building the entities, select the menu "Build" and the option "Entities".

3.3. To create the first entity, select the first icon of the first column of the Graphics Window (a grey cube), to create the second entity click on the second icon of the fourth column (a grey circle), and to create the last entity select the third icon of the first column (a brown box). Feel free to use different icons if desired.

3.4. On the Entities Table, rename the first entity as "TeaBag" and the second one as "Can", and the third one as "Box".

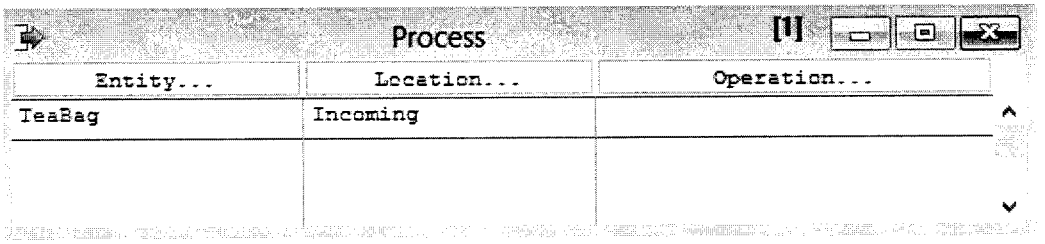
3.5. The Entities Table should look similar to the following. Feel free to use different icons to represent your entities.



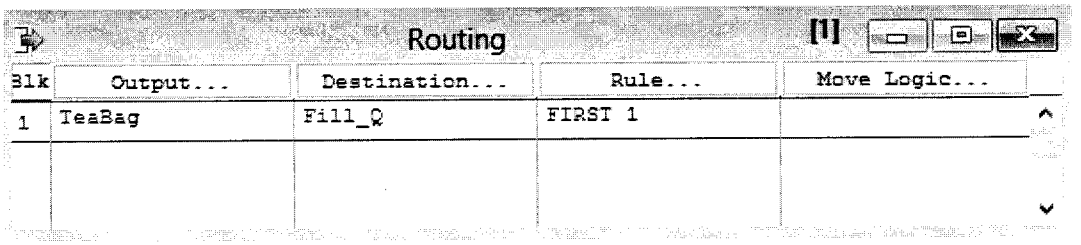
4. Creating Processes

4.1. To start creating the processes, select the menu "Build" and then "Processing".

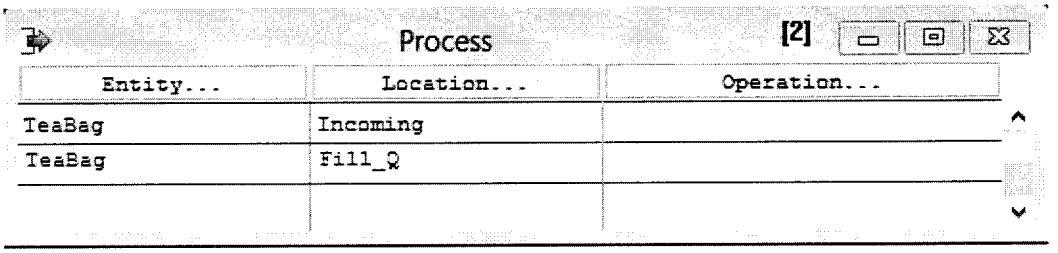
4.2. The entities will start in the Location "Incoming" of the model and will proceed to the Location "Fill Q". On the Process Table, select the Entity "TeaBag" and the Location "Incoming".



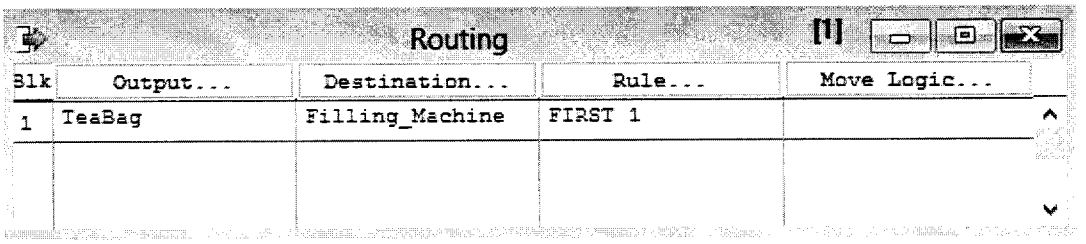
4.3. On the Routing Table, select the "TeaBag" as the output and the "Fill Q" as the Destination.



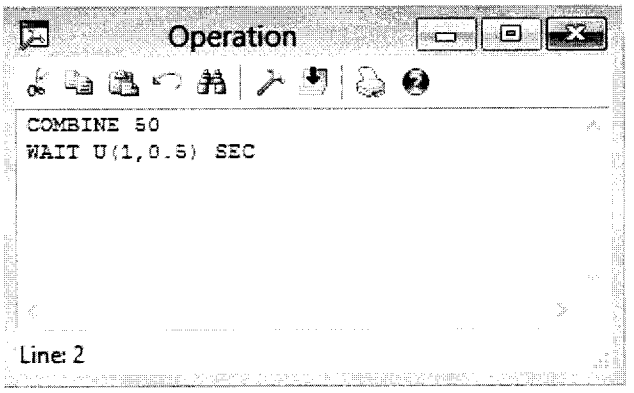
4.4. On the next process, the entities will move from the "Fill Q" to the "Filling Machine". On the Process Table, select the "TeaBag" as the Entity, and the "Fill Q" as the Location.



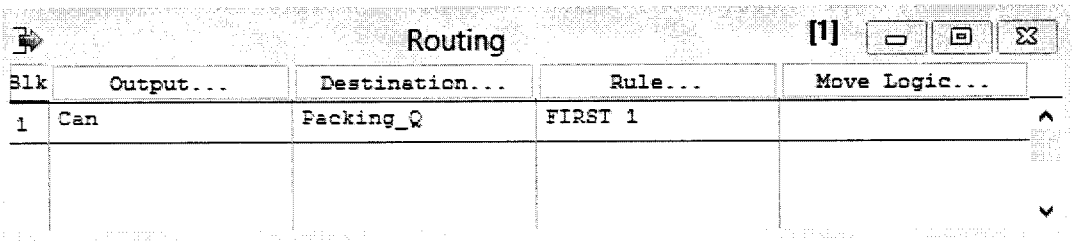
4.5. Next, on the Routing Table select the "TeaBag" as the Output and the "Filling Machine" as the Destination.



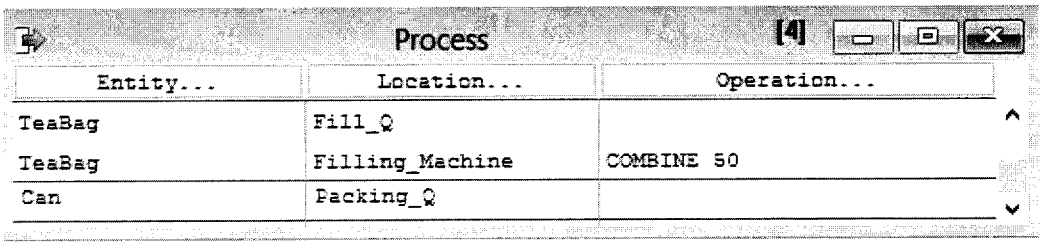
4.6. In the next Process, the TeaBag entities will be combined into a group of 50 put on a can and moved to the Packing_Q location. On the Process Table, select the "TeaBag" as the Entity, the "Filling Machine" as the Location, and then double-click on the Operation Cell. On the Operation Window type the command "COMBINE 50" on the first line, and "WAIT U(1,0.5) SEC" on the second line as shown on the image below.



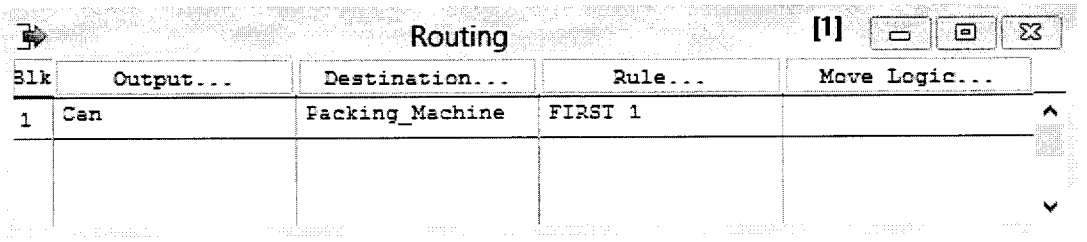
4.7. On the Routing Table, select the entity "Can" as the Output and the "Packing Q" as the Destination.



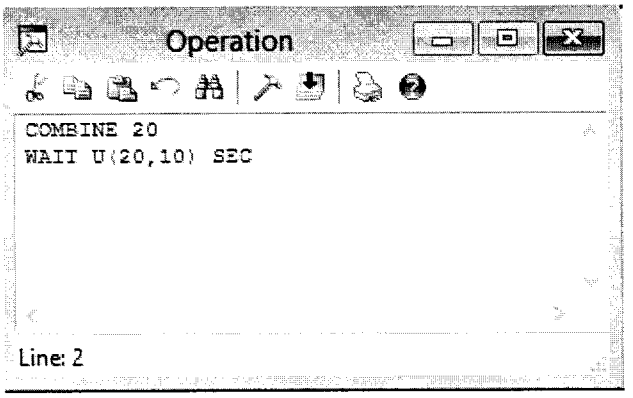
4.8. The Cans will then move from the "Packing Q" to the "Packing Machine" where they will be packed into a box. Add a new Row to the Process Table and select the Entity "Can" and the Location "Packing Q".



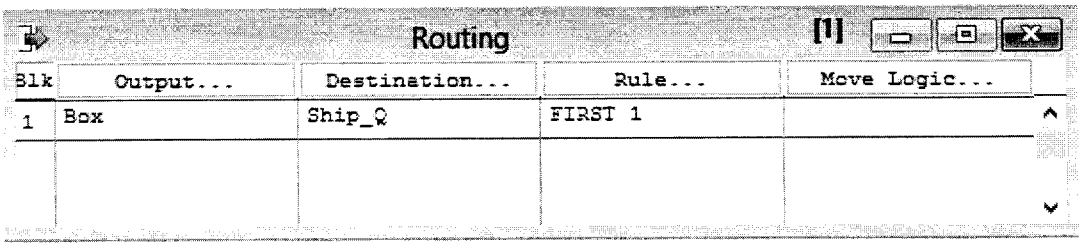
4.9. On the Routing Table, select the "Can" as the Output and the "Packing Machine" as the Destination.



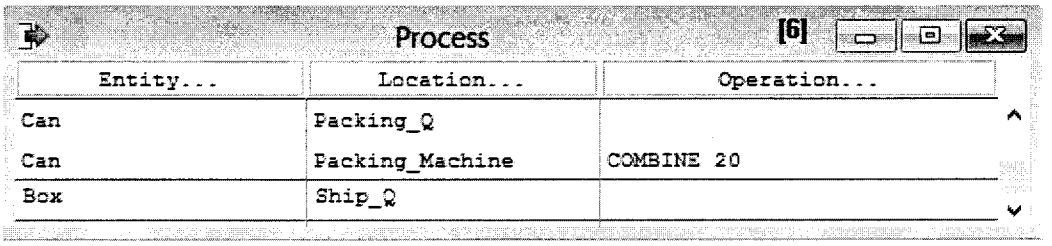
4.10. Add a new row to the Process Table. Select the "Can" for the entity, the "Packing Machine" for the Location, and then double-click the Operation Cell. On the Operation Window type "COMBINE 20" on the first line and then "WAIT U(20, 10) SEC" on the second one.



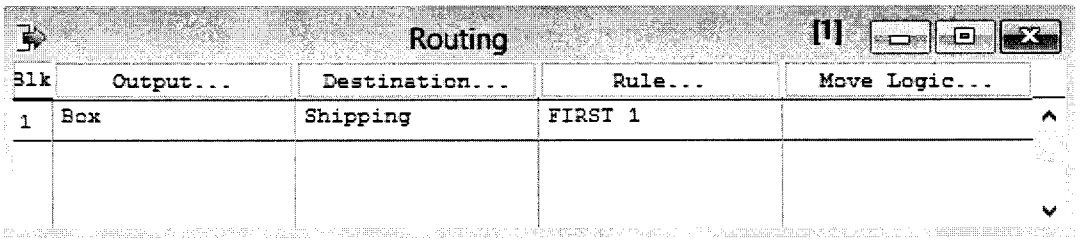
4.11. On the Routing Table, select the "Box" as the Output and the "Ship Q" as the Destination.



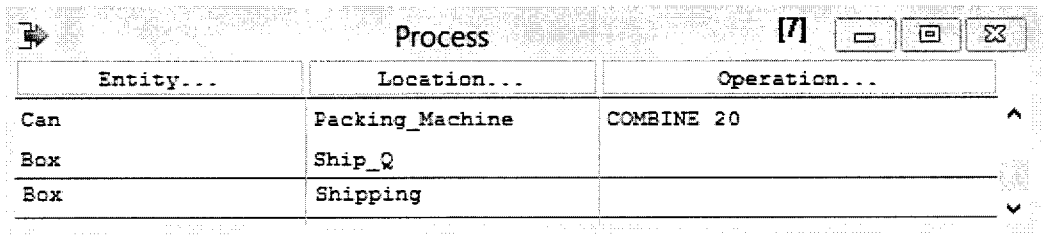
4.12. Add a new row to the Process Table. Select the "Box" as the Entity and the "Ship Q" as the Location.



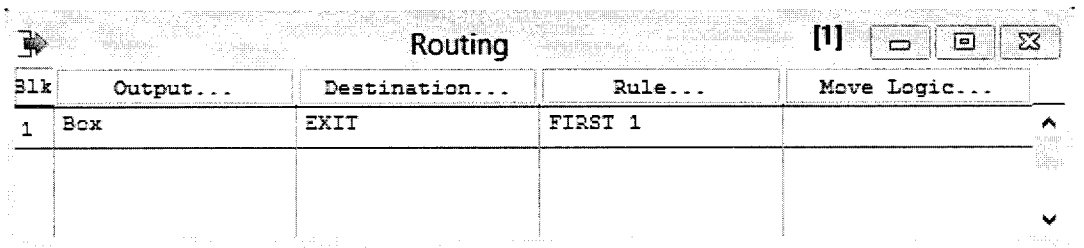
4.13. On the Routing Table, select the "Box" as the Output and the "Shipping" as the Destination.



4.14. Add a new row to the Process Table. Select the "Box" as the Entity and the "Shipping" as the Location. Any processing happens in this location, so it is not necessary to add anything to the Operation Cell.



4.15. On the Routing Table, select the "Box" as the Output and the "EXIT" as the Destination.



4.16. At this point, your Process and Routing tables should resemble the following.

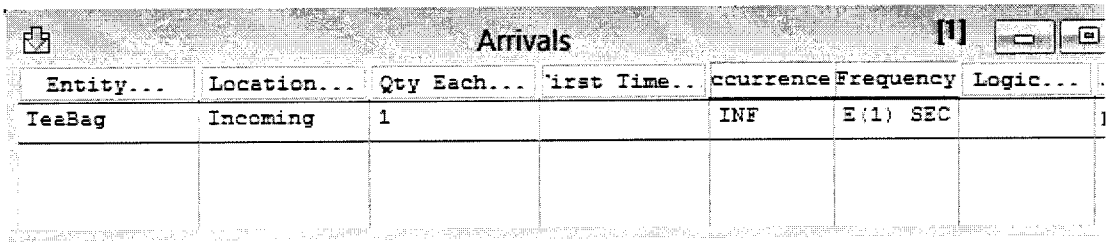
Process				Routing			
Entity	Location	Opeartion	Blk	Output	Destination	Rule	Move Logic
TeaBag	Incoming		1	TeaBag	Fill Q	FIRST 1	
TeaBag	Fill Q		1	TeaBag	Filling Machine	FIRST 1	
TeaBag	Filling Machine	COMBINE 50 WAIT U(1,0.5) SEC	1	Can	Packing Q	FIRST 1	
Can	Packing Q		1	Can	Packing Machine	FIRST 1	
Can	Packing Machine	COMBINE 20 WAIT U(20,10) SEC	1	Box	Ship Q	FIRST 1	
Box	Ship Q		1	Box	Shipping	FIRST 1	
Box	Shipping		1	Box	EXIT	FIRST 1	

5. Creating Arrivals

5.1. Select the menu Build, and the option Arrivals.

5.2. For this Exercise it is only necessary to create the arrival to one of the entities (TeaBag).

5.3. On the Arrival Table, select the "TeaBag" as the Entity, "Incoming" as the Location, "1" as the Qty Each, "INF" as the Occurrences, and "E(1) SEC" as the Frequency. Your arrival table should resemble the following.

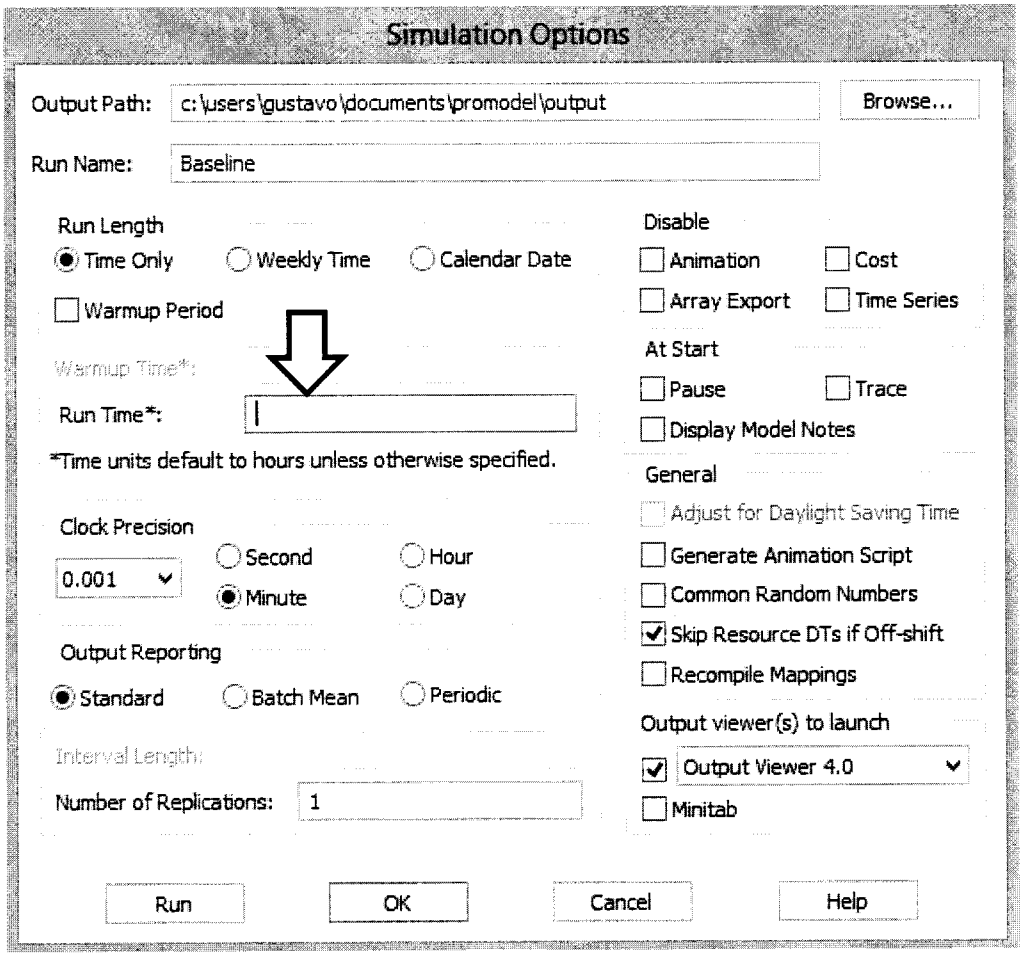


6. Defining Simulation Options, Saving, and Running the Model

6.1. Save your model (Menu File, Option Save).

6.2. Go to the menu Simulation, and select Options.

6.3. Change the "Run Time" value to 24 (Meaning that the model will simulate a period of 24 hours). Click on the Button OK to close the window.

