APPLICATION OF MODELING AND SIMULATION IN A MANUFACTURING SYSTEM

By

SABRINA MOHD RASID

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved:

Dr Nordin Saad
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Sabrina Mohd Rasid

ABSTRACT

The aim of this project is to develop a simulation model of an air conditioners manufacturing system with a discrete event simulation tool. The model would be utilized as a decision support system for the investigation of improving the process by implementing several options like cost cutting and simplifying operation. This report discusses steps in the development of a simulation model for a manufacturing system using the DES tool, ARENA. A modeling procedure for the development of manufacturing simulation model is presented. The current manufacturing system model is developed to ascertain its limitations and problems to achieve the production target. The steps include data gathering, model building, verification and validation. Several experiments were conducted to recognize parameters useful in the interpretation of the simulation data like the warm up period, run length and number of repetition. The results show that the manufacturing system was improved by 40% by speeding up parts delivery to the system, whilst the waiting time and queue at each station can be improved by proper line balancing. The findings demonstrates the ability if the approach to provide potential solution to the decision maker.

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CHAPTER 1
INTRODUCTION

1.1 Simulation in Manufacturing System

Simulation is a concept which has been around since the 1950's and it involves building a model that mimics reality. The Discrete Event Simulation (DES) which ARENA uses involves the modeling of a system as it progresses through time. It gives the ability to model random events based on standard or non standard distributions and to predict the complex interactions between these events.

Simulation is primarily a decision support tool and does not seek optimum solutions. Having built a simulation model (on a computer), experiments were then performed to change the input parameters and predicting responses. The model will then be used to estimate the effects of various actions.

The idea behind simulation process is to imitate a real world simulation mathematically, study its properties and operating characteristics and finally to draw conclusion and make action decisions based on the results of the simulation.

The most notable benefits of simulation are:

- risk reduction
- greater understanding
- operating cost and capital cost reduction
- lead time reduction
- faster plant changes

This simulation study was done at a large scale manufacturer system. Manufacturing, a branch of industry, is the application of tools and a processing medium to the transformation of raw materials into finished goods for sale. This process was also known as fabrication in some industries, such as semiconductor and steel manufacturers [1].

1.1.1 Examples of Manufacturing Systems

- Mass production
- Just In Time manufacturing
- Lean manufacturing
- Flexible manufacturing
- Mass customization
- Agile manufacturing
- Rapid manufacturing

In this project, the company where the study is conducted is practicing lean manufacturing. **Lean manufacturing** is a management philosophy focusing on reduction of the nine wastes to improve overall customer value ([2], [3]):

- Transportation
- Inventory (having more inventory than required)
- Motion (workers moving more than required)
- Waiting time (machine queue or waiting for parts)
- Over-production (making more or earlier than needed)
- Processing Itself (standalone processes)

- Defective Product (Scrap in manufactured products or any type of business.)
- Safety (unsafe work areas creates lost work hours and expenses)
- Information (age of electronic information and enterprise resource planning systems (ERP) requires current / correct master data details)

By eliminating waste, quality is improved; production time and costs are reduced ([4], [5]).

In this project, the studies will emphasize on assembly lines. An **assembly line** is a manufacturing process in which interchangeable parts are added to a product in a sequential manner to create a finished product. The assembly line was improved largely by Henry Ford and his engineers; Ford was also the first to build factories around that concept. It usually consists of four workers in control of one specific job and their work related movements are reduced to a minimum. It is widely considered to be the invention that kicked off the modern craze for consumerism and cheap prices and discounts for everything [6].

1.1.2 Company and Product Background

The company in study is a large manufacturer of air conditioners. XCorp manufactures room air-conditioner, rotary compressors and hermetic motor, fan, blower, toroidal and brushless motor and other component parts.

As one of the largest exporters of room air conditioners in the world, the products are exported to more than 120 countries around the world. This company is a leader in global air conditioning industry with experience spanning 20 years. The company has an annual production of 1 million units of air conditioners and utilized extensive state of the art manufacturing methods to meet today's demanding market requirements.

There are 10 types of series air conditioners manufactured. Amongst it are window type air conditioners, split, dehumidifier and outdoor series. The product used in this simulation is SAB-1234A, one of more than 200 products in N (new) series. This new series production is manufactured in a newly built manufacturing line.

1.2 Problem definition

The company has been involved in the manufacturing of air conditioners since 1980. To cater for the increasing world demand for room air conditioner, the company had invested in a new type assembly line, to manufacture the new N-series window type room air conditioner. However, the line could not achieve its planning target throughput because the target is 930 units per shift but the actual output is only about 80% of the target.

It is proposed to investigate this problem with a simulation model. The requirement and expected time scales and costs are outlined in this specification.

1.3 Objectives

The overall aim is: To achieve target throughput of 930 units or more per shift from the New Line assembly.

The objectives are:

To determine whether 930 units per shift can be achieved with

a. Percentage Rejection

b. Shift Pattern

c. Parts Supply Schedule

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Simulation has been used to design and analyze manufacturing and process system. The primary reason for using simulation to analyze manufacturing operations is the high cost of experimenting with the real system and the ability to compare suggested systems, to observe circumstances rarely available, and to experiment with alternative characteristics of material ([7], [8]).

Arena ([11], [12]) is a graphical simulation environment developed to build and perform discrete-event simulation models. It is one of the leading simulation packages at the moment. It is also a VIS software and it is used widely throughout the world to simulate and improve processes.

Other than using simulation software, the modeling can also be done manually but it is a really tedious process and requires extensive data gathering and must be calculated carefully to have a valid result. There is also another concept called knowledge based system (KBS). A knowledge based system is a program for extending and querying a knowledge base. It is a computer system that is programmed to reproduce human problem-solving by means of artificial intelligence and reference to a database of knowledge on a particular subject. KBS have been introduced in a variety of problem domains, ranging from strategic areas such as market analysis to equipment design. It can also be used to model a process system. Such programs must be developed by experts and normally use the Decision Table [14].

2.2 Related Research Work on Modeling and Manufacturing System

One company even used simulation to close a sale with General Motors Corp. Flex-N-Gate, an automotive supplier in Urbana, was to double the line speed GM was using to apply paint to plastic parts, a specialty at Flex-N-Paint. GM wasn't convinced the supplier could handle the increased line speed. "The simulation showed the paint being applied, and it showed the robot's speed in real time" [15]. This has shown the credibility of computer simulation to be applied in real time situations.

Three-dimensional modeling is also gaining ground in manufacturing simulation. On a survey of 1,200 manufacturers, in 2003, 38 percent of manufacturing design was done in 3-D. In 2004, 51 percent of manufacturing design is in 3D, says Bob McGill, director of business alliances at SolidWorks Corp., a simulation software company in Concord, Massachusetts.

McGill [15] notes that 3-D modeling first caught on in the aerospace and automotive sectors. "You model the robots in 3-D, then select the place for the weld and tell the robot to do it along those lines." As for pressure and the robot's maneuverability, those parameters are built into the simulation delivered by the robot manufacturer, so you can't inadvertently tell the robot to do something that it can't do. This is a breakthrough in achieving lean manufacturing where the number of defects can be significantly decreased.

In addition to using simulation in design, production and training, the technology has also taken on a role in management decisions. "Simulation is becoming a management tool since the results of the simulation are pertinent to making significant business decisions," says Vivek Bapat, product marketing manager for Arena simulation software at Rockwell Software, a unit of Rockwell Automation Inc., in Milwaukee. The management team can look at the production metrics, productivity data and financial metrics. The simulation can tie the production metrics to the financial metrics.

One area where simulations of the entire plant are getting traction is with new plants or newly refitted plants. Before manufacturers determine what equipment they need and where it should go, they simulate the plant's entire operations. "The dynamic simulation provides a model for a new plant to make sure the plant is designed properly," says Marty Israels, marketing communications manager of Honeywell Process Solutions [15]. As a result, the model built can identify future problems and can be tackled during the design of the plant. Machine downtime can be predicted using statistical distribution and proper maintenance schedule can be outlined.

Honeywell has a tool called Shadow Plant, which mimics plant's operations. The simulation helps with training as well as planning. "Shadow Plant looks at pumps and valves and it will simulate the control of the heat valves," says Israels. Engineers use it prior to starting up a plant, and operators use the simulator just like a flight simulator to learn how to properly start up, run and shut down a plant. You get the feel of running the actual plant.

The challenge of computer simulation is gathering data. "Data that is not accurate and representative is usually the downfall of manufacturing simulation activities," says Kohls [15]. "We had to internally develop data collection standards based on requirements of our throughput tools." Types of obtainable and unobtainable data will be discussed in later chapters.

Besides the stereotype manufacturing system, simulation has also proven beneficial for other industries. The Panama Canal Authority has used Arena software to develop a simulation model of the Panama Canal, one of the most famous waterway and locks system of the world. The case is based on the project conducted by Rockwell Software and Paragon Consulting Solutions, helping Panama Canal Authority design a strategic planning tool, based on Arena Simulation Software [16]. This simulation project has produced a powerful and precise simulation tool, allowing the Panama Canal Authority to conduct several experiments with existing and future canal resources, up to the year 2025, while testing different strategies for lock operations, as well as new proposed locks and navigation channels.

A simulation using Arena was implemented on the manufacturing system of chest freezers [13]. The simulation has successfully improved the plants throughput and decrease bottleneck in operations. This was done by expanding the manufacturing floor and adding more work forces which involves a lot of money.

Based on the previous study chest freezers manufacturing system, it is hoped that using Arena, the process will be able to be improved to achieve optimum production capacity. Instead of expanding, possibilities of downsizing the man power and increasing efficiency in terms of machine layout and conveyor speed. The main goal is to increase throughput within the cheapest ways possible.

CHAPTER 3
METHODOLOGY

3.1 Introduction

The particular interest of this simulation study was on a large scale manufacturer of air conditioners. The manufacturing system was based on the assembly line concept. Chapter Two discusses several works that have been carried out on simulation. Simulation has been extensively applied in manufacturing system and also other fields such as medical, authorities and marketing. The analyzing of previous works helps in identifying the gaps or problems in achieving a successful simulation.

From the literature research, it is without doubt that this project will improve the existing manufacturing system but with the uniqueness of reducing costs. Based from the report from the plant engineer, the improvement achieved by increasing the manpower or machine is costly. One of the significant aspects of the manufacturing system management is the control and coordination of production decisions within the financial constraint which is the aim of this project.

Data gathering is one of the important tasks in the project. These involved meetings with the engineers of the manufacturing plant to understand the problem of the existing plant. Following that, more detail data have to be gathered, i.e. the machine times, assembly times and other information as needed to be modeled and specifications of the project have to be clearly defined.

In addition to that, information such as arrival time of entities has to be calculated using statistical distribution. Next the model is built and verified using the production data of past processes. The verified model is then validated through various discussion session with the engineers. Here, the possible changes to the manufacturing system are discussed and the changes are then modeled again to give the most beneficial outcome. Finally, the whole work of the project is documented for presentation, and reference.

3.2 Methodology

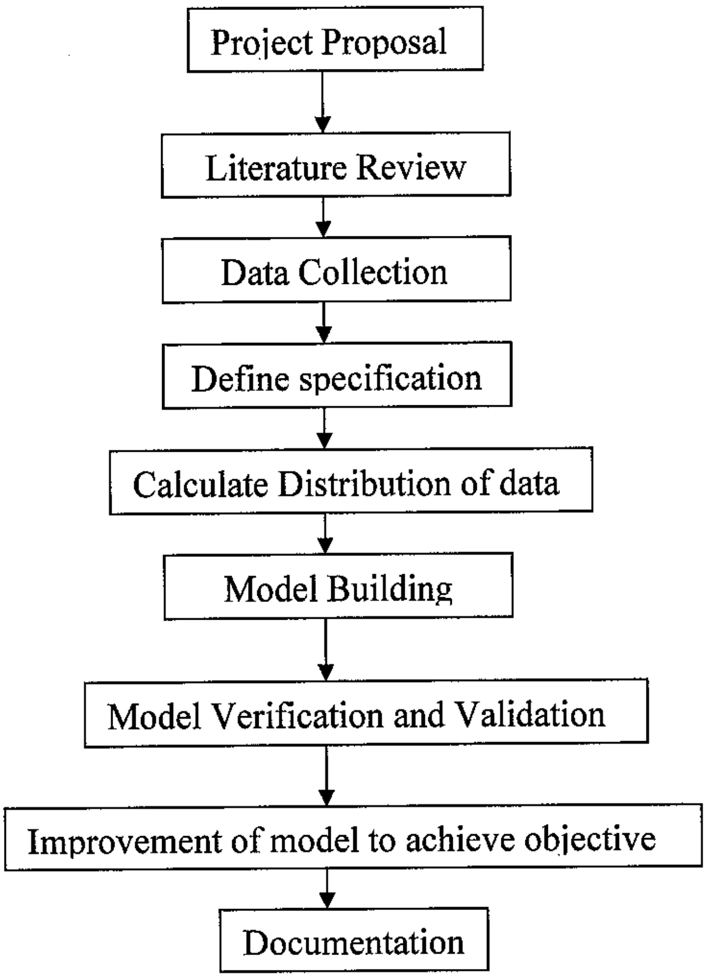


Figure 3.1 Flowchart of the Planned Activities

3.3 Specification

The first phase of the project is the specification phase. This phase will usually involve a meeting at management's site to discuss the goals of the project and the system to be modeled. At the end of this phase, a document (the specification) will be created. Once the specification is completed, it will be signed by the analyst and the management officer to signify the scope of work for the project. The specification will be used as the framework for the final report when the project is completed. Essentially, the specification will serve to document not only the conclusions of the project but also the path that was taken to reach those conclusions.