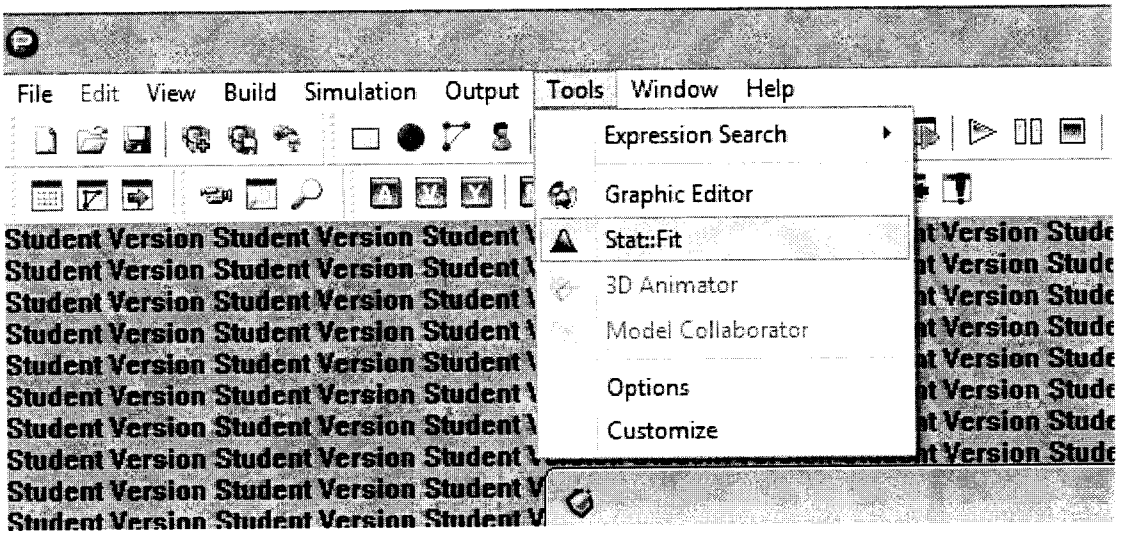


6.4. Run your model. Select the menu Simulation, and the option Run.

6.5. Analyze the Results.

LESSON 9

This lesson will be based on a custom exercise designed to illustrate the use of Stat::Fit. This software is part of the ProModel® package and is installed by default with the Student and Professional versions. You can launch the Stat::Fit from ProModel's start menu folder or from within ProModel on the menu Tools and then selecting the option Stat::Fit.

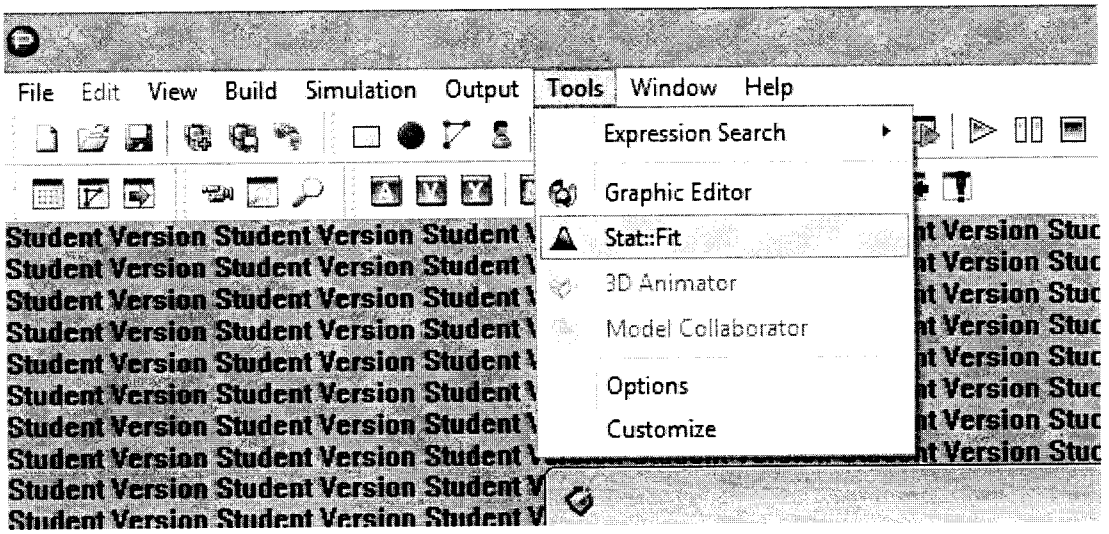


Stat::Fit aims to convert a set of values into probability distributions that can be used as input information for models built using ProModel®. This lesson will focus on how to use and get the best results from Stat::Fit, for the theoretical background about data collection, distribution fitting, and other statistical knowledge please refer to Chapter 5 – Data Collection and Analysis, from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden.

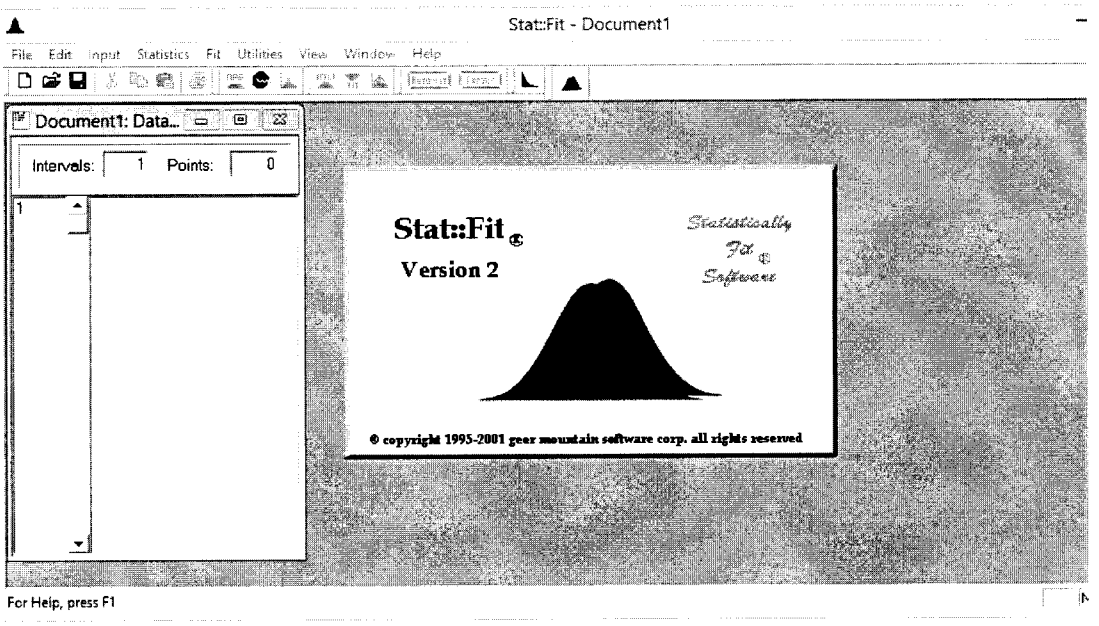
For this lesson a sample of intervals will be provided at first, so the students can learn how to use Stat::Fit to process this sample and obtain a Probability Distribution. And in a later moment they will be required to collect the information themselves and obtain the Probability Distributions on their own.

1. Starting Stat::Fit

The first step in this lesson is to launch Stat::Fit. This can be done by two different methods: the software can be launched by selecting it on ProModel's start menu folder, or by launching it using ProModel menus. To launch it using ProModel, first start the software and then select the menu "Tools" and the option "Stat::Fit".



After that option is selected, the user should be presented with the following screen.



The image above shows Stat::Fit's User Interface (UI). The table on the left side is where the data sample will be inserted to generate the Probability Distributions. And at the top of the screen is where the menus of this software are located.

2. Entering a sample

Suppose that during the development of a simulation model, it was necessary to create a process with a time that varies each time that given process is executed (most of real life processes behave like this). You went to the location you are going to model with a spreadsheet and a stopwatch, and started to measure the time a certain process took to be completed. As an example, imagine that the location you are modeling is a post office and the process you are measuring is the interaction between the post office clerk and the customers that want to ship packages.

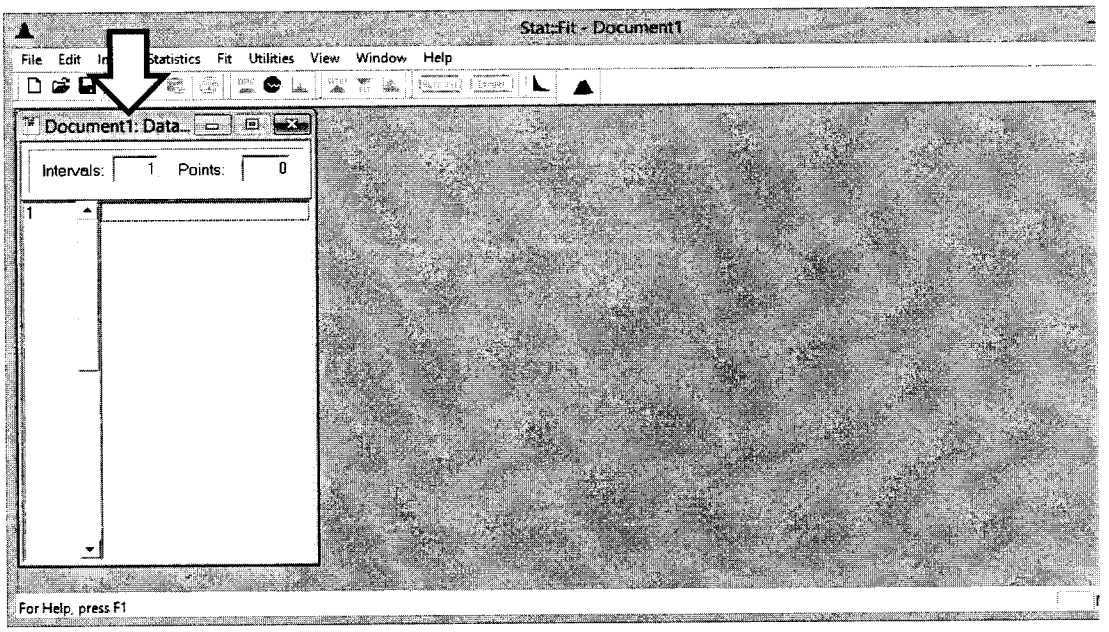
The process starts when the customers approach the counter where the clerk is located, and follows as he informs the destination of his package, pays for shipping,

and move away from the clerk after the package is processed and shipped. In this example imagine that you will measure the time between the customer first contact with the clerk (when he arrives at the counter) and when the customer leaves the counter. You measured the process 40 times and compiled your results in a table below.

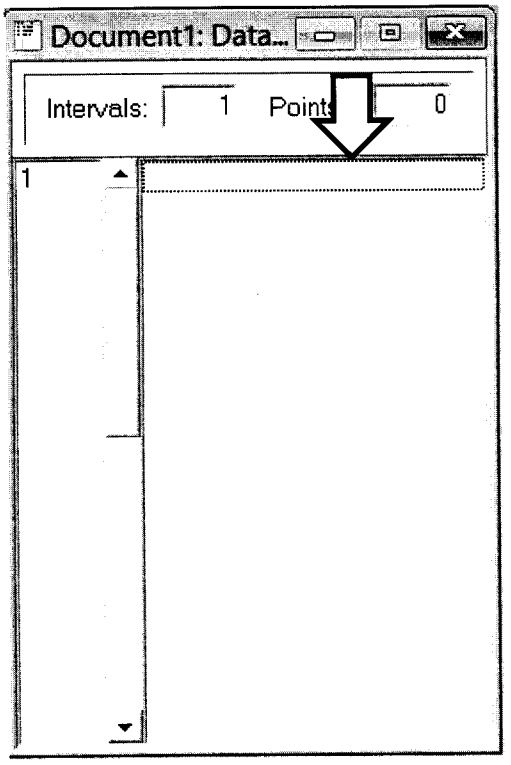
Customer	Time (Seconds)	Customer	Time (Seconds)
1	62	21	69
2	55	22	35
3	67	23	65
4	36	24	74
5	64	25	70
6	49	26	68
7	38	27	62
8	82	28	55
9	55	29	69
10	61	30	65
11	75	31	86
12	54	32	69
13	33	33	54
14	69	34	46
15	37	35	28
16	64	36	42
17	53	37	32
18	62	38	48
19	76	39	86
20	67	40	54

From a fast look at this table, it is possible to notice that the duration of this process varies considerably between each customer, and just making use of an average time would not be enough to correctly represent this process in a model. This is where Stat:Fit will be used. These values will be entered on the Input Table to be processed and generate a distribution probability.

On the Stat::Fit main screen, locate the input table as shown on the image bellow.



Select the first row on the right side.

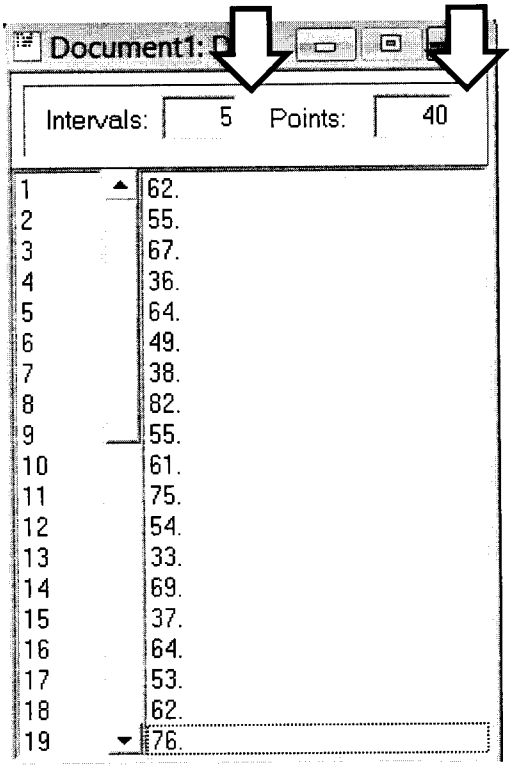


Insert the values in shown on the table above (the post office processing times).

This can be done in two different ways: each number can be typed in individually, or a

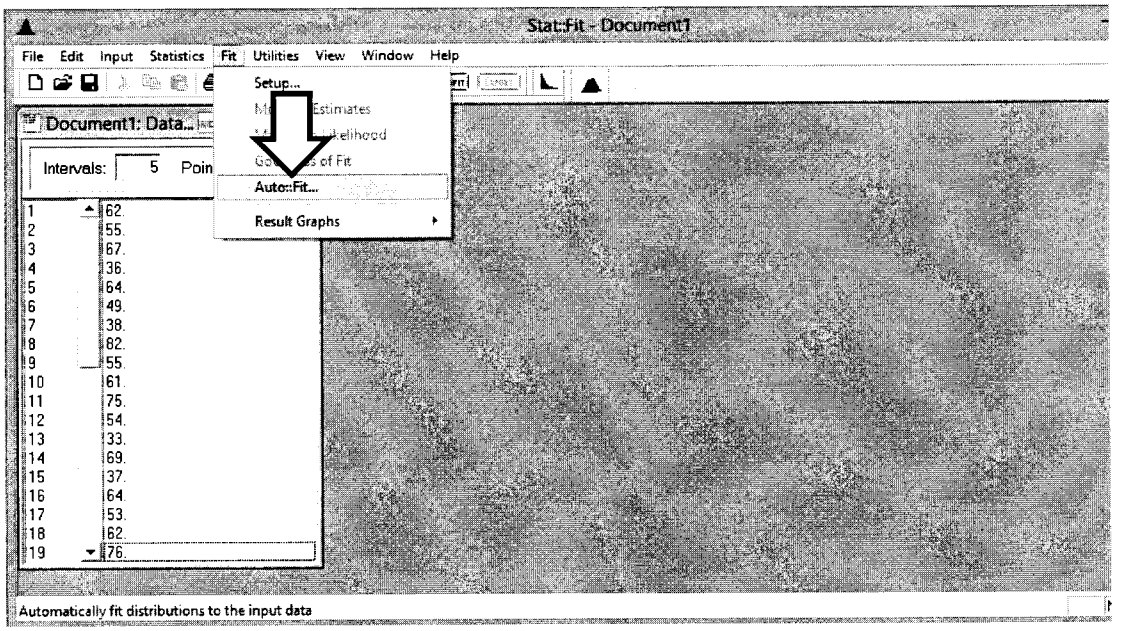
block of numbers can be copied and pasted right into Stat::Fit's input table. If you are typing values manually, hit the enter key after every value to create a new row on the table, and if you are pasting the values make sure that you do not past the same value twice.

After all the values are entered, your input table should show that your data has 5 intervals and 40 points.

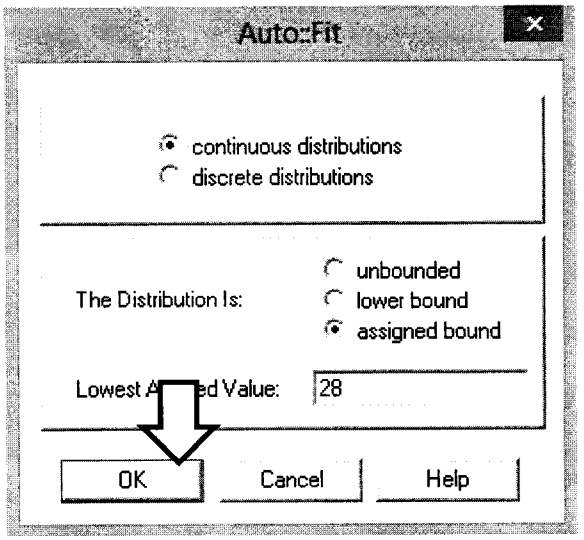


3. Generating a Probability Distribution

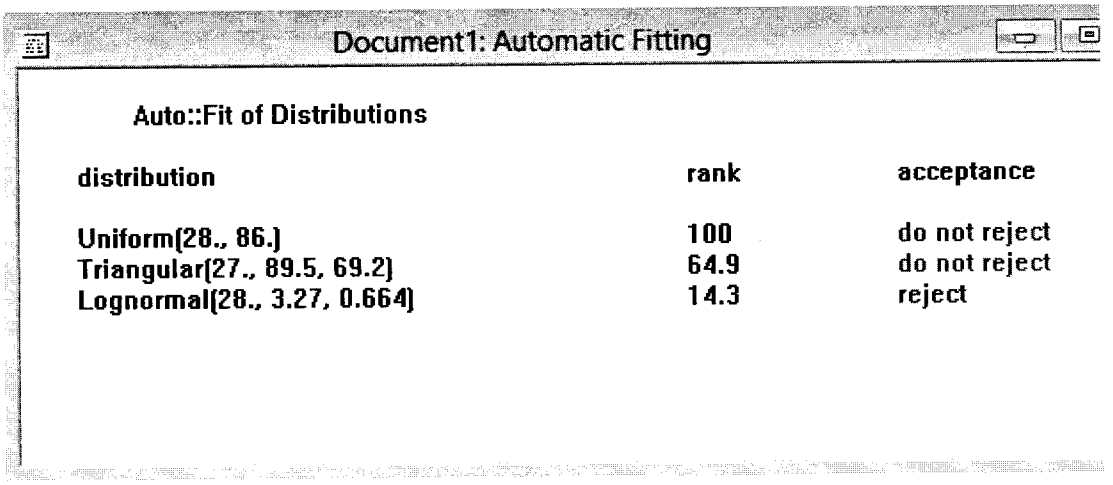
Now it is time to generate the probability distribution. To do so, simply select the menu "Fit" and the option "Auto::Fit".



After the "Auto::Fit" option is selected, the "Auto::Fit" window will appear with a few options that can be selected. For the purpose of this course, we will not go in detail with these options, so simply click on the button "OK".

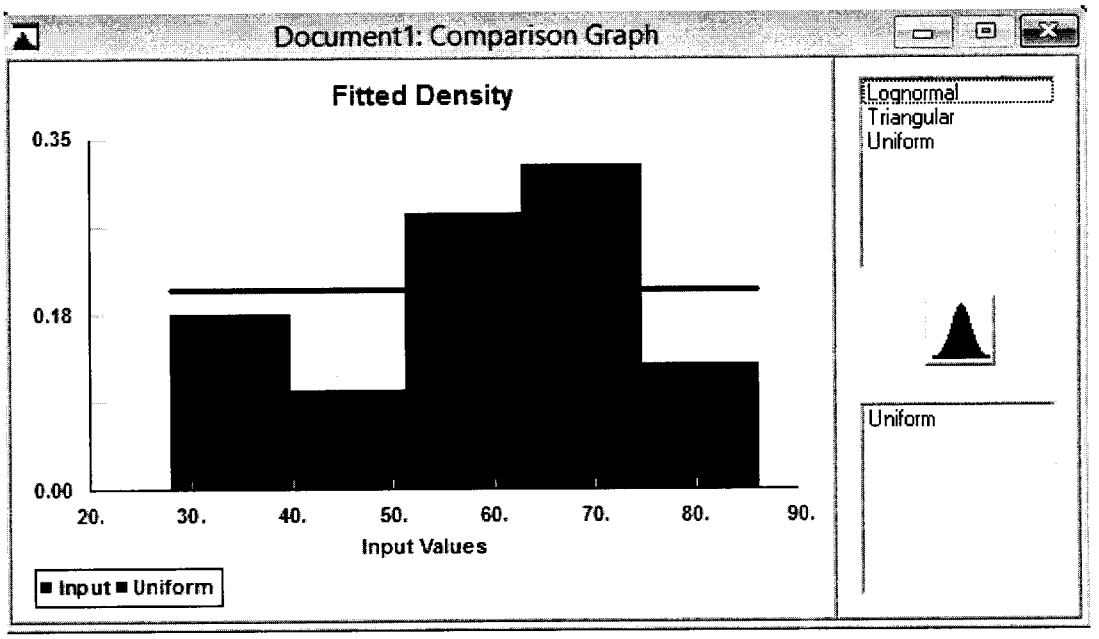


Stat::Fit will analyze your input values, and based on them will provide a set of Probability Distributions that can be used as an input on a simulation model.