3.3.1 The structure of the specification

The specification is a management summary of the project's objectives and the intended method of approach. It is not meant to be a full-blown technical specification including details of intricate modeling techniques. As a guide, the following contents are suggested, however, some sections may be omitted and other added depending on the needs of the project and organization:

- Introduction to the problem and project objectives
- Expected benefits
- Model summary : scope and level of details, assumptions, experimental factors and reports
- Data requirements : what is required, who is to provide the data , when it is to be available, when the data is to be frozen.
- Time scale and milestones
- Estimated cost

3.3.2 Introduction to the Problem and Project Objectives

The first element in project specification is identifying any performance problems for the existing system. For example, the production of a manufacturing facility is below target or a retail outline is not achieving the desired level of service. Having identified the problem, the next step is to set carefully in the simulation's objectives. A useful framework is to consider objective in terms of these three components which is achievements, measurements and constraints.

Achievements

Achievements describe the basic aim of the project. For example:

- To increase output
- To decrease average waiting time
- To understand the effect of breakdowns
- To determine the number of vehicles

All these contain key actions such as increase, reduce, understand, determine, identify, demonstrate, compare, select and communicate. The action is always performed on something, in this case the output, average waiting time, effects of breakdowns and the number of vehicles.

Measurement

It is not wholly useful to state that the objective of a project is to increase throughput. By how much is the throughput to increase? Whenever possible a measure of the achievement should be stated. For example:

- To increase throughput by 10%
- To reduce average waiting time by 1 minute

Constraints

Consideration should be given to any constraints or conditions, under which the achievements are to be made. These are normally expressed in terms of money, people, resources or time. For example:

- To increase throughput by 10% within a capital spend of RM 100000
- To reduce average waiting time by 1 minute without employing more labour.
- To determine number of vehicles required to enable 100% availability of materials

However, one advantage of simulation is that the experiments can be performed without constraint; therefore, they are not always necessary as part of the objectives.

3.3.3 Experimental Factors and Reports

The experimental factors represent the identified methods by which the objectives of the project might be achieved. The objectives describe what should be achieved but no indication is given as to how this might be done. Having set the objectives, the methods of attaining them need to be identified. These methods are then represented by the experimental factors. For example, if the objective is to increase throughput by 10 percent, then the methods of obtaining this might be to change the cycle times and the buffer sizes.

There are a number of ways to present the reports. It is important that the right methods are chosen; this ensured that the results can be interpreted correctly and also communicated effectively. There are some general issues to be addressed on method of reporting.

Firstly many of the reports described below should be used in collaboration with each other and not in isolation. For instance, when a histogram is being used, the mean, standard deviation, maximum and minimum should be normally reported too

Secondly, most simulation packages give facilities for producing many of the reports outline below. In some cases, reports are given automatically; in others they may have to be defined by the modelers.

Finally, How the project is represented in the real world must be taken into account.. If a pie chart is normally used, it is probably best to provide one in the model to take advantage of their familiarity. Tabular reports have a very general meaning. A table could be anything from just one figure to a large array of the numbers. The format of the table is not covered but only the information that it provides.

3.3.4 Scope and level of detail

The model may require a lot of detail or only the simplest representation. For example, when modeling an individual machine, should just the cycle time be represented, or should perhaps the operations, breakdowns, set-ups, repair labour, shift patterns and production schedules be modeled? Alternatively, some middle ground could be found. If a service point is being modeled, which out of random service times, staff roasters, queue jockeying and shortages should be included? This will be explained at chapter 3.5.

3.3.5 Data Requirements

Having defined the scope and level of the model, the data required are identified. These data are either immediately available or need to be collected. Some data cannot be collected and estimates have to be made. Other data require analysis, for example fitting a distribution to the repair time of a machine. Data collection and analysis may take some time and therefore it is performed in parallel with other modeling activities.

3.3.6 Time Scales and Milestones

It is not possible to give exact advice about the time required to complete a simulation project. A typical project probably requires between one and two month to complete. As a general guide, three main factors can be considered which affect the time scale most:

Model size. A simulation of one bank teller with a single queue is about as small as a model can get. At the other extreme, a production assembly such as an air conditioning assembly has many stations and hundreds of queue.

Model complexity. Some models contain only simple logic while others have complex controls for routing, scheduling, and timing, for example, a model of a manufacturing facility demonstrating material scheduling and flows.

Time to experiment. Sometimes only a few experiments are required to obtain a result. For other models there are many factors and many combinations and a significant number of experiments are needed. The speed of the model greatly affects the experimentation time.

3.3.7 Estimated Cost

The costs of the project can be divided into seven areas:

- Software purchases
- Software maintenance
- Hardware Purchase
- Hardware Maintenance
- Simulation Training
- Man and time resources
- Consultancy Support

3.4 Product Background

The new line assembly is producing the latest model of air conditioners. The air conditioner was assembled in 61 stations and also has 16 parts coming in for the completion of the assembly. The parts arrive on the conveyor and will be distributed to the worker on each station depending on the task assigned.

The assembly also used a bending machine at the middle of the production. The production uses the accumulation conveyor belt system. This type of system has the downside of having bottleneck or conveyor jams when any station is not operating.

The 61 assembly stations are lined out in a serial manner. The conveyor will pass through Station 1 until Station 61. This type of layout requires a lot of space in the factory.

Parts arriving at each station are brought by trolley or machines if it is big in size. The parts coming in must not be too many because it will occupy space beside the workstation.

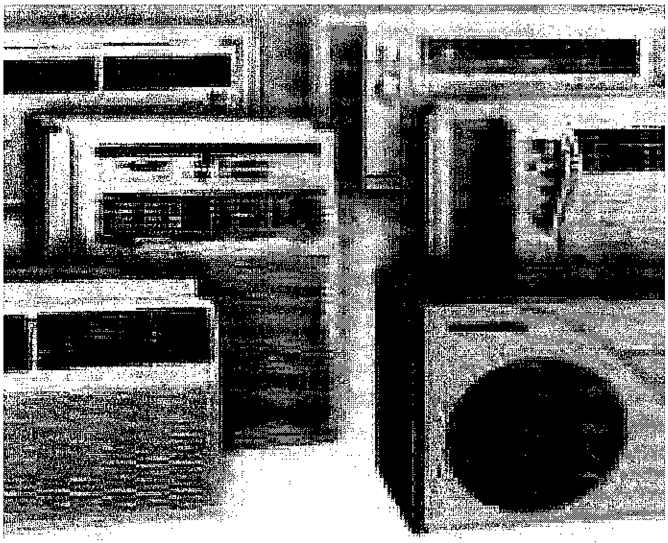


Figure 3.2 Picture of and air conditioner (from Google Images)

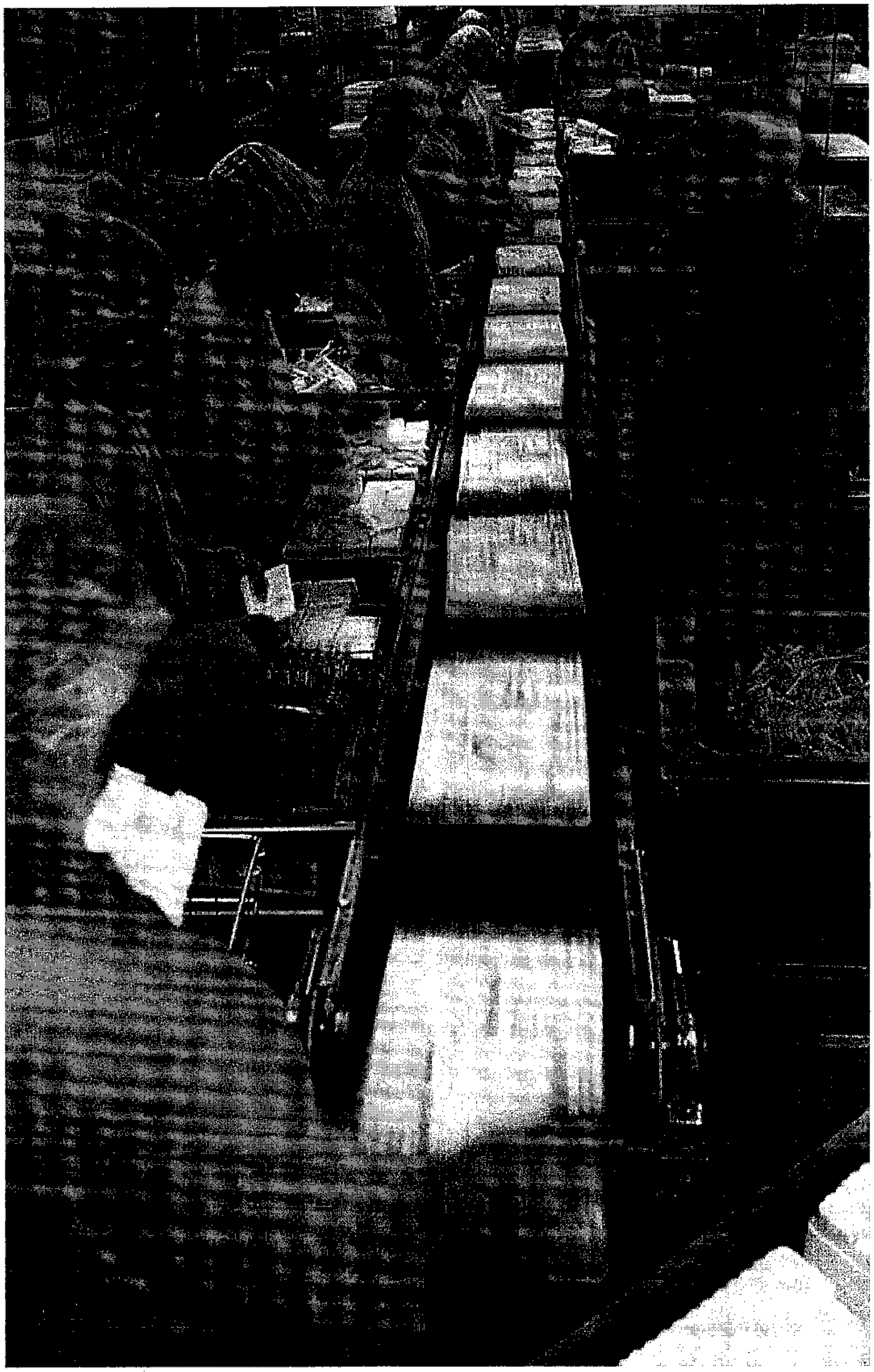


Figure 3.3 An example of air- conditioner manufacturing floor (Google Images)

Table 3.1 Summary Process Flow Chart (Unit)

No	Process	Time Taken (cm)
H1	Set up air-con base Push tap to base pan Set plate to base and screw Supply band, air guider and push button	61.48
H2	Set bulkhead to base, tighten screw Supply base wheel and push button	40.471
H3	Attach tape to bulkhead Fix plate and screw Install push button	34.24
H4	Attach sealer to drain pan Fix band, supply motor and push button	51.98
H5	Set bracket, flex pipe to ban Insert wire to bulkhead hole and push button	44.93
H6	Tighten screw bulkhead to bracket Insert anti vibration bushing and push button	53.66
H7	Tighten screw of wire to bulkhead and base Tighten screw to bulkhead and particular plate	28.36
H8	Remove comp discharge tube cap Bending compressor discharge tube	9.26
H9	Set soundproof material to compressor	19.61
H10	Supply soap to bushing Setting comp to unit Attach poly-e-foam to accum Push button	36.62
H11	Tighten comp nut Bing v/tie to accum & foam Supply a/guider p/fan to unit	40.80
H12	Seting cond to bending machine (breakdown) Pull out cond from machine Push button Put cond to conveyer Tighten screw to a/guider pan fan (right side 1 pcs)	43.65
H13	Tighten b/wheel to f/m shaft Setting strainer to cond lead pipe Braze strainer to cond lead pipe	54.71
H14	Fix b/tape to f/m bracket Tighten screw to a/guider p/fan & b/pan (left side) Fix p/fan to f./m shaft	45.35
H15	Tighten but & plain washer to p/fan & f/m shaft Setting tube assy to cond lead pipe	38.01
H16	Setting cond to unit Setting disch tube to cond	42.21
H17	Tighten screw to cond & pan Tighten screw to cond & a/guider pan fan (right 2 pcs) Tighten screw to cond & a/guider pan fan (left 1 pcs)	34.74
H18	Setting eva to bending machine (breakdown) Insert plastics sheet to eva Bending machine time Push button bending time Put out layer & supply eva to conveyor	47.33

	Set vent door to a/guider Tighten screw to eva (2 pcs)	
H19	Setting tube and cap, setting cap complete to eva pipe Braze capillary to tube	28.34
H20	Attach EPT seal to bulkhead Setting evaporator to unit, attach tape to base	46.65
H21	Tighten screw to evaporator and bulkhead (left) Tighten screw to cond and air guider pan top & bottom	42.25
H22	Fix discharge tube to cond and strainer Fix tube assembly to evaporator Attach ring bushing to discharge tube	39.961
H23	Braze capp & strainer Braze disch tube complete to comp	37.71
H24	Braze eva lead pipe to tube assy Braze cond lead pipe & disch tube	38.34
H25	Fix sensor holder to eva Attach pink sealer to b/pan	53.17
H26	Remove out comp terminal cap Fix gasket to terminal Wiring olp to terminal	41.89
H27	Line inspection Stamping model number	43.43

Table 3.2 Summary Process Flow Chart (Inner)