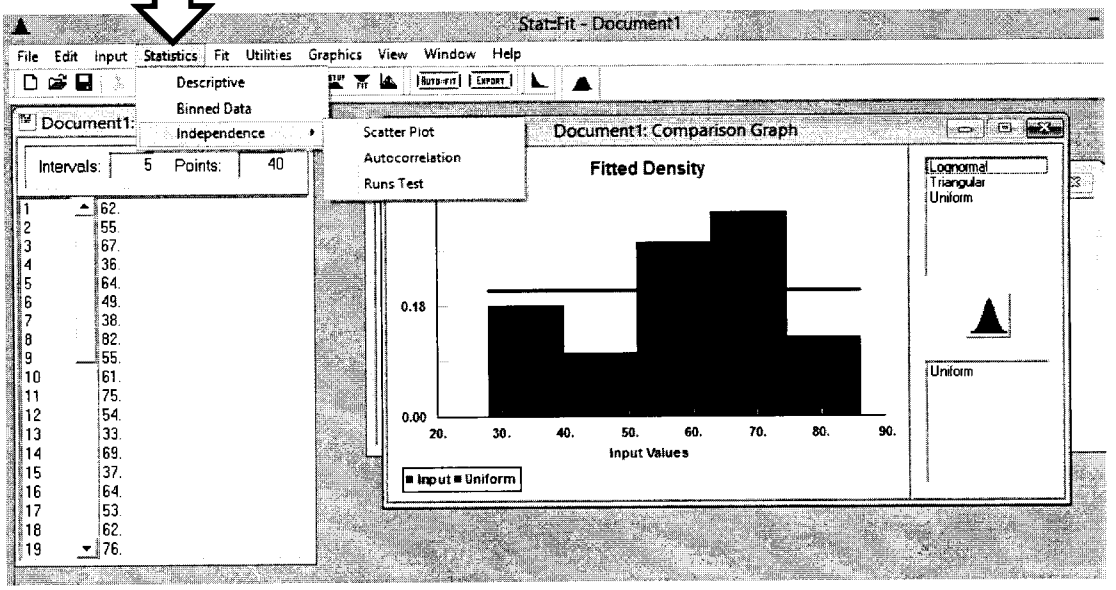
For the values entered as an input, Stat::Fit provided three Probability Distributions that can be used in the simulation model. The distributions are shown on the image above, and the best distribution for the values is shown at the top of the list. The first column of the table displays the distribution and its parameters, the second the distribution rank, and the third if the distribution can or cannot be used to represent the entered values.

If you click on any of the distributions shown on the Automatic Fitting window, Stat::Fit will show you the input values as a histogram, and the probability distribution as a line. Click on the first distribution and the following will be displayed.

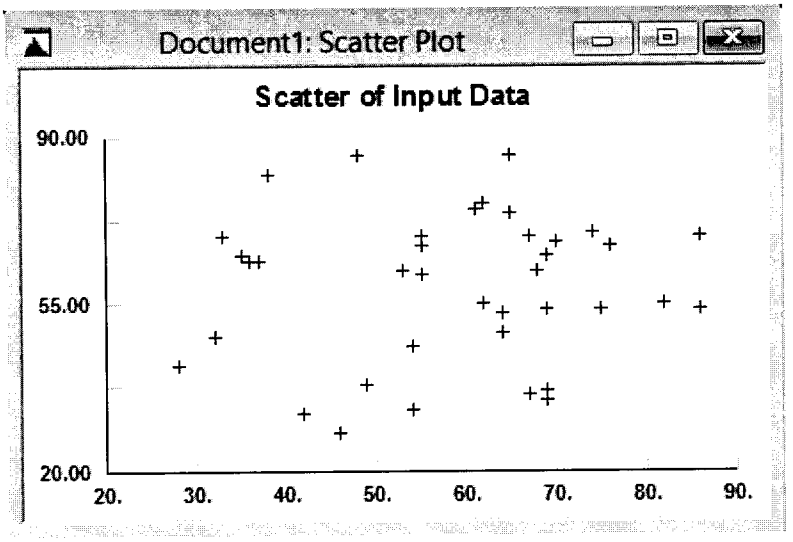


4. Analyze the data

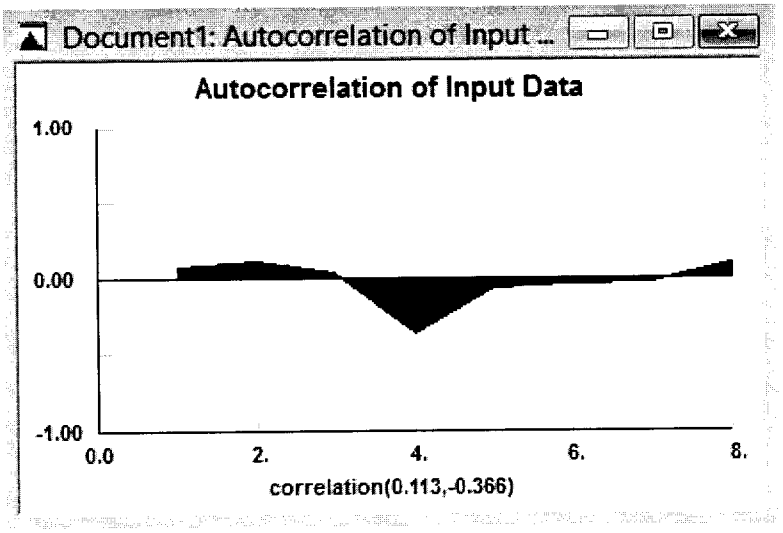
Stat::Fit also allows the user to perform some statistical tests on the input data. To perform these analyses select the menu "Statistics" – all the options under this menu are statistical tests that can be applied to the input sample.



As an example, select the option "Scatter Plot" (under the Independence sub-menu). Observe the resulting graph (image below) and try to analyze it accordingly to the information contained on the Chapter 5 of the textbook.



The scatter plot shows that the variable is independent, once the points on the plot are scattered and no trend is evident. Now, execute the "Autocorrelation" test (Statistics > Independence > Autocorrelation), you will be presented with a result similar to the one below.



Once the values of the plot are really close to zero, and the correlation values at the bottom are small, it is possible to affirm that there is little or no correlation on collected samples.

This tutorial is now over, after this point you will be requested to execute a similar exercise by yourself. Select **one** of the tasks below and complete the assignment.

Task 1

1. Go to a street that has a MILD traffic, either one way or two way but (very important) only one line in either direction (if two way) or ONE line (in one direction (one way, NO two lines)

2. The street must have a speed limit NO greater than 35 miles/hour

3. DO NOT choose a LIGHT or stop as an arrival point (reference) or any point too close to a light or stop (i.e. at least 100 feet away from a light/stop in a way that a lot of cars do not "pile" at your reference point)

4. IF you choose a point close to a light or a stop be sure the piling of cars beyond the light or stop never surpass your reference point when measuring.

5. RECORD the time (Hour/minutes/second or just minutes/second) at which each car pass through your reference point (i.e. the corner of an intersection, a pole, a tree etc).

6. Always use THE SAME reference point to measure the time of arrival, make at least 101 measurements (101 cars!)

    a. Measure the arrival to a fixed point of cars moving in ONE direction only

    b. Use a precision digital chronometer or a watch capable of giving an accurate measure to the second.

    c. If two cars are close to each other at the arrival (i.e. "near bumper to bumper", do your best to record the difference (i.e. half or one second).

(That is WHY a MILD traffic street/35 mph with just space for one car per direction away from a stop or light is recommended)

7. In an Excel file (column) record the 101 times of arrival to the reference point

8. Subtract the first time of arrival from the second one, the second time of arrival from the third one and in this way until you do it for all the recorded times. (Therefore you will end up with 100 points). Fill a parallel column (in excel) with these differences IN SECONDS (even if the difference is let's say 72 seconds)

9. USE PROMODEL STAT FIT to find out the most likely distribution (Save the results in a word document for reporting purposes)

IMPORTANT:

a) Be sure the temperature of the day is above 32 Fahrenheit and the climate conditions ARE ABSOLUTELY SAFE for this activity. In other words NEVER take an unnecessary risk. (I.e. stay far away from the intersection, preferable sit in a park with warm clothes, inside a restaurant or inside your car parked in a safe and legal place).

b) I suggest not waiting to do this activity near the due date when you may not have too many choices.

c) Try to be discrete in the way you take your measurements in public, we do not want people calling the police that someone is observing and

taking notes in the corner of the street looking all cars! Note: For traffic simulation the measurements are done with a sensor cable across the street.

d)! **NEVER take Risk! Exercise your best judgment to do this safely, if you have any question or disability that does not allow you to do this or is there any potential risk please choose option B.**

Task 2

Propose your own research about finding a distribution, some examples may be

- Time of a particular worker in front of a machine (the completion time must depend on the worker skills and not just waiting a fixed time in front of it)
- Arrivals to a fast food restaurant
- Be sure to record at least 100 measurements, however if the activity time takes more than 5 minutes per observation, 40 measurements might be accepted. (let me know)
- Arrivals to a bank teller
    - USE PROMODEL to find out the most likely distribution (Save the results in a word document for reporting purposes)
- Other (let me hear about it, proposal in writing only. If is something related with the company you work for, better.

IMPORTANT:

a) If you choose your own project, please e-mail me ASAP and explain it in detail for approval you can NOT work with a class partner if you choose option B.

b) Be sure to have the proper company permissions to measure your observations, the results will not be disclosed and are only for HW purposes

Deliverables:

- Your Excel File with the recorded times
- Plot of the best fit curve (distribution) over the histogram (similar to Figure L5.10 in page 471 textbook)
- Your report of automatic fitting (similar to Figure L5.8 in page 470 textbook)

LESSON 10

This exercise from the tenth lesson will be based on the Laboratory 6.1.1 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concept of Attributes.

Attributes are similar to variables, they are used to store a specific value, but the main difference is that they can be associated with specific locations or entities when Variables are shared across the model. Examples of attribute would be part numbers, entity weight, time stamps, and others.

For this exercise, the model built on the Lesson 2 (Laboratory 2.1 – Fantastic Dan) will be used as a base, and a few alterations will be made in order to introduce the concept of attributes. Start by loading the Fantastic Dan model (Laboratory 2.); to do so select the menu "File", the option "Open", locate your model file and load it.

The difference between this model and the one built on Laboratory 2.1 is that different classes of customers will be considered, and these classes will have different processing times. To make this work, an attribute will be created and a specific value of this attribute will be set for each type of customer. This will allow the model to identify and treat it type of customer individually by using an "IF-THEN-ELSE" logic (laboratory 4.11).

The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"Customers visit the neighborhood barbershop Fantastic Dan for a haircut. Among the customers there are 20 percent children, 50 percent women, and 30 percent men. The customer inter-arrival time is triangularly distributed with a minimum, mode, and maximum of seven, eight, and nine minutes respectively. The haircut time depends on the type of customer." The processing time for each of these customers is shown on the table below.

Haircut times for all customers

	Haircut Time (minutes)	
Customer Type	**Mean**	**Half-Width**
Children	8	2
Women	12	3
Men	10	2

Run the model for 480 minutes and answer:

1. How many customers of each type does Dan serve per day
2. Track number of customers of each type on the salon throughout the day.

1. Creating a new model

1.1. Once the base model for this lesson was already built on Laboratory 2.1, select the menu "File" and the option "Open". Load your model from Laboratory 2.1.

1.2. With the model loaded, select the menu "File" and then "Save As...". Save your model with the name **Fantastic Dan Attributes**.

2. Creating Locations

2.1. The locations of this model will remain the same as the ones in the previous model, hence no alteration will be necessary.

3. Creating Entities

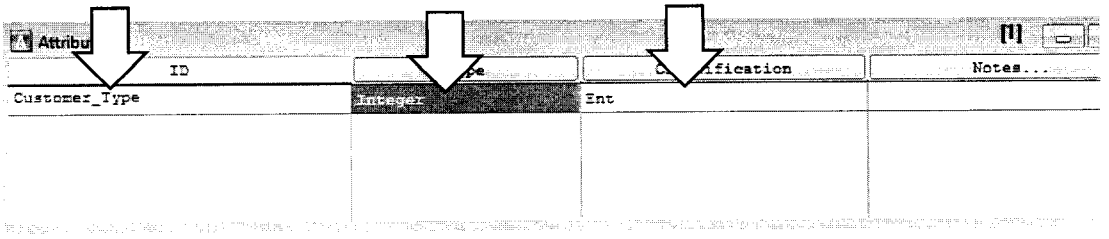
3.1. The only entity for this model will still be the Customer. The differentiation between the types of customer will be made using Attributes, therefore no alteration in this section has to be made.

4. Creating Processes

4.1. Here is where most of the alterations will be made in this model. The concepts of Attributes will be introduced and the "IF-THEN-ELSE" logic will be put to use.

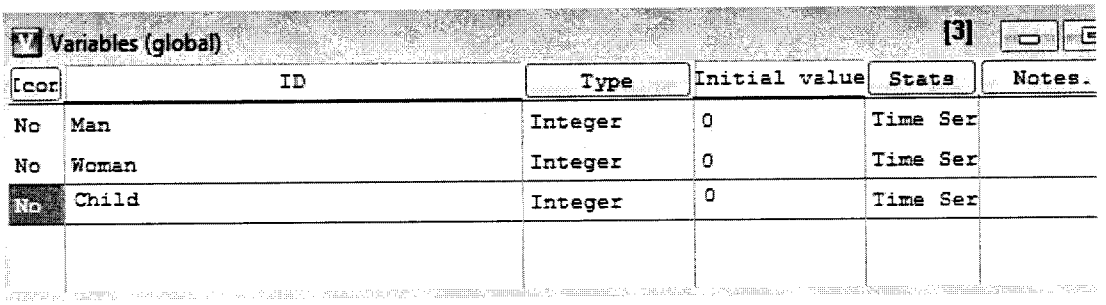
4.2. Before proceeding with modifications in the Processing Logics, it is necessary to create the Attribute that will identify each customer. To do so, select the menu "Build" and the option "Attributes".

4.3. On the Attributes Table, type "Customer_Type" on the ID field (1), double click the Type Field and select the option "Integer" (2), and double click the field Classification and select the option "Ent" (3). By doing this we informed ProModel that the attribute "Customer_Type" will hold Integer values and will be used to identify Entities.



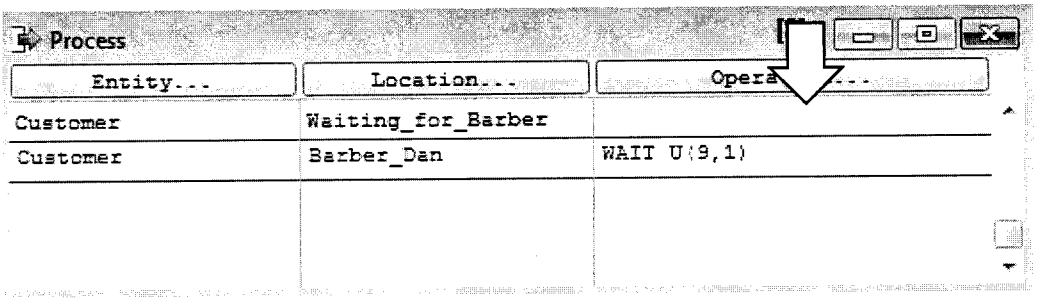
4.4. Next, the Variables that will count the number of each type of a customer will be created. Select the menu "Build" and the option "Variables".

4.5. On the Variables Table three variables will be created: Man, Woman, and Child. After these variables are created, your Variables table should resemble the following.



4.6. Now that the Attribute and Variables were created, the processing logics of the model can be altered. Select the menu "Build" and the option "Processing"

4.7. On the first row of the Process Table, double-click on the Operation Cell (1). This will open the Operation Window.

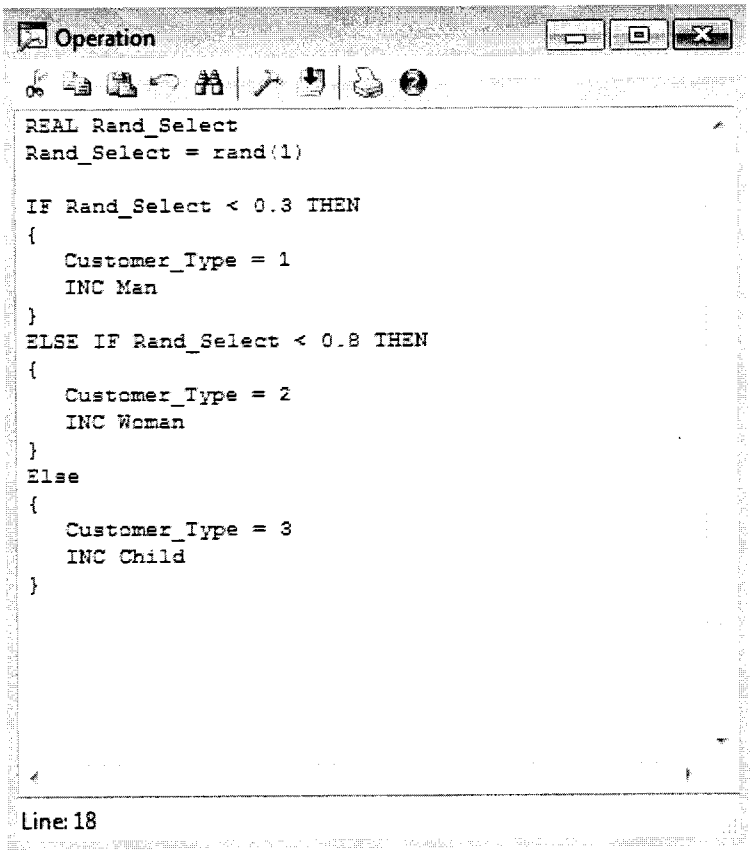


4.8. On the Operation Window Type the following Commands. If you used different Entity or Attribute names, make sure to make the appropriate substitutions on the presented code. The explanation of each line of code is presented on the right side of the code.

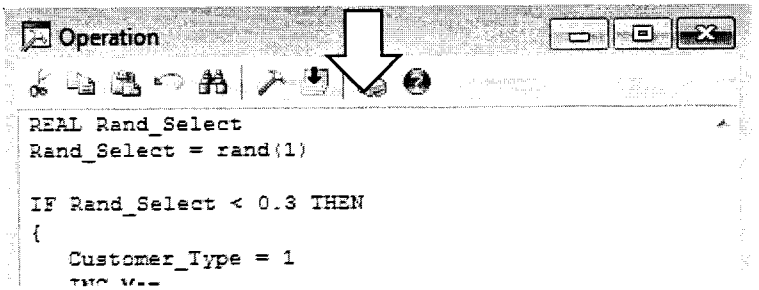
Code	Description
REAL Rand_Select	*Creates a "Local Variable" that can store Real values.*
Rand_Select = rand(1)	*Gives this variable a value between 0 and 1.*

```
IF Rand_Select < 0.3 THEN          If the value of the local variable is smaller
                                   than 0.3 (30% of customers)
{
  Customer_Type = 1                Make the attribute Customer_Type = 1,
                                   identifying this customer as a Man type.
  INC Man                          Increase the value of the Variable Man (to
                                   count how many of this type of customer are
                                   in the system)
}
ELSE IF Rand_Select < 0.8 THEN     If the value of the local variable is not
                                   smaller than 0.3 but is smaller than 0.8
                                   (Difference of 0.5 or 50% of the customers)
{
  Customer_Type = 2                Make the attribute Customer_Type = 2,
                                   identifying this customer as a Woman type.
  INC Woman                        Increase the value of the Variable Woman
                                   (to count how many of this type of customer
                                   are in the system)
}
ELSE                               If the value of the variable is larger than 0.8
                                   (the remaining 20% of the customers)
{
  Customer_Type = 3                Make the attribute Customer_Type = 3,
                                   identifying this customer as a Child type.
  INC Child                        Increase the value of the Variable Child (to
                                   count how many of this type of customer are
                                   in the system)
}
```

4.9. Your Operation Window should look like the following. IT IS VERY IMPORTANT THAT YOUR CODE CONTAINS ALL THE ELEMENTS SHOWN, THE ABSCENSE OF ANY OF THEM COULD CAUSE UNDESIRED BEHAVIORS ON THE MODEL.



4.10. To make sure you typed the correct name of your variables, click on the button on the right side of the "Hammer" (1). If your code does not have any syntax error, the message "Compiled Successfully" should be displayed. After this verification, close your Operation Window.