H28 & H29	Fix vacuum hose socket (top) Fix vacuum hose socket (bottom) Vacuuming (machine time) Walk to next station Plug out from vacuum hose (bottom) Plug out from vacuum hose (top) Push button Waiting set in and out at each station	44.85
H30	Fix gas charge gun to coupler Push gas charging gun button Charging time Stamping date chop Insert ring o disch tube Pull out gun	32.98
H31	Seal brazing at tube assy process tube	44.09
H32	Seal brazing at cond process tube	34.81
H33	Fix bushing to b/head Supply c/board onto pallet Attach wire diagram onto c/board	58.59
H34	Fix terminal cover to comp Tighten to terminal cover and comp Insert olp wire into b/head hole & arrange wire	58.32
H35	Connect F/M orange wire to terminal board Connect comp blue wire to comp capasitor Connect F/M blue wire to comp capacitor Connect comp grey wire to main board	56.02
H36	Fix sensor holder to eva fins Connect F/M red wire to F/M capasitor Connect comp pink wire to comp capacitor Connect F/M yellow wire to main board	50.36
H37	Attach b/tape to capp & m/b tube Insert and fix bushing to receiver comp Bind band to bushing	43.71
H38	Tube adjustment	38.53
H39	Set c/board to unit Tighten screw to c/board & b/pan Tighten screw to c/board & particular plate	48.97
H40	Apply pink sealer to terminal cover & flex pipe Cut excess band	35.74
H41	Bind band to wire comp and f/m Fix bushing to particular plate	47.77
H42	Attach w/sealer to b/head hold Insert comp lead wire to band	39.72
H43	Apply silicon grease to vane Set connection vane to jig & switch on opr starter Fix thermostat sensor to sensor holder of eva Apply grease to unit Set vane to unit	37.61
H44	Supply a/guider blower wheel to pallet Attach poly-e-foam to a/guider b/wheel Attach particular piece to a/guider Fix connecting bar to particular piece & A/huider	45.00

	Set a/guider to unit Fix vane to connecting bar & a/guider	
H45	Set plate to b/head and a/guider p/fan Tighten screw p/plate to a/guider p/fan & b/head Fix p/piece to b/pan & p/plate complete Tighten screw to p/plate & p/plate complete	46.05
H46	Attach/tape to p/plate & tube assy	35.72
H47	Inner line inspection & attach f/tape to particular plate	66.10

Table 3.3 Summary Process Flow Chart (Final)

H48	Fix knob to ventilation level Push button Water disch process at b/pan Push button	40.66
H49	Attach cc board to b/head & cond with f/tape	31.26
H50	Fix cab to unit Supply f/grille to top unit Push button	28.31
H51	Tighten screw particular piece to unit Take down front grille into conveyor Take out wire	34.30
H52	Attach budge (national to cab)	14.26
H53	Attach f/tape to opr instruction & cab Attach f/tape to cab Peel off c/panel plastic cover Set c/panel to c/board Insert knob to c/panel (2 knob)	50.91
H54	Attach f/tape to c/panel Tighten ps cond with ciny/tie	36.10
H55	Attach f/tape to bag complete & stick to d/pan Attach f/tape to pan & set d/pan to unit Attach f/tape to cab	36.41
H56	Attach caution label t b/pan Check d/pan with bag complete Check opr instruction Supply f/tape to cab	24.05

Table 3.4 Summary Process Flow Chart (Packing)

H57	Attach f/tape to ps cond Fix ccboard to a/v & attachment f/tape	30.32
H58	Arrange unit Lift up unit using machine Put shock absorber & base board to unit Put down unit Fix front grille to shock absorber	43.60
H59	Attach sellophane tape to inspection certificate Take d/pam to upper cab Cover unit with plastic bag Push button	24.39
H60	Arrange cc case Apply glue to cc case Attach (inspection) certificate to cc case Fix cc case to unit Push button	36.31
H61	Fix shock absorber at top cab Close top flap cc base	20.54

3.5 New Line Assembly Specification

The overall aim: To achieve target throughput of 930 units per shift from the New Line assembly.

The objectives are:

To determine whether 930 units per shift can be achieved with

a) Percentage Rejection
b) Shift Pattern
c) Parts Supply Schedule

Assumptions

The following are assumed:

- The conveyor breakdowns are infrequent
- Sub-component, such as wire, screws, seal, nuts, etc are always available
- Work only take place around the normal shift time and no overtime working times are taken
- Productions are run continuously although the products are changeover and set up time on products changeover are small and can be neglected.

Experimental factor

- The interval time for parts supply, with a maximum of 40% increase
- The layout arrangement, with an expected range of conveyor length of 2 to 12 pallet length
- The conveyor transfer times between 45 to 55 centi minutes

Data requirements

The following are the needed data to build the simulation.

- Physical Layout
- Production schedule
- Number of pallets
- Station; cycle time, breakdown, repair time and set up time.
- Conveyor : capacity, transfer times
- Production rejection
- Validation data

Estimated cost

It is estimated that total of 60 man-days of effort are required to complete the project. This is after familiarizing the software which will take another 30 days. The training are necessary to learn the software if the manual is insufficient to learn from. There are no hardware costs. The only cost in this project is actually purchasing the software from Rockwell Technologies. The training is provided by Rockwell technologies.

3.6 Data Collection

In the process of performing a simulation project, various types of data are required. These are of a quantitative nature, for example cycle times, arrival rates and resource requirements; they explain logic rules such as the control of flows, scheduling strategies and work allocation; and they describe the physical layout. Some of these data are deterministic- their value does not vary during a simulation- while other data are stochastic- they are subject to random variation during a run. Stochastic data are normally described using a distribution.

3.6.1 Data Categories

It is important to consider the availability of the data that are required Category A is available data, Category B is not available but collectible, and Category C is not available and not collected.

Category A represents those data that are immediately available.

Category B data are not available but can be collected within the available time scale of the project.

Category C data are neither available nor they can be collected, normally due to time and resource constraints, or simply because there are no similar process existing at that point of time.

3.6.2 Dealing with Unobtainable Data (Category C)

Unobtainable data Category C may at first sight present a stumbling block to the success of the project. However, this is not the case. The following discussion shows two methods of dealing with the data in Category C

3.6.2.1 Estimate the Data

There are various ways of estimating data, for example:

- Studying similar facilities
- Interviewing operational staff
- Discussing the data with equipment vendors
- Making an intelligent guess.

3.6.2.2 The model creates the data

Rather than asking what the data are, turn the question around and ask what the data need to be. In other words, use the model to create the data and aim to achieve this in reality.

3.7 Handling Data Changes

Many simulation projects are carried out in an environment of change, especially when a new facility is being modeled. Adjustments are constantly being made to the layout, timings, control, and other data. A lot of time is spent keeping up to date with the changes and including them in the model; it is not long before time scale of the project begins to slip.

In order to avoid this situation, it is important to have a procedure in place for handling changes in the model data. A useful means for doing this is to agree a time after which the data will be frozen and no further changes to the model will be made. By doing this, the time scale of the project is more likely to be kept.

However the real world continues to progress despite the frozen data in the model and so it must be recognized that there will be some inaccuracy in the simulation result. In general, the benefit of keeping to time is greater than the disadvantage of the inaccuracy, as long as it remains small. There are situations where the changes are so significant that it is necessary to unfreeze the data

3.8 Standard statistical distributions

There are a number of standard statistical distributions that can be used to describe the random nature of events and will be discussed later in this section.

3.8.1 Statistical Distributions

In order to carry out a simulation of a system having inputs (such as inter arrival times) which are random variable we have to specify the probability distributions of these inputs. In this section, a few statistical distributions are described. Normally they are provided as standard options in the simulation software. Of these distributions the most commonly used are the negative exponential, Erlang, Gamma, normal, triangular and uniform.

For each one the following details are given:

- Density / shape
- Parameters
- Range

- Mean Variance
- Typical Application
- Additional comments

3.8.2 Pseudo-Random Number Streams

When building the model, the distributions normally require an additional parameter, a pseudo-random number stream. A random number is a value that is obtained in a purely random fashion that is with no particular pattern. Everyday examples are tossing a coin, giving a 'head' or 'tail', and a throwing a die, giving a number between one and six. The main properties of random numbers are that:

i. There is an equal probability of any number being generated, i.e. when rolling a die a value of one is a likely as a value of two, etc.
ii. The numbers are completely independent, i.e. the fact that a six was rolled last time does not affect the probability of a six being rolled again.

When using the Arena software, random numbers are generated by special mathematical techniques that can be found in the software and will be explained in later chapters.

3.8.3 Select a Statistical Distribution

By visually inspecting the shape of the data it is possible to draw conclusions about a probable candidate. For a New-Line assembly, assume machine H18 (Evaporator

Bending Machine). The time between failure and repair time have same distributions. Data have been collected on the repair time of these machine and summarized below:

Table 3.5 Repair time for H18 data

Repair Time (min)	Frequency
0.0 – 6.0	10
6.0 – 12.0	37
12.0 – 18.0	23
18.0 – 24.0	14
24.0 – 30.0	7
30.0 – 36.0	5
36.0 – 42.0	2
42.0 – 48.0	2
48.0 – 54.0	0

Initially an Erlang Distribution is used since it appears to match the shape of the data.

3.8.4 Estimate the Parameters

Secondly the parameters of the distribution must be estimated. For parameter such as the mean and standard deviation it is normally possible to calculate them. Visual inspection and estimation are the best methods for selecting parameters that cannot be calculated, for instance the shape and scale.

The mean of the distribution is calculated in the table below. Since it has been necessary to calculate the mean using the mid-point in each range, it is only an estimate.

For now, using the Erlang Distribution, the parameters K of 1, 3, and 5 is used. This was done using the Input Analyzer in the Arena software.

Table 3.6 Mean Average of repair time data

Mean Repair Time (min)	Frequency	Mean Repair Time x Frequency
3.0	10	30
9.0	37	333
15.0	23	345
21.0	14	294
27.0	7	189
33.0	5	165
39.0	2	78
45.0	2	90
51.0	0	0
Total Mean Average		15.24

From the input analyzer, we can vary values of K to see the effect of K on the distribution. K equals to one will produce an exponential line and K larger than one will achieve more of a normal distribution and can be roved mathematically using the formula.

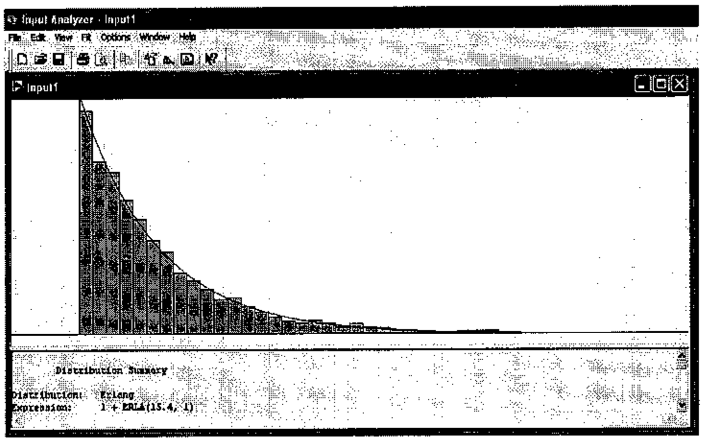


Figure 3.4 Erlang distribution with K= 1

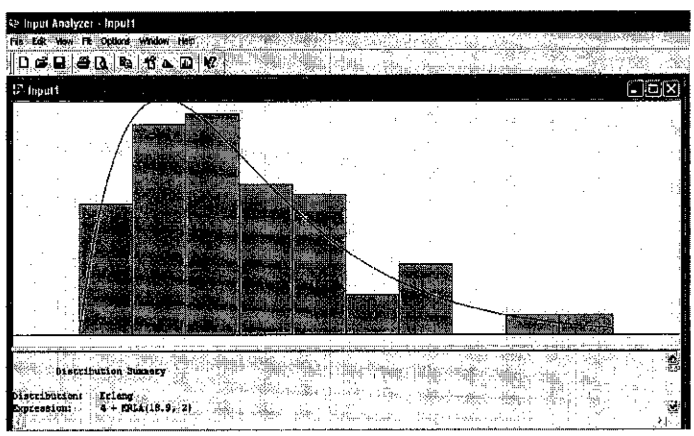


Figure 3.5 Erlang distribution with K= 3

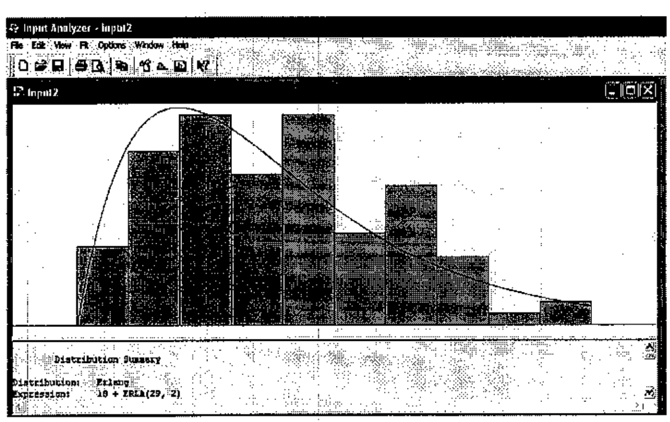


Figure 3.6 Erlang distribution with K= 5

3.9 Summary of CU-Line Assembly Data

All times are in centiminutes (cm) : 1minute = 100cm

The time in centi minute will be multiplied by 0.6 to get the time in actual seconds for the modeling.

1. Production Planning schedule : 930 units per shift
2. Number of pallet : 100 units
3. Shift element :

Working Time	**Rest Time**
8.00-10.00 am	10.00-10.10 pm
10.10-12.20 pm	12.20-1.00pm
1.00-3.00 pm	3.00-3.10 pm
3.10-5.20 pm	5.20-6.00 pm

Table 3.7 Detail of stations:

Station	Cycle Time (cm)	Conveyor length	Part Supply (unit/min)
H1	61.48	4	Base 100/65, Aguider 72/47
H2	40.471	4	Bulkhead 108/70,Basewheel 85/55
H3	34.24	4	
H4	51.98	4	Motor 72/47
H5	44.93	4	Bracket 250/162
H6	53.66	4	
H7	28.36	4	
H8	9.26	-	Comp 30/20
H9	19.61	-	
H10	36.62	7	