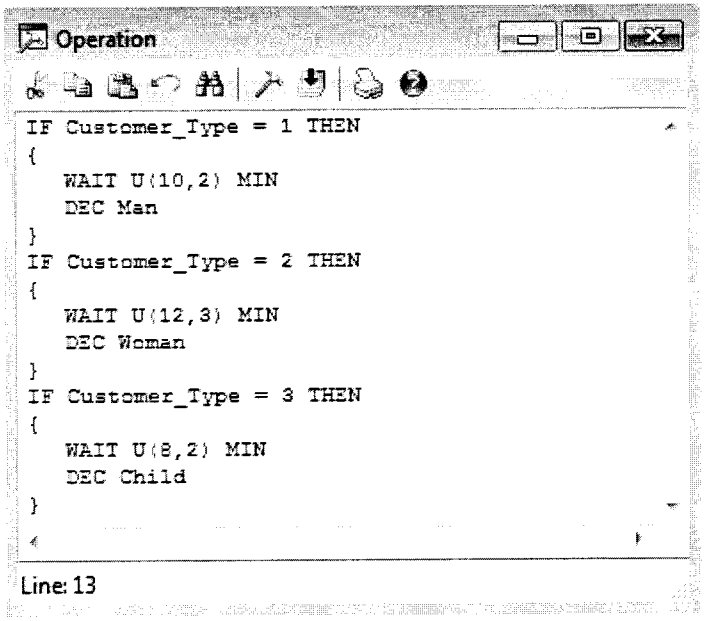


4.11. Select the second row of the Process Table and double click on the Operation Cell to bring up the Operation Window. Delete the code displayed on the Operations Window.

4.12. For the new code, two things must be kept in mind. First, each different customer (identified by the Customer_Type attribute) will have a different processing time; second, we need to decrease the value of the variables that store the number of each type of customer present on the model. With this in mind, enter the following code on the Operation Window.

Code	Description
IF Customer_Type = 1 THEN	*If the attribute Customer Type is equal to 1 (The customer is a Man).*
{	
WAIT U(10,2) MIN	*The processing time is equal to U(10,2) Minutes.*
DEC Man	*Decrease the value of the variable Man.*
}	
IF Customer_Type = 2 THEN	*If the attribute Customer Type is equal to 2 (The customer is a Woman).*
{	
WAIT U(12,3) MIN	*The processing time is equal to U(12,3) Minutes.*
DEC Woman	*Decrease the value of the variable Woman.*
}	
IF Customer_Type = 3 THEN	*If the attribute Customer Type is equal to 3 (The customer is a Child).*
{	
WAIT U(8,2) MIN	*The processing time is equal to U(8,2) Minutes.*
DEC Child	*Decrease the value of the variable Child.*
}	

4.13. At this point, the Operation Window for this process should look like the following.

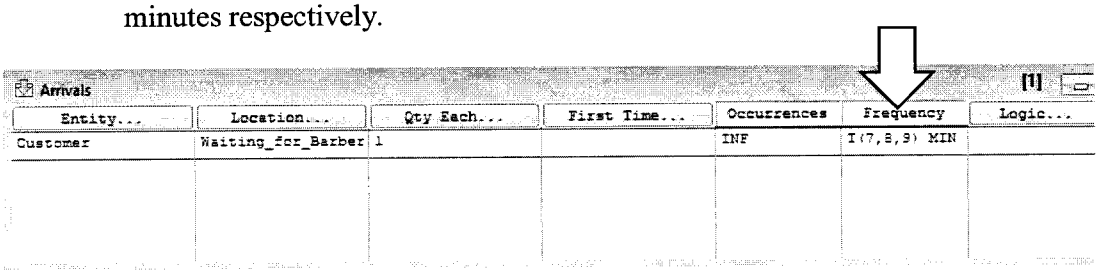


4.14. Check your code for Syntaxes errors (Step 4.10).

5. Creating Arrivals

5.1. The Arrival logic from the new model is slightly different from the original version. To make the necessary alterations select the menu "Build" and the option "Arrivals".

5.2. It is necessary to alter the value in the Frequency Field. Type in the new value "T(7,8,9) MIN" (1), this means that the interval of arrival will be determined by a triangular distribution with a minimum, mode, and a maximum of 7, 8, and 9 minutes respectively.



6. Defining Simulation Options, Saving, and Running the Model.

6.1. The Simulation Options will remain unchanged (You can check them at the menu "Simulation" -> "Options").

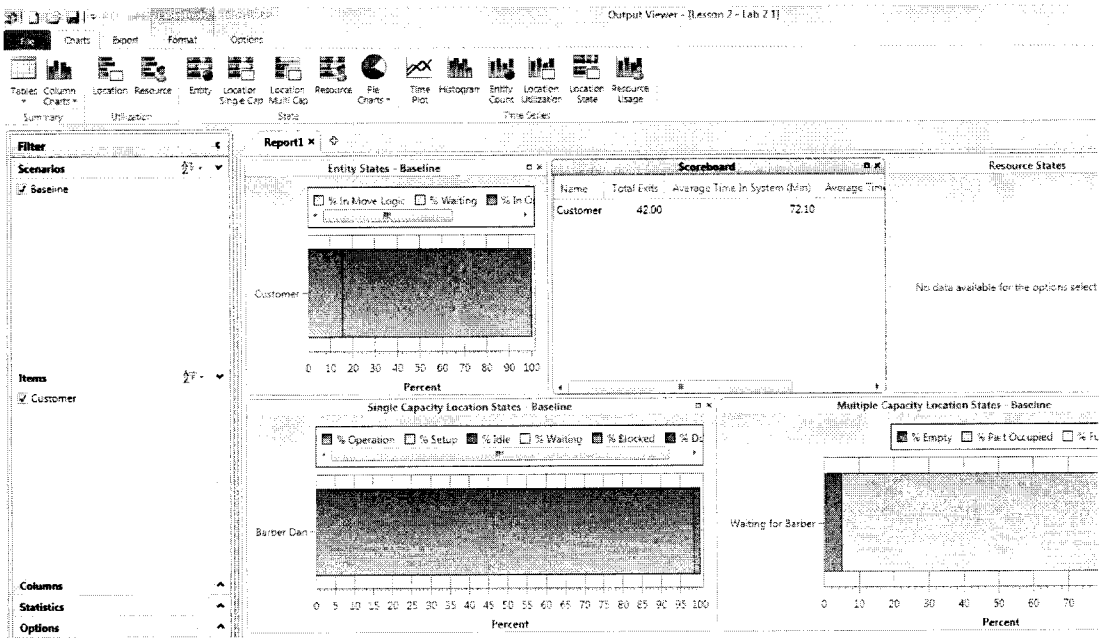
6.2. Save your model (Menu File -> Save).

6.3. Run the Model: select the menu "Simulation" and the option "Run".

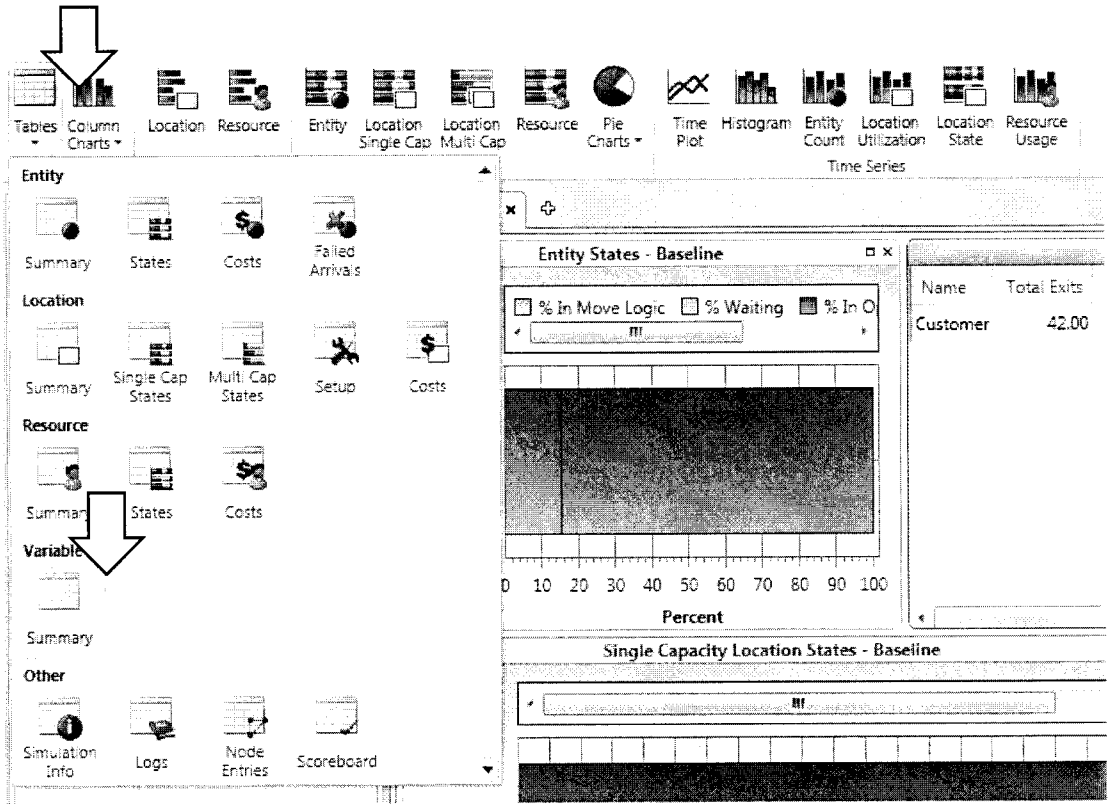
6.4. After your model finishes running, select the option to see the results.

7. Analyzing the Results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.



7.2. In order to answer the first question of this lesson (How many customers of each type Dan serve per day?), click on the button "Tables" (1) and select the option "Summary" under Variables (2).

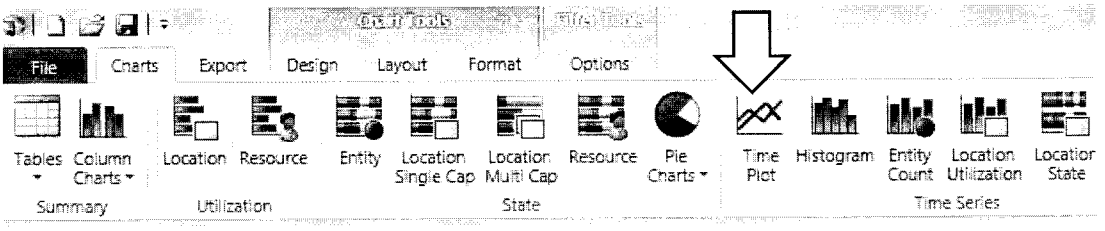


7.3. A table containing a summary of the Variables Statistics will be presented. The second row "Total Changes" indicates the total number of customers of each type that Dan served during the simulation period.

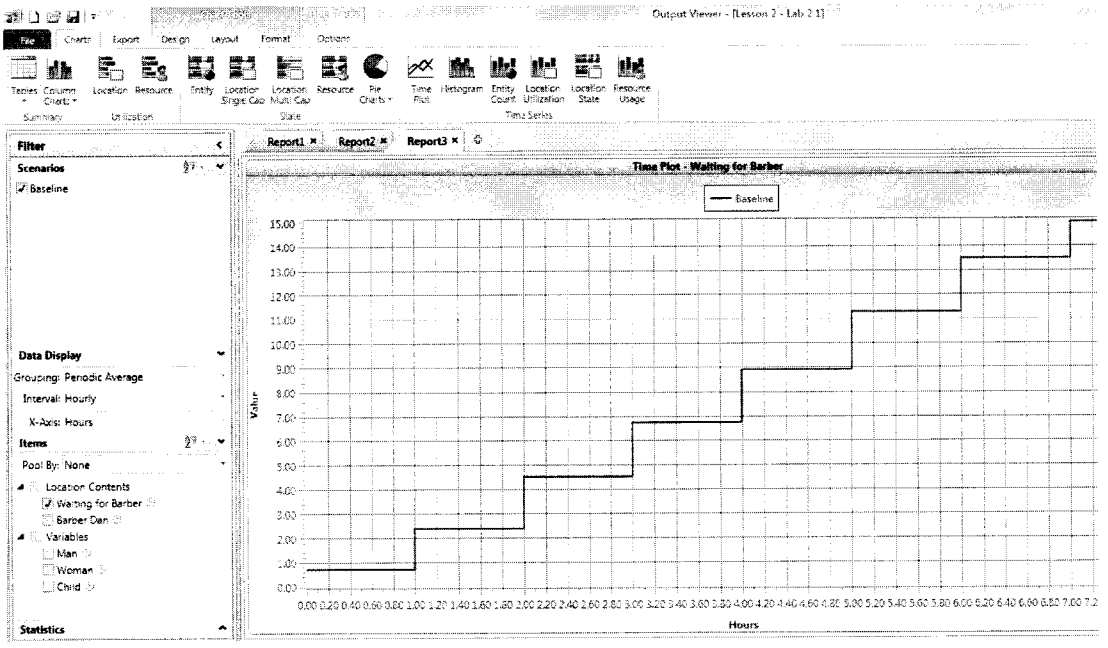
Name	Total Changes	Average Time Per Change (Min)	Minimum Value	Maximum Value	Current Value	Avera
Man	32.00	13.99	0.00	6.00	4.00	
Woman	58.00	8.14	0.00	12.00	12.00	
Child	11.00	39.37	0.00	2.00	1.00	

7.4. Do not be alarmed if your values are slightly different, this could happen once we are dealing with a local variable that assumes random values (Rand_Select).

7.5. To observe the variation on the quantity of each customer during the simulation period, select the button "Time Plot" (1).



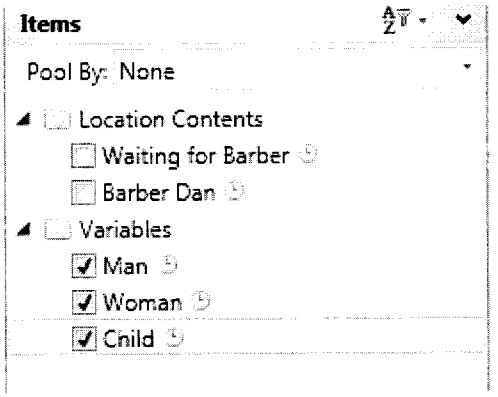
7.6. You will be presented with the following setup.



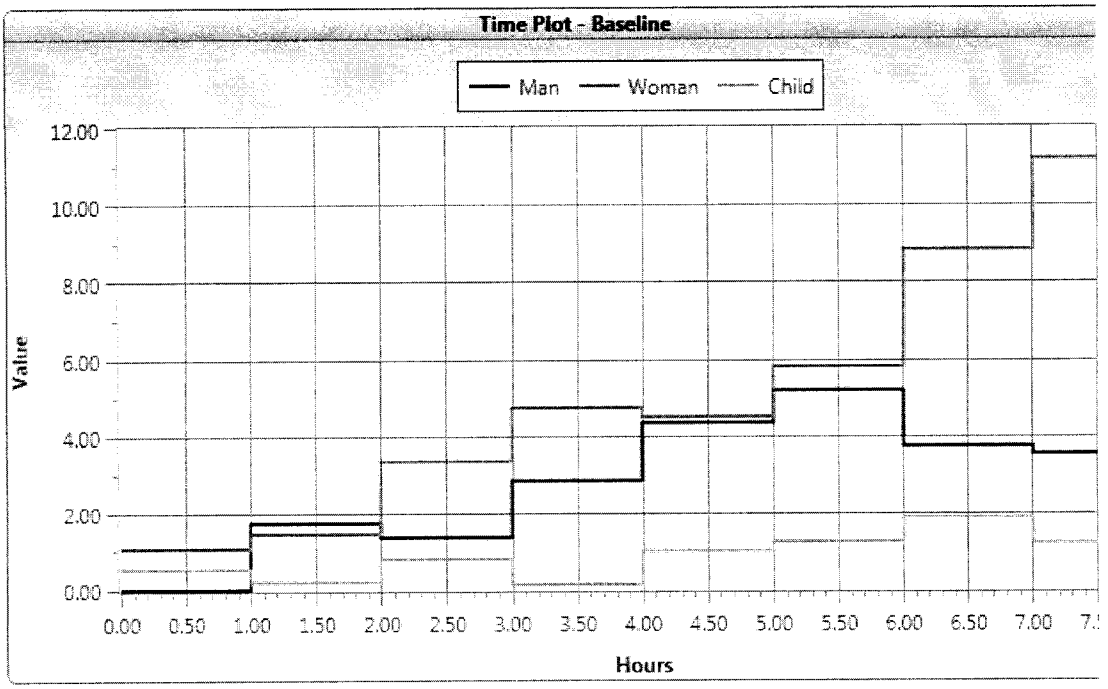
7.7. On the lower left corner of the screen there is an area name "Items". Inside this area there should be a few items categorized under "Location Contents" and "Variables". As the name suggests, items under the first category will display the name of entities in a location during the simulation, and the items under the second category will display the values of the variables during the simulation period.

7.8. Once the exercise asks for the variation of the number of types of customers during the simulated period (variables), uncheck any item that is selected under

the "Location Contents" category, and then select the items "Man", "Woman", and "Child" under the Variables category as shown below.



7.9. Once the desired Items are selected, the Time Plot Graph should resemble the following.



7.10. Based on this Graph, and on the information provided by the Variables Summary Table it is possible to answer both questions of this lesson.

LESSON 11

This exercise from the tenth lesson will be based on the Laboratory 6.2 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise the focus will be given to the concept of Cycle Times.

Cycle Times are calculated by the difference of the moment when an entity entered the system and the one when it left it. In order to make this calculation the time of entrance of each entity will be stored in an Attribute, and it will be subtracted from the current simulation time when the entity leaves the system. To make this calculation possible, ProModel has the functions "Clock()" and "Log". The first returns the simulation time hours, minutes, seconds, or any other time unit; the second automatically calculates the time difference between a value stored in an attribute and the current simulation time.

For this lesson, the model used on the Lesson 10 (Lab 6.1.1) will be used with a few alterations. After the model is built with the required alterations, answer the following questions:

a. The cycle time for each type of customer of Barber Dan.

b. The average cycle for all customers.

c. The average time spent in the salon by each time of customer.

d. The average waiting time for each type of customer.

1. Creating a new model

1.1. Once the base model for this lesson was already built on Laboratory 2.1, select the menu "File" and the option "Open". Load your model from Laboratory 2.1.

1.2. With the model loaded, select the menu "File" and then "Save As...". Save your model with the name **Fantastic Dan Time Cycle**.

2. Creating Locations

2.1. The locations of this model will remain the same as the ones in the previous model, hence no alteration will be necessary.

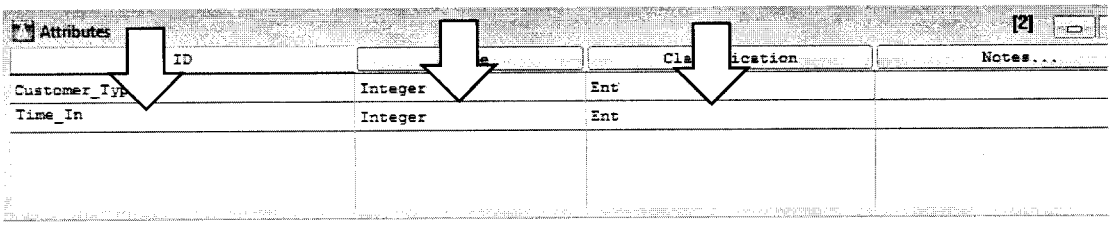
3. Creating Entities

3.1. The only entity for this model will still be the Customer. The differentiation between the types of customer will be made using Attributes, therefore no alteration in this section has to be made.

4. Creating Processes

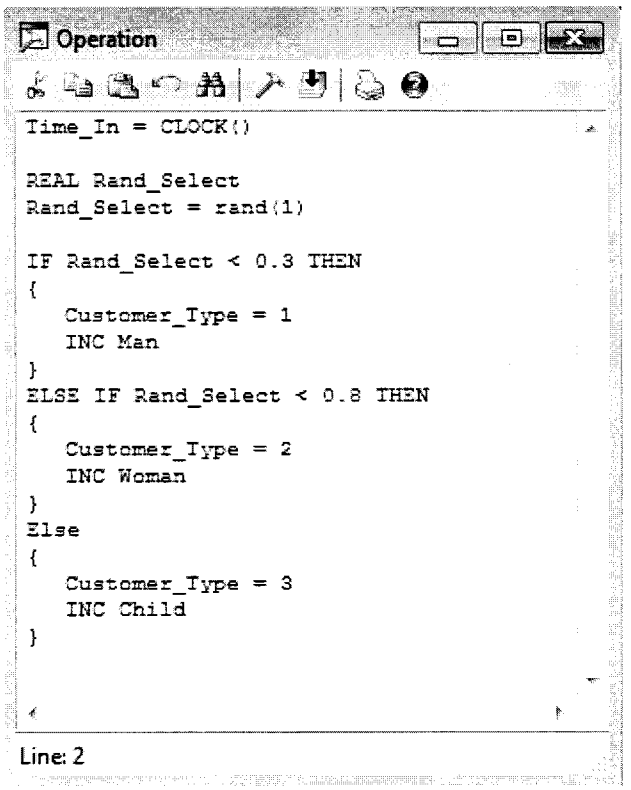
4.1. For this model it will be necessary to create a new attribute to store the time of entrance in the model for each entity. Select the menu "Build" and the option "Attributes"

4.2. On the Attribute Table, create a new attribute named "Time In" (1), select "Integer" as the Type (2), and "Ent" as the Classification (3).

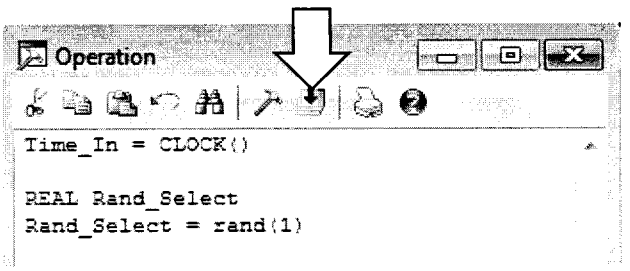


4.3. Next, the Processing Logics of the model will have to be slightly altered to include the Cycle Time calculation logics. Select the menu "Build" and the option "Processing".

4.4. Double-click on the Operation Cell of the first row in the Process Table. On top of all the code present on the Operation Window insert the following command "Time_In = CLOCK()", this will make the attribute Time_In equal to the moment in which the entity entered the system. The code on your operation window should look like the following.



4.5. Verify your code syntax by clicking on the button to the right of the hammer icon.

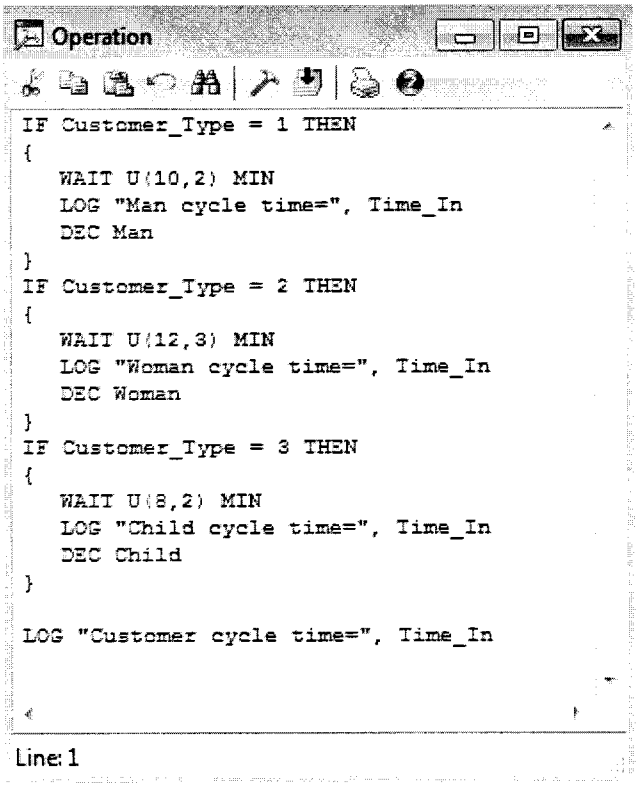


4.6. Now it is time to edit the code on the Operation Cell of the second row of the Process Table. Here the "Log" functions will be added, the code is displayed below and the additions are underlined.

Code	Description
IF Customer_Type = 1 THEN	*If the attribute Customer Type is equal to 1 (The customer is a Man).*
{	
WAIT U(10,2) MIN	*The processing time is equal to U(10,2) Minutes.*
LOG "Man cycle time=", Time_In	*Man Cycle Time, calculated by the difference between the values on the attribute "Time In" and the present simulation time.*
DEC Man	*Decrease the value of the variable Man.*
}	
IF Customer_Type = 2 THEN	*If the attribute Customer Type is equal to 2 (The customer is a Woman).*
{	
WAIT U(12,3) MIN	*The processing time is equal to U(12,3) Minutes.*
LOG "Woman cycle time=", Time_In	*Woman Cycle Time, calculated by the difference between the values on the attribute "Time In" and the present simulation time.*
DEC Woman	*Decrease the value of the variable Woman.*
}	
IF Customer_Type = 3 THEN	*If the attribute Customer Type is equal to 3 (The customer is a Child).*
{	
WAIT U(8,2) MIN	*The processing time is equal to U(8,2) Minutes.*
LOG "Child cycle time=", Time_In	*Child Cycle Time, calculated by the difference between the values on the attribute "Time In" and the present simulation time.*
DEC Child	*Decrease the value of the variable Child.*

} Log "Customer cycle time=", Time_In	*Average Cycle Time, calculated by the difference between the values on the attribute "Time In" and the present simulation time.*

4.7. At this point, the Operation Window for this process should look like the following.



4.8. Check your code for Syntax errors (Step 4.5).

5. Creating Arrivals

5.1. The arrivals will not have to be changed for this model.

6. Defining Simulation Options, Saving, and Running the Model

6.1. The Simulation Options will remain unchanged (You can check them at the menu "Simulation" -> "Options").

6.2. Save your model (Menu File -> Save).

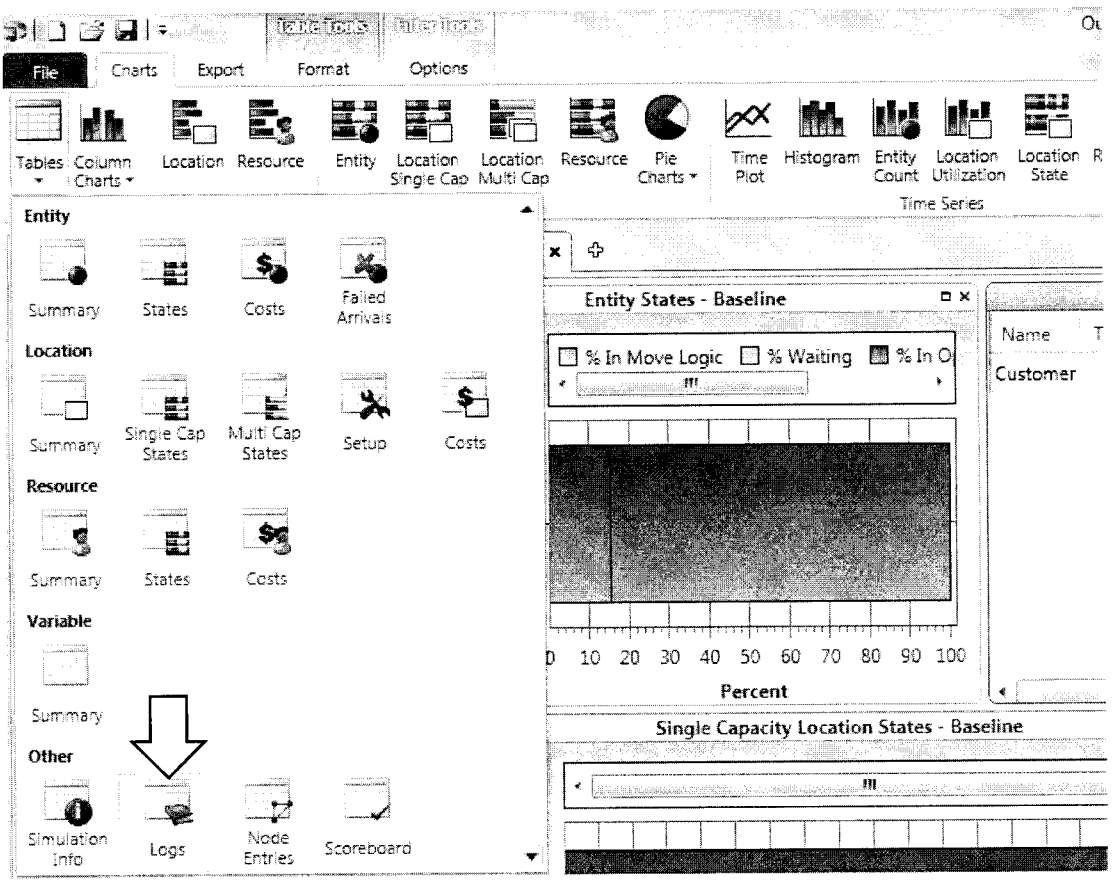
6.3. Run the Model: select the menu "Simulation" and the option "Run".

6.4. After your model finishes running, select the option to see the results.

7. Analyzing the Results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. In order to answer the questions of this lesson, click on the button "Tables" and select the option "Logs".



7.3. You should be presented with a table containing all the information regarding the LOG functions inserted in the code. The first column of the table displays the LOG name, the second the amount of times that each LOG function was executed, the third shows the smaller cycle time for each entity, the fourth the maximum cycle time, and the fifth displays the average cycle time for each entity.

LESSON 12

This exercise from the twelfth lesson will be based on the Laboratory 6.3 from the textbook "Simulation Using ProModel" (third edition) by Harrel, Ghosh & Bowden. For this exercise, some concepts learned in past exercises will be applied to develop a model that will sort, inspect a sample, and rework a few entities. The exercise as described by Harrel, Ghosh & Bowden (2012) is as follows:

"Discs-R-US Manufacturing Inc. receives orders for two types of discs (disc A and disc B). Disc A and disc B orders arrive on average every five and every ten minutes (exponentially distributed), respectively. Both discs arrive at the input queue. An attribute Part_Type is defined to differentiate between the two types of discs.

Disc A goes to the lathe for turning operations that take Normal(5,1) minutes. Disc B goes to the mill for processing that takes Uniform(6,2) minutes. Both type of discs go on to an inspection queue, where every fifth part is inspected. Discs that are not inspected are shipped directly. Inspection takes Normal(6,2) minutes. After inspection 70 percent of the discs pass and leave the system; 30 percent of the discs fail and are sent back to the input queue for rework. Determine the following:

a. Number of discs of each type shipped each week (40-hour week)?
b. Number of discs machined each week?
c. Number of discs inspected every week?
d. Average cycle time for each type of disc?
e. Number of discs reworked each week?

f. Average number of discs waiting in the input queue and the inspection queue?"

1. Creating a new model

1.1. Select the menu "File" and then the option "New".

1.2. On the General Information window, name your model "**Discs-R-Us Manufacturing**" (on the "Title" text box).

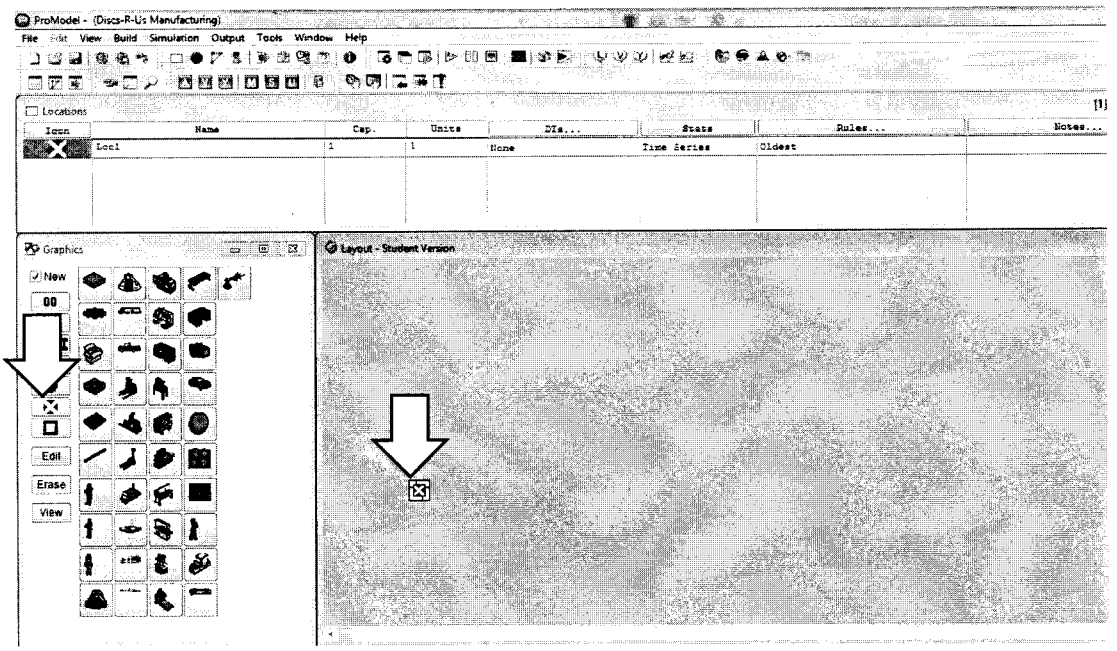
1.3. Hit "OK".

2. Creating Locations

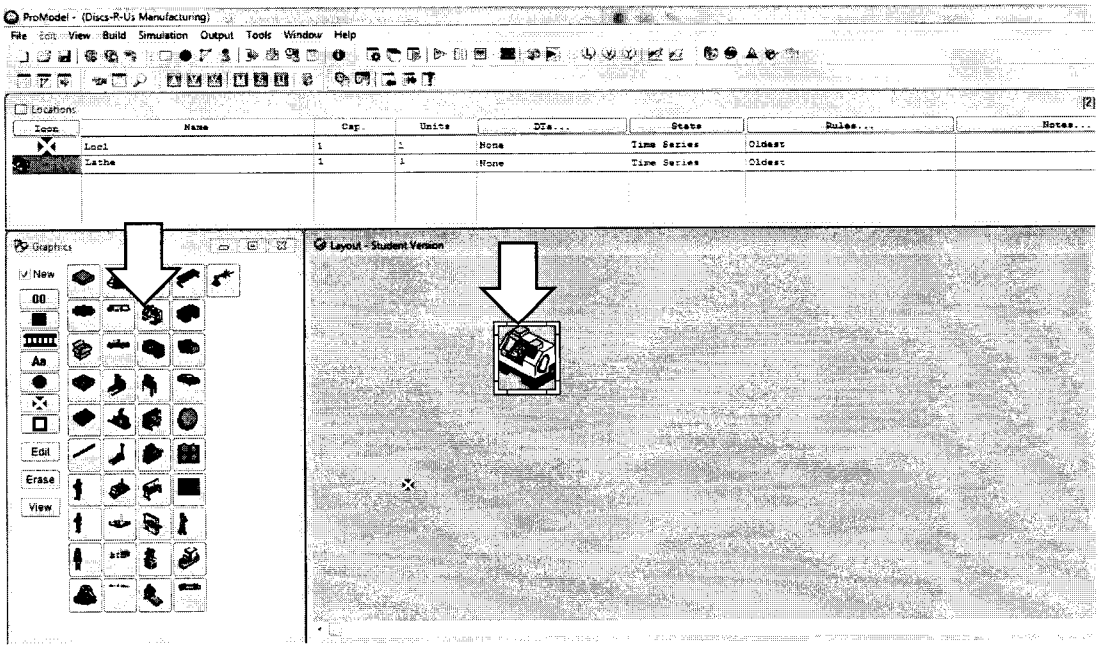
2.1. For this exercise, five different locations will be created: Input Q, Lathe, Mill, Inspect Q, and Inspect.

2.2. To begin the locations building process select the menu "Build" and then the option "Locations".

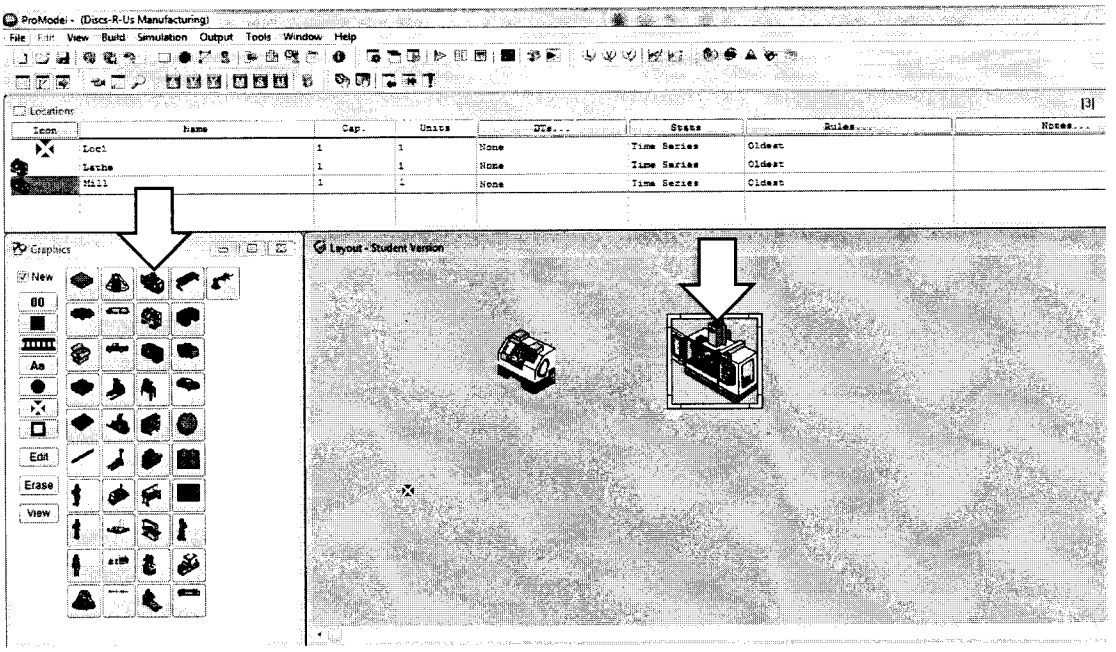
2.3. The first location will be the "Input Q". Select the sixth icon on the first column (1) and place it on the layout (2).



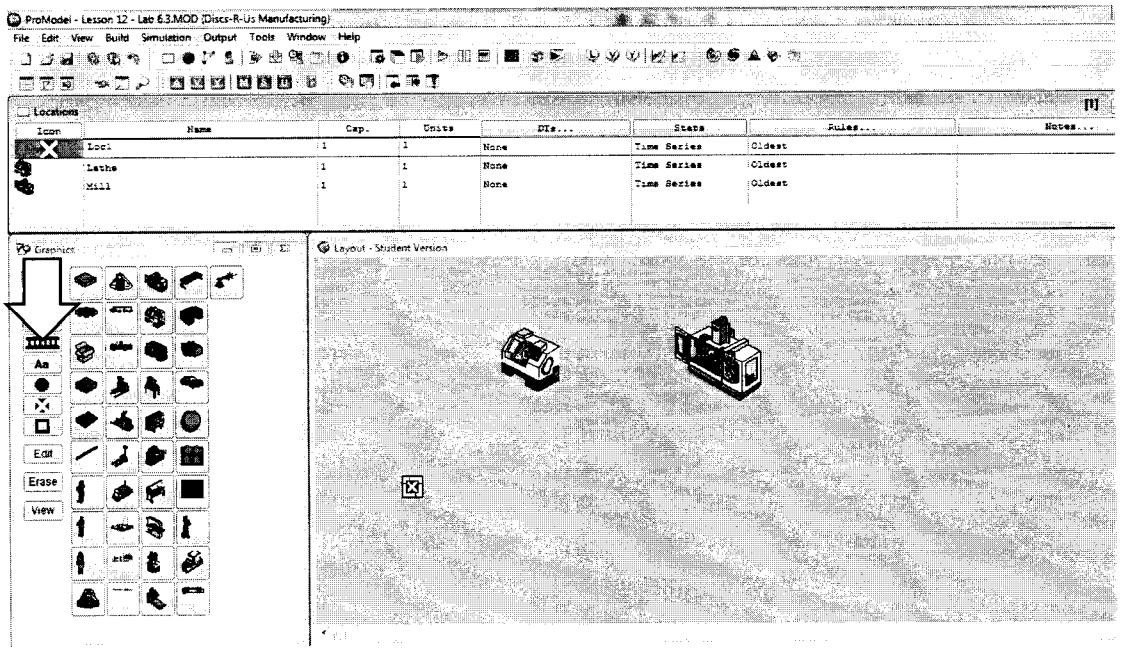
2.4. The next location to be created will be the "Lathe". Select the second icon on the fourth column of the Graphics window.