H11	40.80	4	Aguider 100/65
H12	43.65	4	Condenser 48/31
H13	54.71	4	
H14	45.35	4	Fan 160/104
H15	38.01	4	
H16	42.21	4	
H17	34.74	4	
H18	47.33	12	Evaporator 55/36
H19	28.34	3	
H20	46.65	3	
H21	42.25	3	
H22	39.961	3	
H23	37.71	3	
H24	38.34	3	
H25	53.17	3	
H26	41.89	3	
H27	43.43	3	
H28 & H29	44.85	4	
H30	32.98	4	
H31	44.09	4	
H32	34.81	4	
H33	58.59	2	Board 100/54
H34	58.32	2	
H35	56.02	2	
H36	50.36	2	
H37	43.71	2	
H38	38.53	2	
H39	48.97	2	
H40	35.74	2	
H41	47.77	2	
H42	39.72	2	
H43	37.61	2	
H44	45.00	2	Guider Base wheel 96/45
H45	46.05	2	
H46	35.72	2	
H47	66.10	3	
H48	40.66	3	
H49	31.26	3	
H50	28.31	3	Cabinet 60/40
H51	34.30	3	

H52	14.26	3	
H53	50.91	3	
H54	36.10	3	
H55	36.41	3	
H56	24.05	3	
H57	30.32	2	
H58	43.60	2	Board 60/40
H59	24.39	2	Bag 540/400
H60	36.31	2	Case 100/70
H61	20.54	2	Abs 100/70

4. Set up time : 5cm per set
5. Breakdowns:

   Time between failures: user distribution

Period (min)	**Frequency**
500-1000	1
1000-1500	3
1500-2000	8
2000-2500	6
2500-3500	2

6. Repair time : Erlang (15.24,3)
7. Rejection Rate : 12%

CHAPTER 4

THE MANUFACTURING SYSTEM MODEL ON ARENA

4.1 Block Diagram of the process

The concept of improving the manufacturing process is very much similar to a control process loop. Theoretical projection can never be carried out practically because of the disturbance that exists in plants. The Arena simulation can model these disturbances and the effects on the production of the air conditioners could be observed.

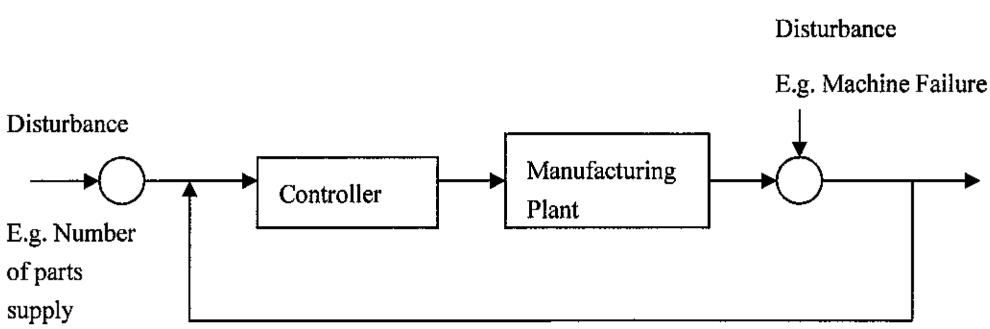


Figure 4.1 Block Diagram of the Process

The disturbances are anything that effects the production. In this simulation, the disturbances are part supply rate. The increase and decrease of parts coming into the plant will determine the output. Too many parts coming in will result in bottleneck situations and vice versa.

Also, disturbances are in the form of machine failure. For this simulation, only one machine is used in the process. So the failure of the machine has been included in the simulation and contributed to lower output of production.

4.2 Arena Model

The model consists of several types of the element. First, there are 61 stations (H1 to H61 modeled in this project. The entities are represented by the modules in the basic process template. The conveyor is depicted using the non accumulating conveyor function in the software. The entities or parts are the Control Board, A/G Blower Wheel, Cabinet, C.C Case etc. In the conveyor module, the set up time, the speed and the length is determined. The sub-models are used to depict each of the stations so it will save space in the main window.

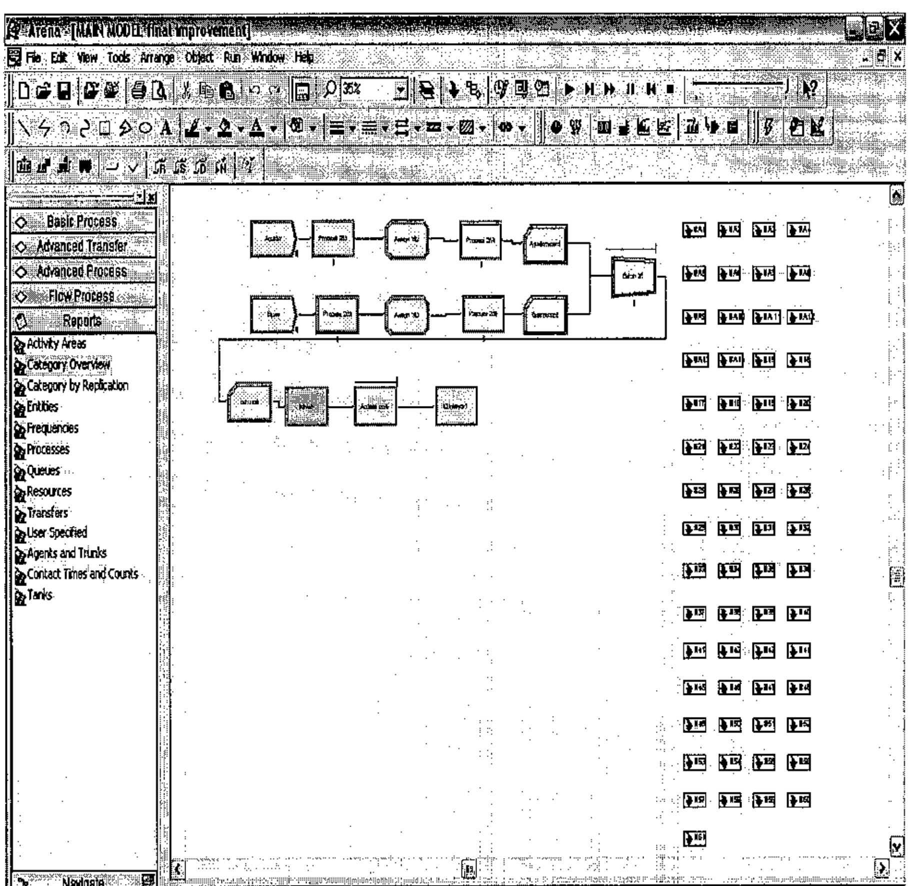
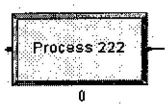
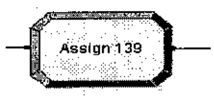
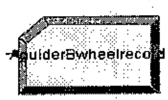
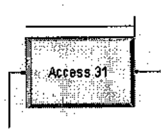


Figure 4.2 Model of Simulation

Table 4.1 Table showing the modules used in Arena Simulation

The model is built using modules below:

Module	Function
	Create entity or in the simulation, creates the parts arriving at each station
	Process the parts and represent machines or manpower at each station
	Assign a part to each manpower or machine
	Record the number of parts processed by each station
	Access the conveyor for each segment
	Stations of the conveyors. Will determine starting and ending point of each conveyor segment

The animation of the manufacturing system is done using stations module and segment module. The pictures are from the clip art and then modified to depict each station states such as IDLE, BUSY AND FAILED. While the model is running the stations changing following the states could be seen.