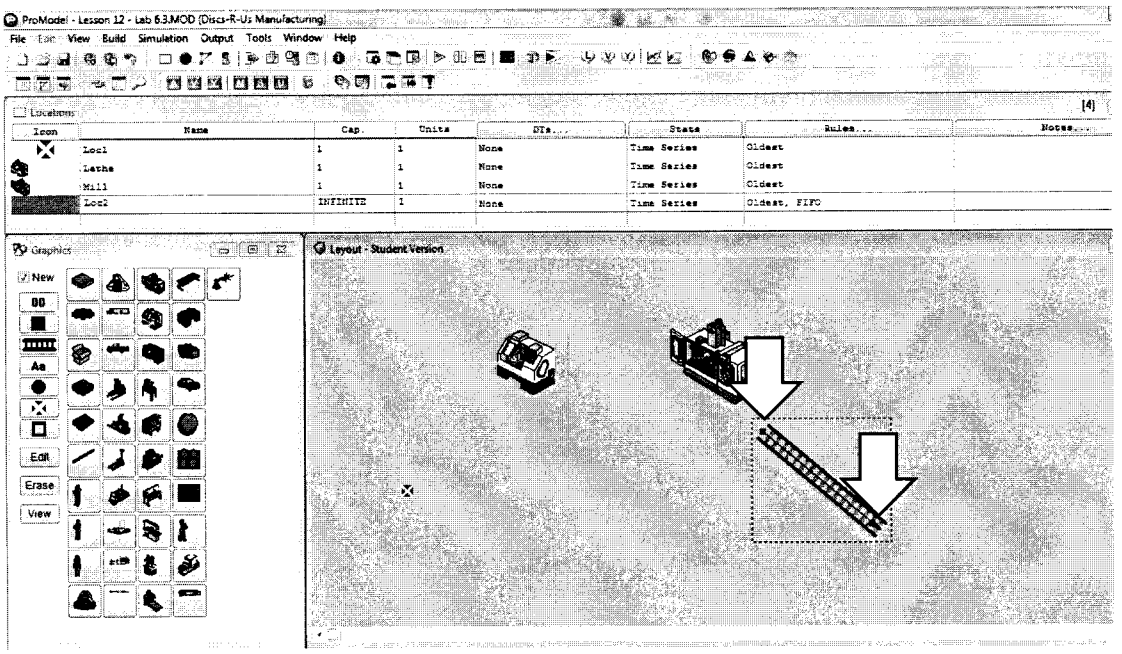
2.5. The third location to be created will be the "Mill". Select the first icon on the fourth column (1) and place it on the layout (2).



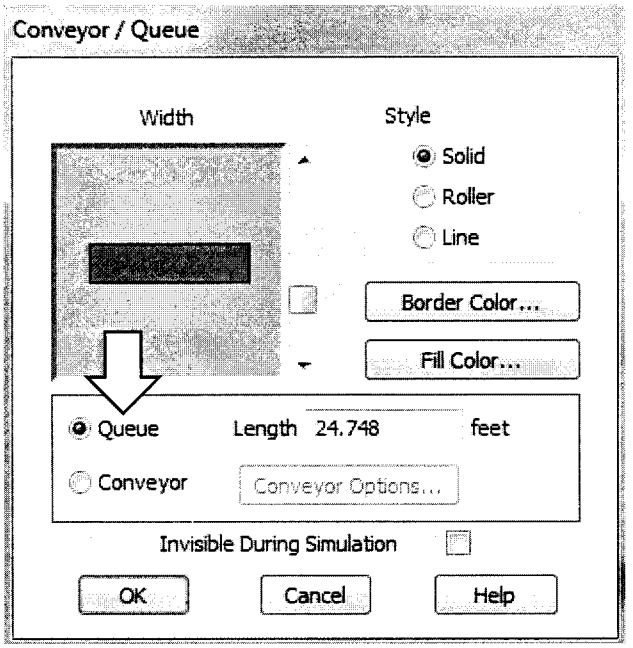
2.6. The next location to be created will be the "Inspect Q". The creation of the location involves a little more than just selecting an icon and placing it on the layout. First, select the third icon on the first column of the Graphics window.



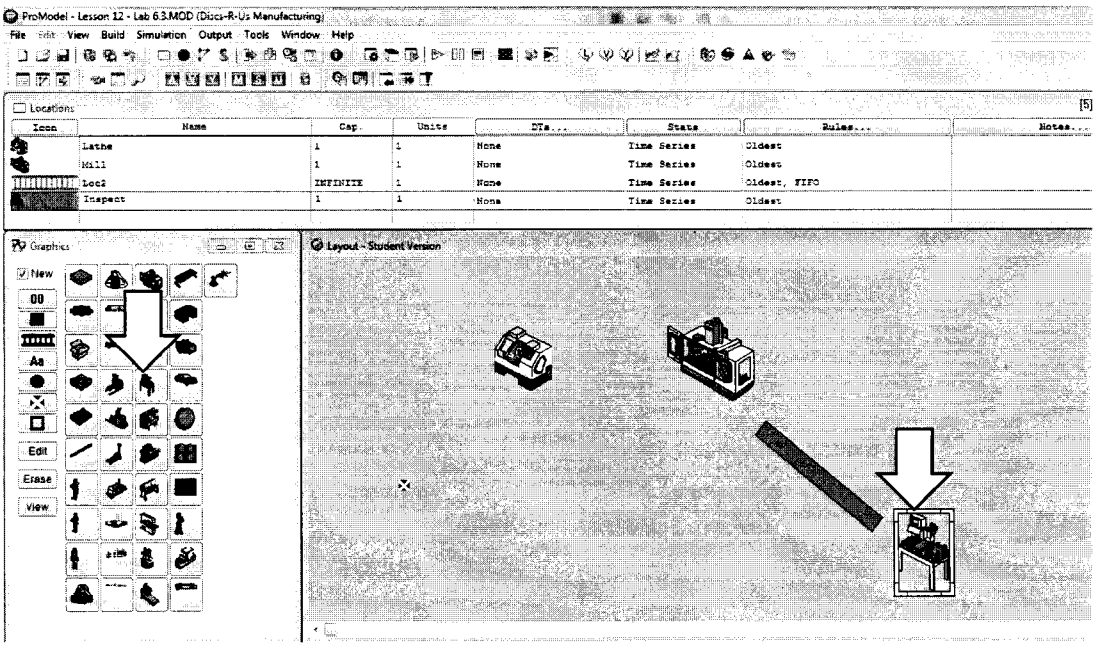
2.7. Next, click with the left button of your mouse where the Queue will start (1) and to finish your queue, click with the right button of your mouse where the queue will end (2).



2.8. Now it is necessary to inform ProModel that this location is a Queue and not a Conveyor. Right click on the location that was just placed on the layout and select the option "Edit Graphic" from the menu. On the new Conveyor/Queue window, select the option "Queue".



2.9. The last location to be created will be the "Inspect". Select the fourth icon on the fourth column (1) and place it on the layout (2).



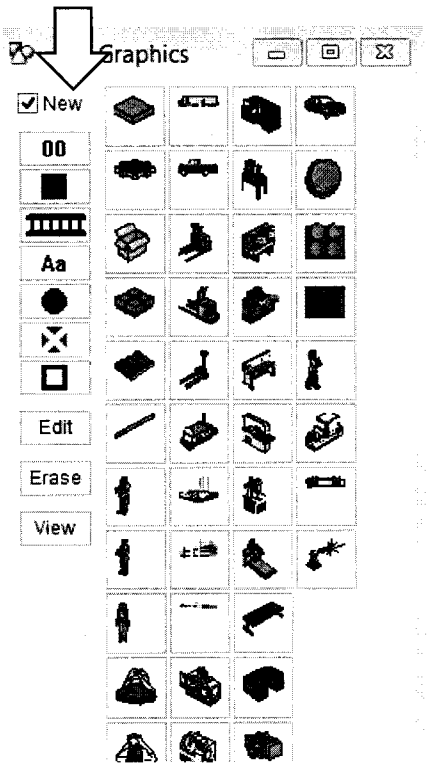
2.10. If you have not done it yet, now it is time to rename your locations. Follow the order in which they were created, and on the Locations Table rename your locations to "Input Q", "Lathe", "Mill", "Inspect Q", and "Inspect".

2.11. Change the Cap for the "Input Q" location to INF. At this point, your Locations Table should resemble the following.

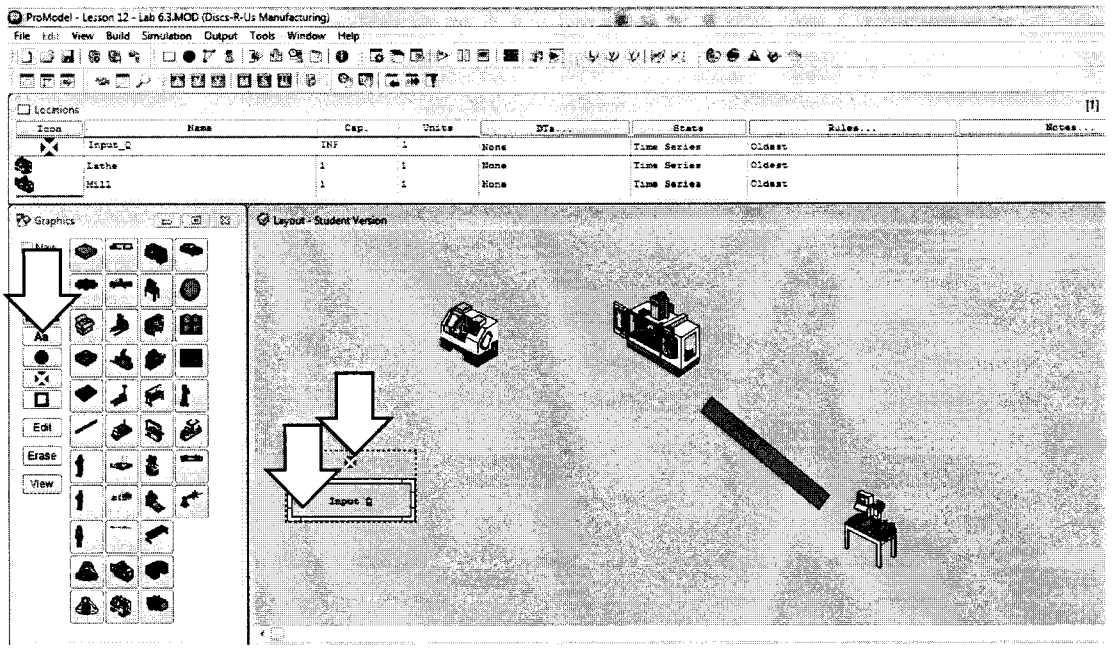
Locations

Icon	Name	Cap.	Units	DTs...	Stats	Rules...	Notes...
	Input_Q	INF	1	None	Time Serie	Oldest	
	Lathe	1	1	None	Time Serie	Oldest	
	Mill	1	1	None	Time Serie	Oldest	
	Inspect_Q	INFINIT	1	None	Time Serie	Oldest, FIFO	
	Inspect	1	1	None	Time Serie	Oldest	

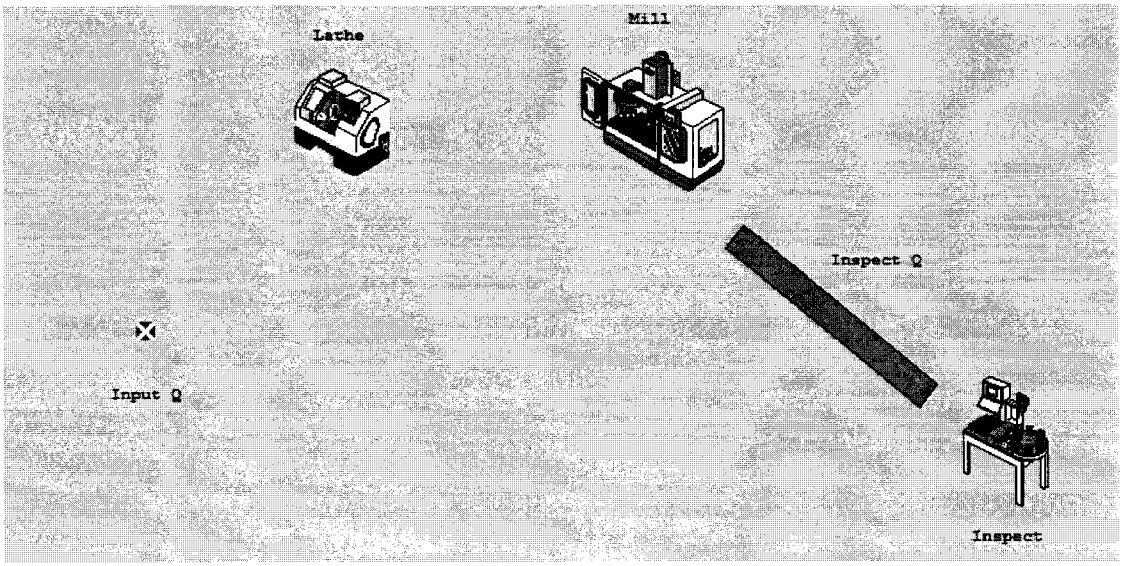
2.12. Insert the locations' name on the layout. First uncheck the "New" option on the Graphics Window.



2.13. Select the Location "Input Q" (1), click on the fourth button of the first column (2) and click on the layout (3) to place the location name.



2.14. Repeat the step 2.13 and insert the names of all the locations on the layout. At this point your layout should resemble the following.



2.15. It is very important that you only have 5 rows on your Location Table. If you have more than five, consider deleting the extra ones. This can be done by selecting the row you wish to erase and clicking on the menu "Edit" and selecting the option "Delete". BE VERY CAREFUL: ProModel DOES NOT HAVE AN "UNDO" FUNCTION.

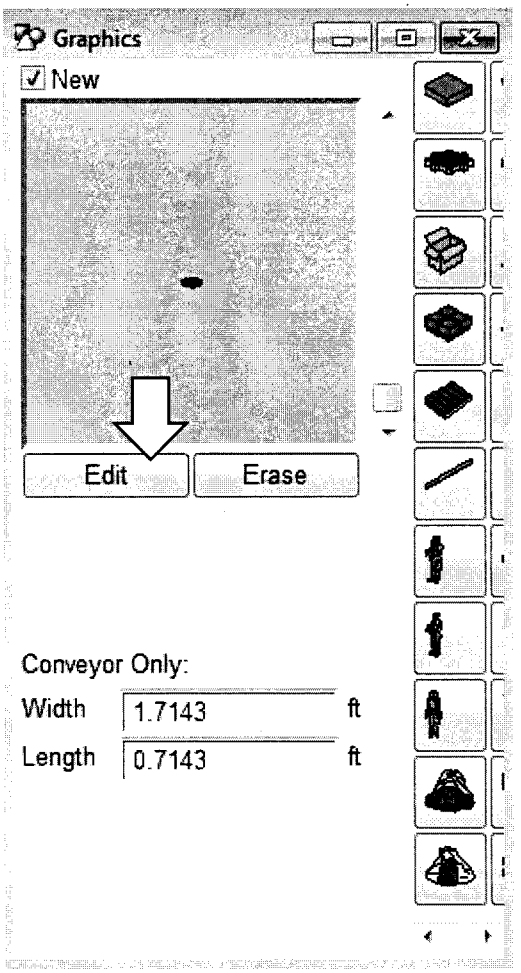
3. Creating Entities

3.1. This model will make use of two entities: "Disc A", and "Disc B".

3.2. To start building the entities, select the menu "Build" and the option "Entities".

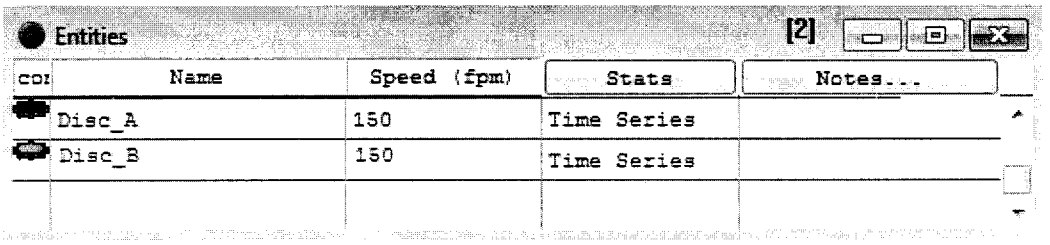
3.3. To create the first entity, select the second icon of the first column of the Graphics Window (a purple gear). And then click on the same icon a second time to create the second entity.

3.4. To differentiate the entities, click on the button "Edit" (1) in the Graphics Window.



3.5. The Library Graphic window will open. Click on the button "Color..." and select a shade of green. Click on the "OK" button to close the Color window, and hit "OK" again to close the Library Graphic window.

3.6. On the Entity Table, rename the first entity to "Disc A" and the second one to "Disc B". Your Entity table should look like the following.



4. Creating Processes

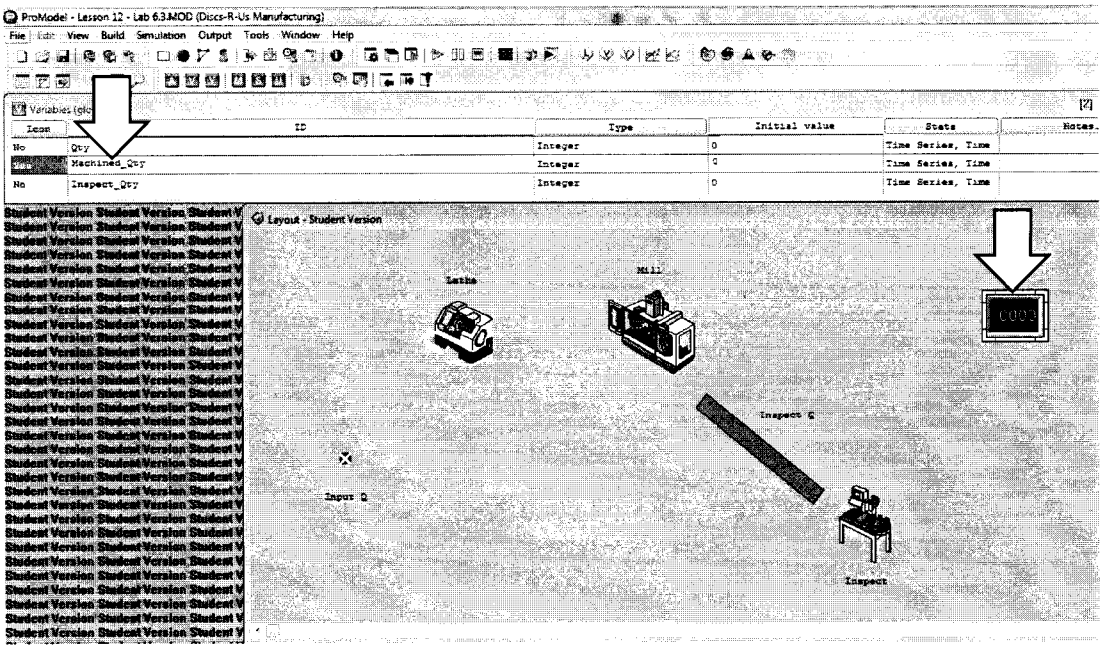
4.1. First, it will be necessary to create a few variables to store some values of the model. Select the menu "Build" and the option "Variables".

4.2. It will be necessary to create four variables. Input them on the Variables table on the following order: "Qty", "Machined Qty", "Inspect Qty", and "Rework Qty". Your Variables table should contain the same elements as the following.

Variables (global) [1]

Icon	ID	Type	Initial value	Stats	Notes..
No	Qty	Integer	0	Time Series	
No	Machined_Qty	Integer	0	Time Series	
No	Inspect_Qty	Integer	0	Time Series	
No	Rework_Qty	Integer	0	Time Series	

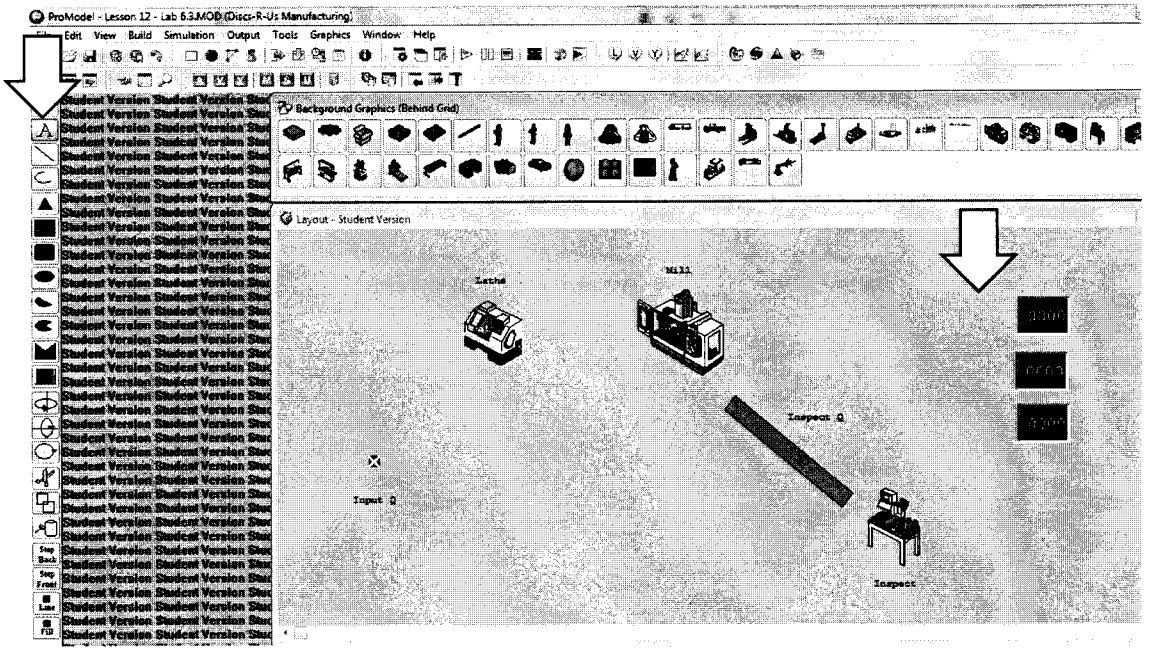
4.3. Insert counters for the last three variables on your model. Select the second row of the table (1) and click on the layout to place the counter (2).



4.4. Repeat the step 4.3, and insert the counters for the variables "Inspect Qty", and "Rework Qty" (in this order).

4.5. Insert the name of the variables to identify the counters on the layout. Select the menu "Build", the option "Background Graphics", and then "Behind the Grid".

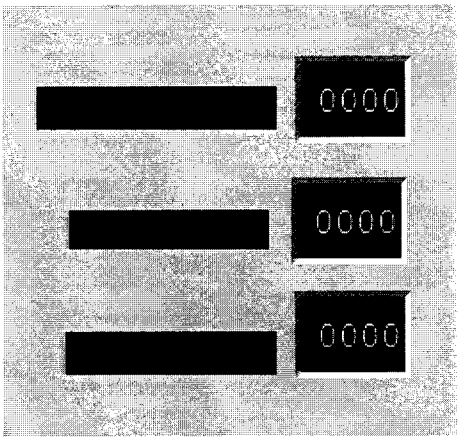
4.6. Click on the second icon located on the column on the right side of the screen (1), and click on the right left side of the first counter (Machined Qty) (2).



4.7. A window called "Text Options" will show up. Type "Machined Qty" on the text box and hit "OK". The name of your variable should show up by the counter.

4.8. Repeat steps 4.6 and 4.7 to insert the variable names on the other two counters (Inspect Qty, and Rework Qty).

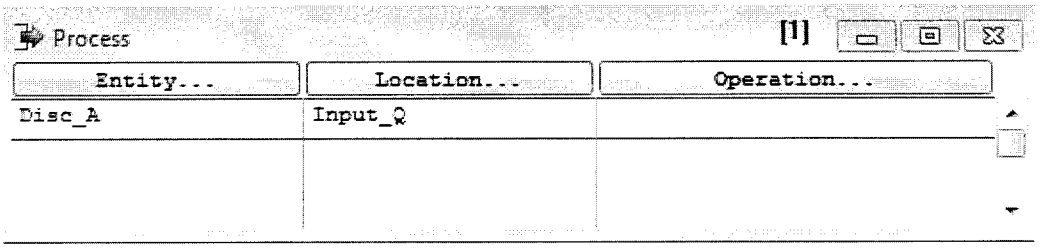
4.9. Your counters should be looking similar to the following (Feel free to use different colors and fonts).



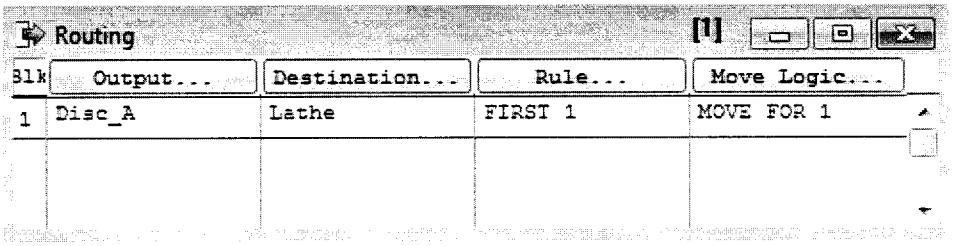
4.10. Now that the variables are created, it is time to create the processes. Select the menu "Build" and the option "Processing".

4.11. Two different entities will be processed with partially different routes. So first, part of the processing logic for "Disc A" will be created.

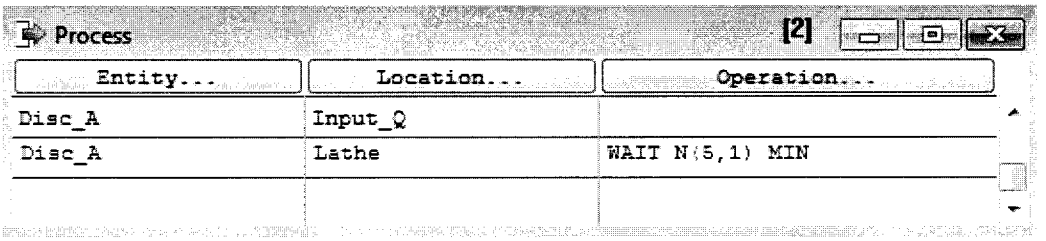
4.12. On the Processing Table, click on the first row, then select the "Disc A" as the Entity, and "Input Q" as the location.



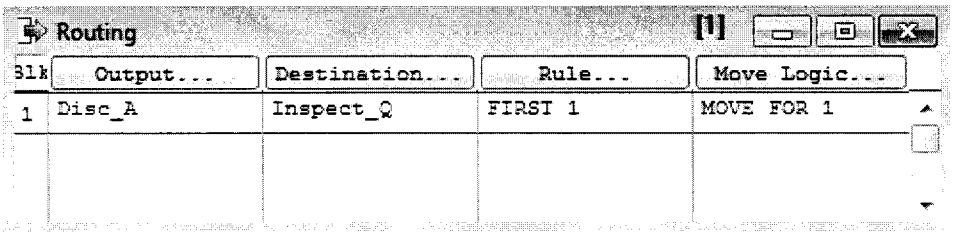
4.13. On the Routing Window, select "Disc A" as the Output and the "Lathe" as the Destination. On the Move Logic, type "Move for 1".



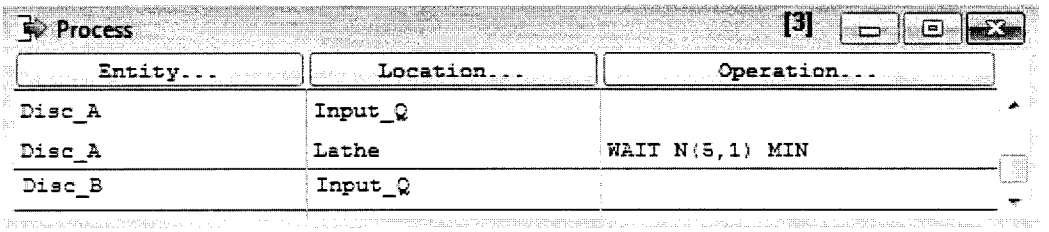
4.14. Insert a new row on the Process Table. Select the "Disc A" as the Entity, and the "Lathe" as the Location. On the Operation Cell, insert the code "WAIT N(5,1) MIN" (The process time for Disc A in this location).



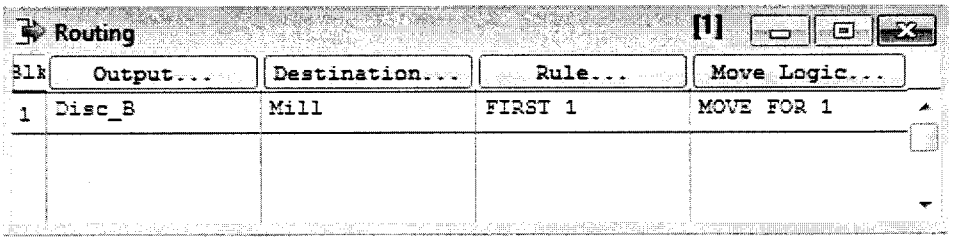
4.15. After the Lathe, the Disc A entities follow to the "Inspect Q" location. On the Routing Table, select the "Disc A" as the Output and the "Inspect Q" as the Destination. Once again, on the Move Logic, insert the command "MOVE FOR 1"



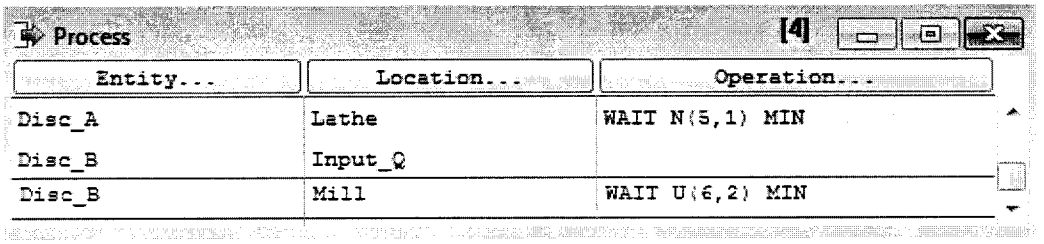
4.16. Now the setup for Disc B will be made. Add a new row to the Process Table, and select "Disc B" as the Entity, and "Inspect Q" as the Location.



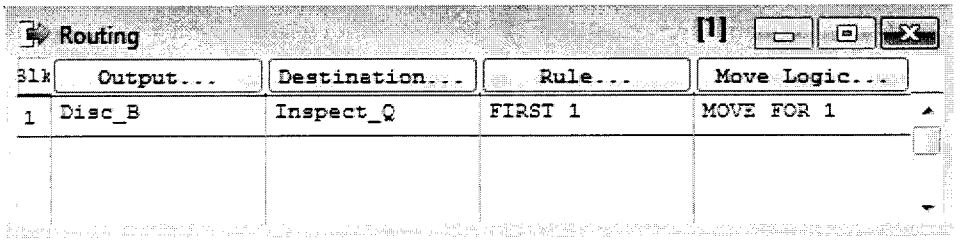
4.17. On the Routing Table, select "Disc B" as the Output, and the "Mill" as the Destination. On the Move Logic, insert the value "MOVE FOR 1".



4.18. Back to the Process Table, add a new row. Select the "Disc B" as the Entity, and the "Mill" as the Location. On the Operation Cell, insert the command "WAIT U(6,2) MIN".



4.19. On the Routing Table, select "Disc B" as the Output and the "Inspect Q" as the Destination. On the Move Logic, type "MOVE FOR 1".



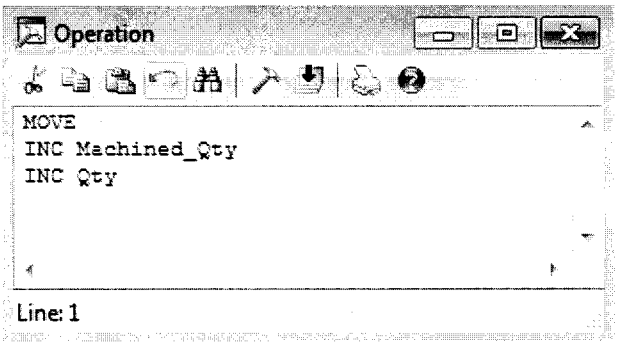
4.20. Until this step nothing really new was introduced, and now is when the new functions and ideas will be introduced. Read them carefully.

4.21. Insert a new row on the Process Table, and then select "ALL" as the Entity (since different entities will be "processed" on the Inspect Q location, the use of ALL instead of an entity name eliminates the need of creating one entry per entity on

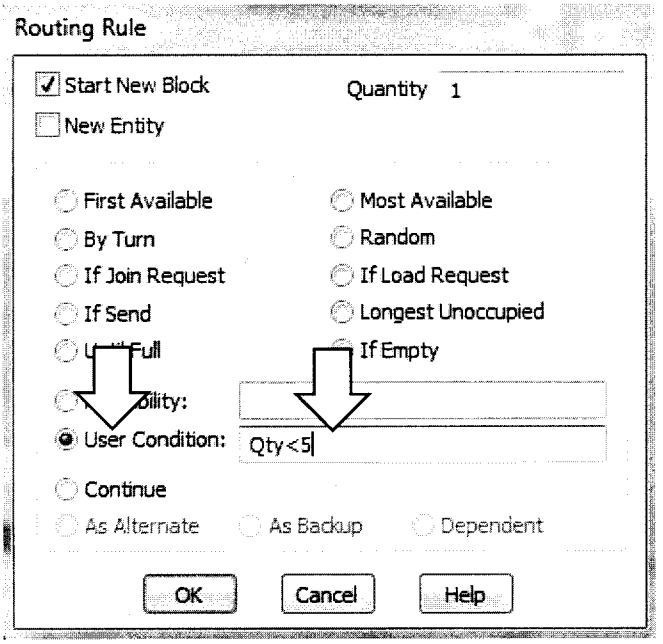
the Process Table), and select the "Inspect Q" as the Location. Double click on the Operation Cell and insert the following code.

Code	Explanation
MOVE	*Move the entity before proceeding with the following code*
INC Machined_Qty	*Counts how many Discs (A and B) where machined.*
INC Qty	*This variable will be used to determine which discs will be inspected (1 of each 5).*

4.22. The Operation Window for this Process entry should resemble the following:

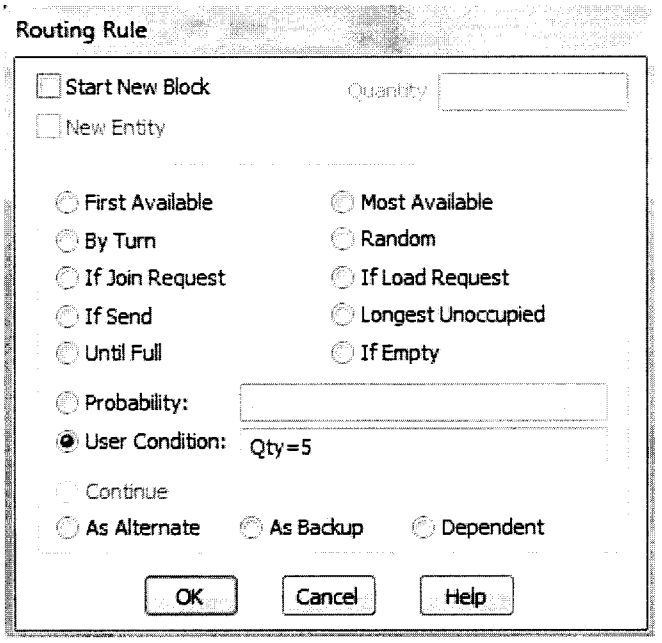


4.23. On the Routing Table select "ALL" as the Output and "EXIT" as the Destination. Now things will get a little different. Double-click on the field "Rule" (Where it says FIRST 1). This will cause the Routing Rule window to open. On this window select the option "User Condition" (1) and insert the value "Qty < 5" (2).



4.24. By the use of this Routing Rule, ProModel will observe the value of the variable "Qty" and if it is smaller than 5, it will send the entity to the EXIT of the model. Add a new row on the Routing Table (Hit Enter).

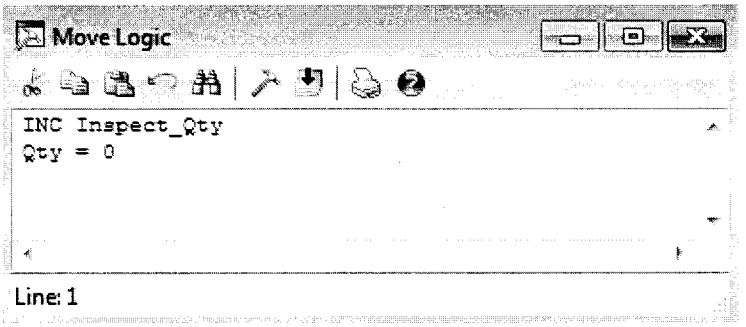
4.25. On the new row, select "ALL" as the Output and "Inspect" as the Destination. Double-click on the Rule field for this row to bring up the Routing Rule window. Once again select the option "User Condition", and then type the value "Qty = 5".



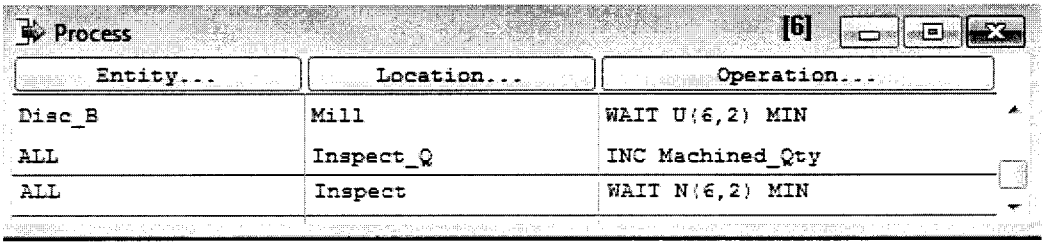
4.26. Now double-click on the Move Logic field for this row, things will make a little more sense now. On the Move Logic Window type the following code.

Code	Explanation
INC Inspect_Qty	*Counts how many Discs (A and B) where inspected.*
Qty = 0	*Sets the value of the variable Qty to 0. The variable Qty is the one controlling which entities are inspected, and when its value is equal to 5 one entity is inspected. Setting the variable to 0 causes the count to restart, and the next entity to cause the variable to be equal five will be inspected, restarting the cycle.*

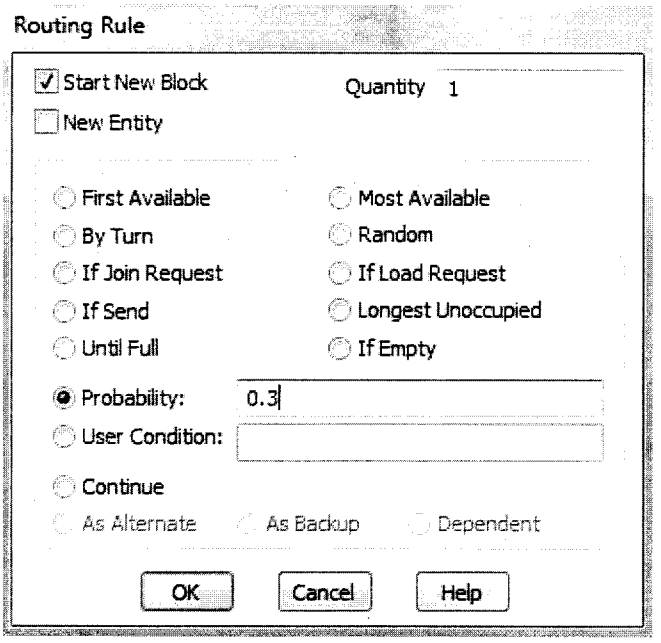
4.27. The move logic window should look like the following.



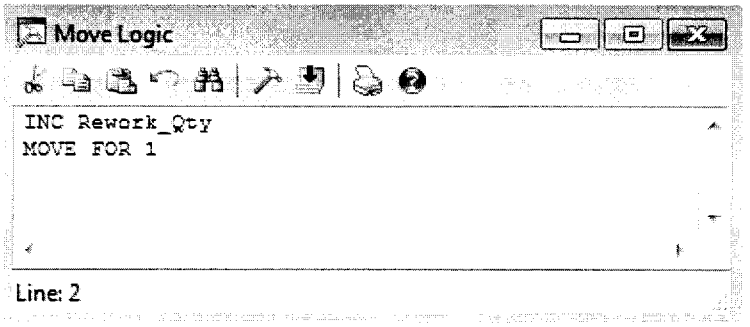
4.28. Back on the Process Table, add a new row. Select "ALL" as the entity and "Inspect" as the Location. On the Operation cell, type "WAIT N(6,2) MIN".



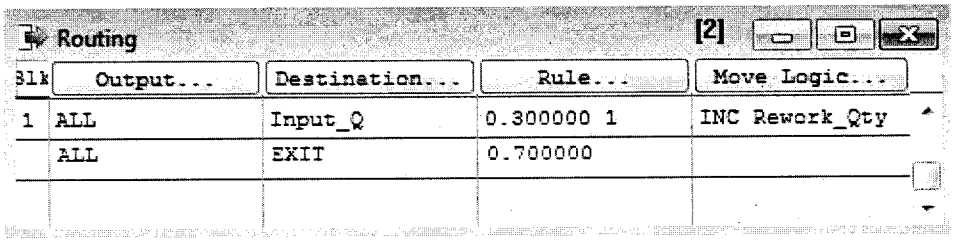
4.29. On the Routing Table: select "ALL" as the Output and "Input Q" as the Destination. Double-click the Rule cell, and on the Routing Rule window select "Probability" (1) and type the value 0.3 (2). This means that 30% of all the entities that are inspected will have to return to the Input Q to be reworked.



4.30. Still on the same row, double-click the Move Logic cell and insert the following code.



4.31. Add a new row to the Routing Table. Select "ALL" as the Output, and "EXIT" as the Destination. Once again double-click on the Rule cell of this row, and select the option "Probability" and type the value "0.7". Meaning that 70% of inspect items will be approved and will leave the system.



4.32. At this point, your processing window should look like the following.

Process				Routing			
Entity	**Location**	**Operation**	**Blk**	**Output**	**Destination**	**Rule**	**Move Logic**
Disc_A	Input_Q		1	Disc_A	Lathe	First 1	MOVE FOR 1
Disc_A	Lathe	WAIT N(5,1) MIN	1	Disc_A	Inspect_Q	First 1	MOVE FOR 1
Disc_B	Input_Q		1	Disc_B	Mill	First 1	MOVE FOR 1
Disc_B	Mill	WAIT U(6,2) MIN	1	Disc_B	Inspect_Q	First 1	MOVE FOR 1
ALL	Inspect_Q	MOVE	1	ALL	EXIT	IF Qty<5 , 1	
		INC Machined_Qty		ALL	Inspect	IF Qty=5	INC Inspect_Qty
		INC Qty					Qty = 0
ALL	Inspect	WAIT N(6,2) MIN	1	ALL	Input_Q	0.3000 1	INC Rework_Qty
							MOVE FOR 1
				ALL	EXIT	0.7000 1	

5. Creating Arrivals

5.1. Select the menu Build, and the option Arrivals.

5.2. For this Exercise it is only necessary to create the arrival for two entities (Disc_A and Disc_B).

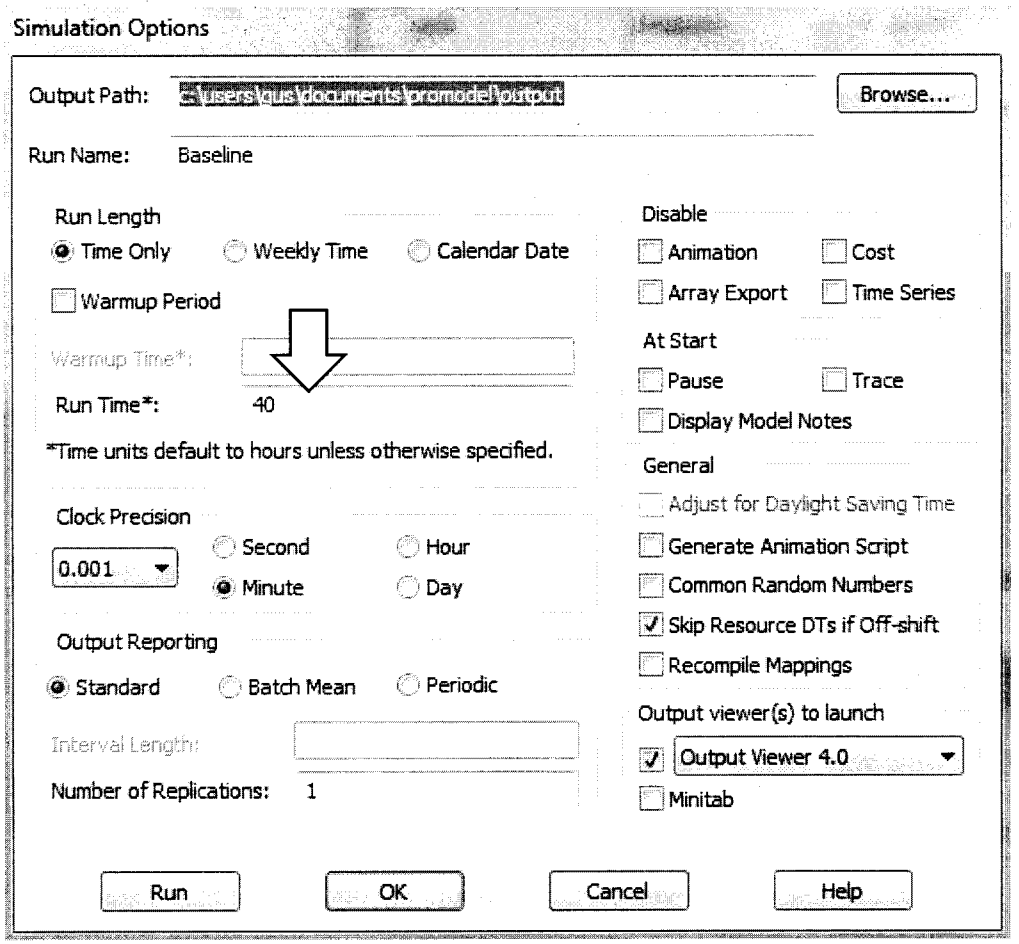
5.3. Insert the following information on the Arrival Table.

Entity	Location	Qty Each	First Time	Occurrences	Frequency	Logic	Disable
Disc A	Input Q	1	0	INF	E(5) MIN		No
Disc B	Input Q	1	0	INF	E(10) MIN		No

6. Defining Simulation Options, Saving, and Running the Model

6.1. Select the menu "Simulation" and the option "Options".

6.2. Input the "40" as the Run Time.



6.3. Save your model (Menu File -> Save).

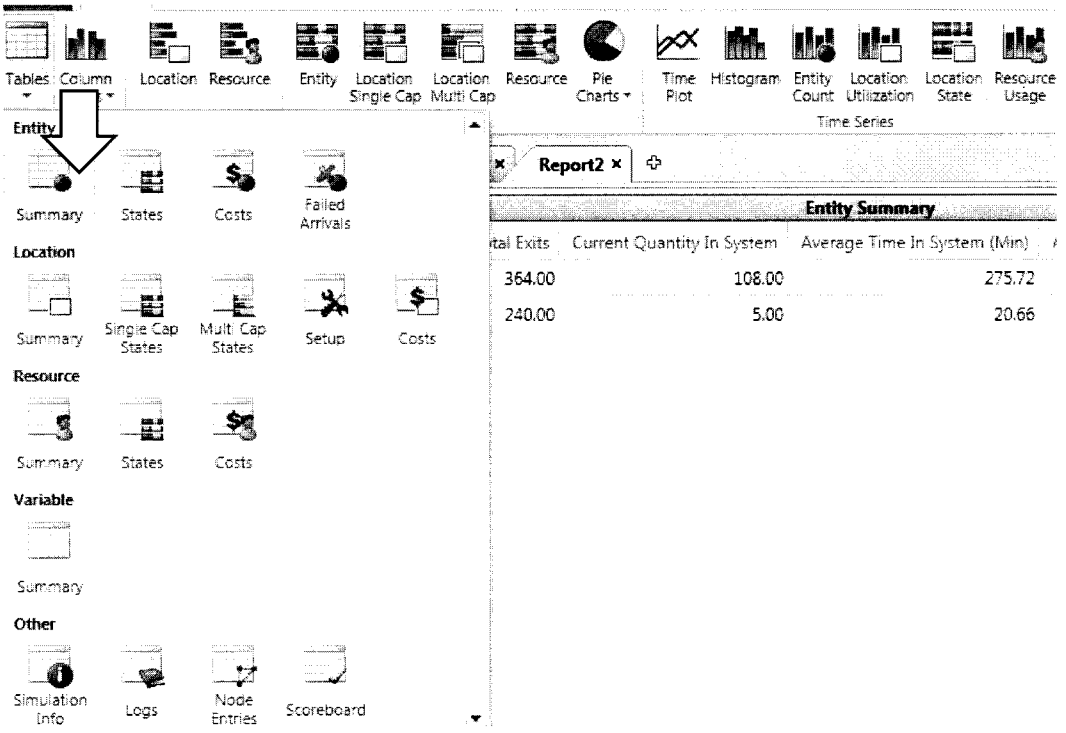
6.4. Run the Model, select the menu "Simulation" and the option "Run".

6.5. After your model finishes running, select the option to see the results.

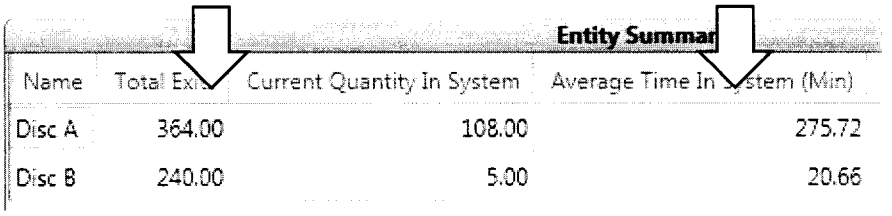
7. Analyzing the Results

7.1. If you follow the instructions of step 6 carefully, the Output Viewer should be presented to you.

7.2. To answer the questions "a" (Number of discs of each type shipped each week?), and "d" (Average cycle time for each type of disc?), click on the button "Tables", locate the "Entity" section on the menu, and click on the icon "Summary"



7.3. A table containing a Summary of the Entities' Statistics will be displayed. The column "Total Exits" shows how many of each disc was shipped during the week (1), and the column "Average Time in System (Min)" shows the average cycle time for each entity (2).



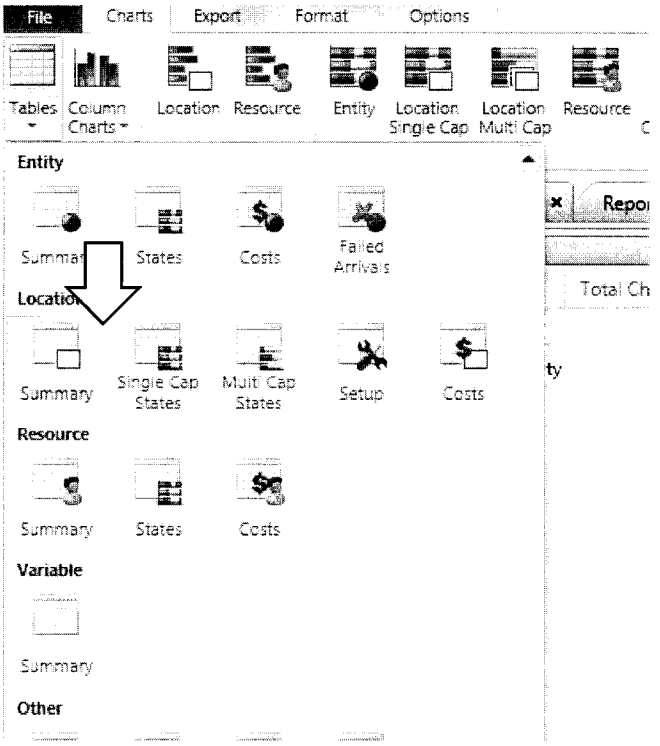
7.4. To answer questions "b" (Number of discs machined each week), "c" (Number of discs inspected each week), and "e" (Number of discs reworked each week),

click on the button "Tables", and under the section "Variables" select the option "Summary". The column "Total Changes" has the answer to questions "b", "c", and "e".

Variable Summary

Name	Total Changes	Average Time Per Change (Min)	Minimum Va
Qty	783.00	3.07	
Machined Qty	653.00	3.68	
Inspect Qty	130.00	18.38	
Rework Qty	49.00	48.06	

7.5. To answer the question "f" (Average number of discs waiting on the input queue and the inspection queue?), click on the button "Tables", and under the section "Locations" select the option "Summary".



7.6. The column "Average Contents" has the answer to question "f".

Location Summary

Name	Scheduled Time (Hr)	Capacity	Total Entries	Average Time Per Entry (Min)	Average Contents	M
Input Q	40.00	999,999.00	766.00	169.50	54.10	
Lathe	40.00	1.00	399.00	5.00	0.83	
Mill	40.00	1.00	256.00	6.02	0.64	
Inspect Q	40.00	999,999.00	653.00	0.16	0.04	
Inspect	40.00	1.00	130.00	5.72	0.31	

APPENDIX C

Video Lessons

APPENDIX D

The proposed Syllabus

TEC 5523: SYSTEMS SIMULATION

Spring 2014 EASTERN ILLINOIS UNIVERSITY

Instructor:	Rigoberto Chinchilla, PhD
Office:	KLEHM 4010
Phone:	217-581-8534
E-mail:	**ONLY** Use Desire2learn e-mail for course related

Course Description:

Numerical modeling of industrial processes and systems on digital computers. Course topics include: Problem formulation, model building, data acquisition, model translation, validation, and analysis of results.

Text: Harrell, Ghosh, and Bowden, "Simulation Using Promodel". McGraw-Hill, New York, 2012, Third Edition.

Objectives: Be able to:

- Describe key terminology and aspects of modeling used in simulation.
- Describe what simulation software is and how it is used to model processes and systems.

- Apply simulation techniques to specific complex situations.
- Interpret the results generated by simulation software.
- Use the results in management decision making.

Prerequisites: You have the pre-requisites to take this course IF AND ONLY IF:

- You have the ability to work independently, SELF-GUIDED and willing to use office hours when needed.
- You do NOT expect the instructor figures out that you need help with your readings, HW and course materials (This course is completely delivered online): Whenever you feel you are behind or need help please schedule an appointment with your instructor (Phone, Chat, and Messenger etc.) ASAP.
- You do not wait until one/two days before a HW is due to start to work on it
- You do not start studying for the exam one or two days before is due

Students with Disabilities:

If you have a documented disability and wish to discuss academic accommodations, please contact the coordinator of the Office of Disabilities (581-6583) as soon as possible.

Evaluation:	- Midterms (2 @ 150 points each)	300 Points
	- Final Exam	150 Points
	- Homework (5 HW assignments @50 points each)	250 Points
	- Five Process Simulations Laboratories	150 Points
	- Final project	150 Points

Your grade will be based on the total points "**X**" earned from the total as follows:

|X ≥901: A|; | 801 ≤ X ≤ 900: B|; | 701≤ X ≤ 800: C|; |600 ≤ X ≤ 700: D|; |X< 600:F|

Student Responsibilities:

- Study the PowerPoint (PP) presentations Posted on Desire2learn.
- Use office hours to clarify your doubts about the PowerPoint presentations before the midterm (Same apply for your Textbook lectures).
- Any document posted on Desire2Learn will be considered equivalent to be "handed out" to the student. The student can't claim ignorance of any material posted ONLINE.
- The last page of this syllabus gives a detailed calendar of activities from the semester, use this page to keep up with all course activities.
- ONLINE COURSES are for students with a self-guidance attitude, that means They :
    - Read the materials carefully every week and ask questions at the end of every week or use office hours to clarify the material
    - Start working in the HW with anticipation : A cramming style is not part of their strategy
    - Plan ahead course activities
    - Are personally responsible to obtain the work assigned, discussion information, laboratories, lectures, handouts, etc. on their own if you miss any of these activities.
- Access the class web site (Desire2learn) at least once a week to keep up to date on specific class activities, download assignments review lectures, etc.

- Be prepared by reading assigned materials, preparing appropriate questions, completing assigned projects, etc.
- Participate through active listening, personal and group discussions, asking and answering questions.
- Use a professional attitude in your approach towards fellow classmates, and instructor.
- You are personally responsible to obtain the work assigned, discussion information, laboratories, lectures, handouts, etc. on your own if you miss any of these activities.
- ProModel software activities will be part of some HW assignments
- Do NOT e-mail your HW unless you have written approval from your instructor: HW should be dropped at the appropriate Desire2learn drop box.

Cheating/Plagiarism policy:

- Homework, exams, and laboratory workshops should be **done individually** (unless otherwise explicitly allowed by the instructor). Failure to work individually will be considered as cheating and/or plagiarism. Cheating and/or plagiarism are not appropriate at any time and can result in dismissal from the class and a report to the university authorities.
- Plagiarism/cheating in a homework or laboratory workshop will result in a zero grade for the first time, the second time will be reported to the EIU authorities and will be penalized with a zero grade on the course. Cheating in an exam will be penalized with a zero grade on the course and report to the EIU authorities

Homework Policies:

c) Homework should be done individually, use office hours if you need help. Homework fulfills best the objectives when students do not cram.

d) Late Homework will be accepted with penalties applied as follows:

   a. Any late HW (within 24 hours late) 20% reduction (automatic) penalty from your grade

   b. HW submitted more than 24 hours late will have zero credit.

COURSE CALENDAR

The instructor reserves the right to change the syllabus at any time due to special circumstances. In case of a change this will be announced at least with 5 days of anticipation and in writing via e-mail.

Week	Topics and Activities
Jan 6 - Jan 17	- **Read the Syllabus** - **Read Chapter 1, 2 and 3 textbook. Omit sections 2.9.3, 3.4 and 3.5.** - **DONWLOAD SOFTWARE (details on D2L)** - **Do lesson 1 from the Lessons Guide (Use video and written instructions)** - **Submit your eventual questions and model to the instructor.**
Jan 20 - Jan 31	- **Read Chapter 4: (Omit section 4.3.3)** - **Read Chapter 6.**

	- **Read the Statistics Material on D2L (Statistics Fundamentals I, II, and III and also Mean Value Theory)** - **Do lessons 2, 3, and 4 from the Lesson Guide (Use video and written instructions)** - **"Building your first model Laboratory" (L2.1, L2.2,L2.3, L2.4,L2.5) (submit your models to the instructor on D2L)** - **MIDTERM 1** - **Turn in HW 1+HW2: Any question? Send E-mail or set an appointment with your instructor(i.e. Skype)**
Feb 3 – Feb 14	- **Read Chapter 8 from the textbook.** - **Complete lessons 5, 6, 7, and 8 from the provided lessons guide.** - **Complete "ProModel's Output Viewer" Laboratory (pp. 405-415).** - **Complete "Basic Modeling Concepts (P1)" Laboratory (pp. 419-460).**
Feb 17 – Feb 28	- **Read Chapters 5 and 9 from the textbook.** - **Complete lesson 9 from the provided lessons guide, select your task at the end of it and turn it in after completion.**

Mar 3 – Mar 14	- **Read Chapter 7** - **Complete Lessons 10, and 11 from the provided lessons guide** - **Turn IN HW 3+ HW 4+ HW 5. Any question? Send E-mail or set an appointment with your instructor.** - **MIDTERM 2** - **Choose Final project: Send e-mail to instructor**
Mar 17 – Mar 28	- **Questions about Chapters 6, 7, 8 and 9?** - **Course Evaluation** - **Complete lesson 12 from the provided lessons guide** - **"Basic Modeling Concepts (P2)" Laboratory (pp.430-453)**
	- **FINAL EXAM** - **Final project due no later than 4 p.m. MAY FIRST @ Desire2Learn**

APPENDIX E

Course evaluation survey

Lesson Evaluation

Name _____

Lesson # _____ Exercise # _____

In a scale from 1 to 5 (where 1 is equal to poor and 5 is equal to excellent), indicate your impression on the following categories.

1. Were the objectives of this lesson clearly exposed?

1	2	3	4	5

2. Were graphics on the written lessons helpful?

1	2	3	4	5

3. Were the steps easy to understand on the written guide?

1	2	3	4	5

4. Was the voice narration on the videos clear?

1	2	3	4	5

5. Were the videos and written guides compatible?

1	2	3	4	5

5. Were you able to obtain the expected results?

1	2	3	4	5

6. Do you believe that the objectives of this exercise were accomplished?

1	2	3	4	5

7. Additional comments?

APPENDIX F

Survey results

Following are the results for each of the exercises of the first six lessons of the material that was developed during this research. The higher the score for each category, the better the evaluation given by the students that tested the program.

Evaluation for Lesson 1

Area	Average Score
Objectives explanation	4.67
Utility of the graphics on the written lesson	5.00
Easy to understand steps	4.33
Voice narration on the video lessons	4.33
Compatibility between written lessons and videos	5.00
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 2 - Exercise 1

Area	Average Score
Clear objectives	5.00
Utility of the graphics on the written lesson	4.67
Easy to understand steps	4.67
Voice narration on the video lessons	4.67
Compatibility between written lessons and videos	5.00
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 2 - Exercise 2

Area	Average Score
Clear objectives	4.67
Utility of the graphics on the written lesson	5.00
Easy to understand steps	4.67
Voice narration on the video lessons	5.00
Compatibility between written lessons and videos	4.67
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 3 - Exercise 1

Area	Average Score
Clear objectives	4.67
Utility of the graphics on the written lesson	5.00
Easy to understand steps	5.00
Voice narration on the video lessons	4.00
Compatibility between written lessons and videos	4.67
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 3 - Exercise 2

Area	Average Score
Clear objectives	4.33
Utility of the graphics on the written lesson	4.67
Easy to understand steps	5.00
Voice narration on the video lessons	4.33
Compatibility between written lessons and videos	5.00
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 4

Area	Average Score
Clear objectives	4.67
Utility of the graphics on the written lesson	5.00
Easy to understand steps	4.33
Voice narration on the video lessons	4.67
Compatibility between written lessons and videos	4.67
Compatibility of results	5.00
Accomplishment of objectives	5.00

Evaluation for Lesson 5

Area	Average Score
Clear objectives	4.33
Utility of the graphics on the written lesson	4.67
Easy to understand steps	5.00
Voice narration on the video lessons	4.33
Compatibility between written lessons and videos	4.67
Compatibility of results	4.67
Accomplishment of objectives	5.00

Evaluation for Lesson 6

Area	Average Score
Clear objectives	5.00
Utility of the graphics on the written lesson	4.67
Easy to understand steps	4.67
Voice narration on the video lessons	4.67
Compatibility between written lessons and videos	5.00
Compatibility of results	4.67
Accomplishment of objectives	5.00