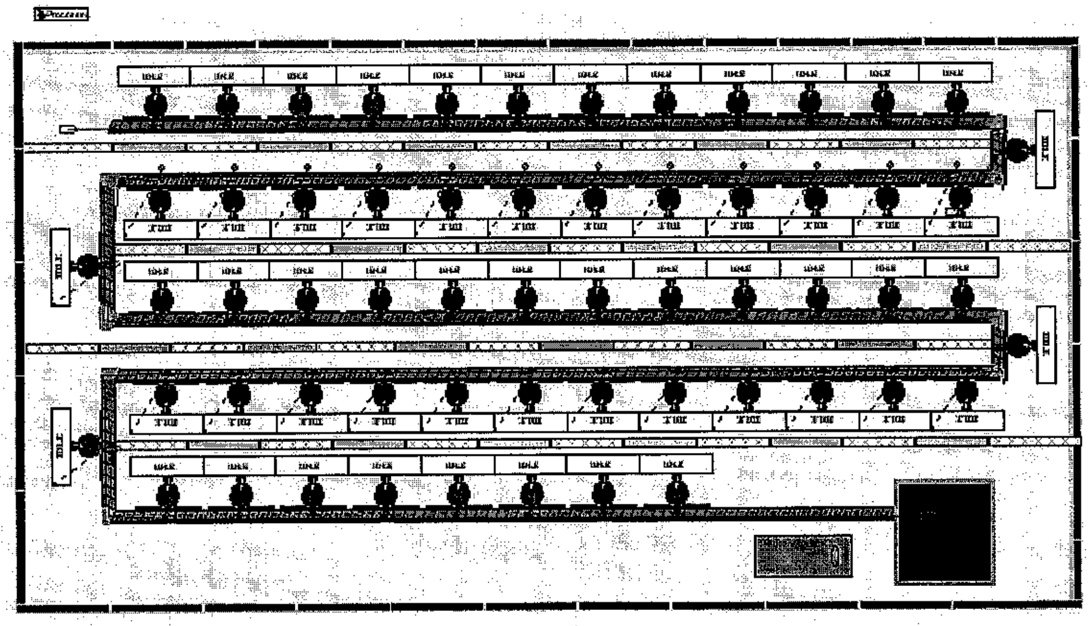


Figure 4.3 Animation of the Simulation

4.3 Fitting Input Distributions via the Input Analyzer

If an input data consisting of a probability distribution is available, we can use the Input Analyzer can be used to provide numerical estimates of the appropriate parameters or a number of distributions to the data can be fitted and the most appropriate one can be selected.

The mean of the distribution is calculated in the table below. Since it has been necessary to calculate the mean using the mid-point in each range, it is only an estimate. For now, using the Erlang Distribution, the parameters K of 1, 3, and 5 is used. This was done using the Input Analyzer in the Arena software.

Table 4.2 Mean Average Time of Repair Data

Mean Repair Time (min)	Frequency	Mean Repair Time x Frequency
3.0	10	30
9.0	37	333
15.0	23	345
21.0	14	294
27.0	7	189
33.0	5	165
39.0	2	78
45.0	2	90
51.0	0	0
Total Mean Average		15.24

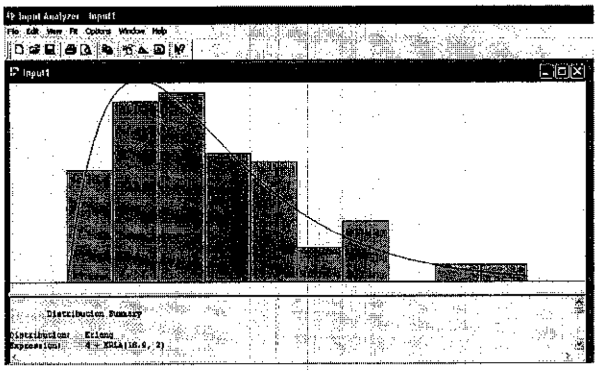


Figure 4.4 Erlang distribution with K= 3

4.4 VBA Automation

Using Visual Basic for Applications in Arena, Graphic User Interface can be developed to serve a variety of purpose, As shown in figure 4.5, the supply of the parts are incremented in runtime by just typing the number and clicking on the add pallet button. This function can simplify the process of analyzing a certain model.

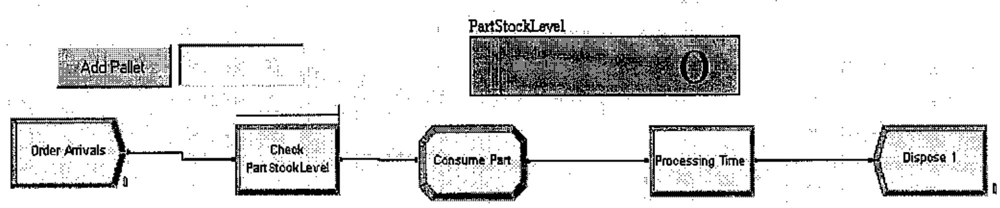


Figure 4.5 Visual Basic Program for Add Part

VBA was also used to start and stop the simulation. The programs develop will just output a simple window to indicated that the simulation run has been just started, or stopped. These simple functions will be a security function to avoid sudden termination of a simulation.

Figure 4.6 Visual Basic Program for Start/Stop Simulation

For the final simulation, a new Visual Basic program was built. This time the user of the program can use the interactive menu at start of simulation to input the parts arrival time. All the parts arrival time can be varied at the same time without having to edit the model at every step. This can save a lot of time when we have an improvement process going on and time is limited

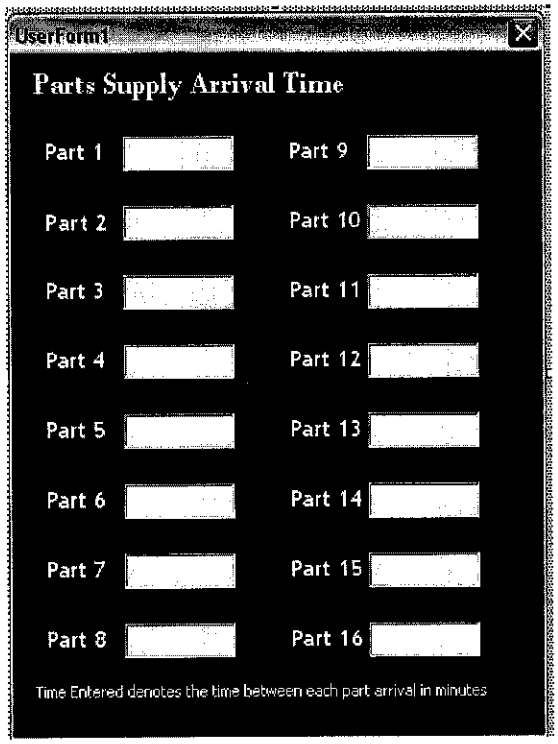


Figure 4.7 Visual Basic Menus at Start of Simulation

The program for the Visual Basic is shown in the appendix:

4.5 Crystal Reports

The crystal reports in arena consist of many areas of data collection. One of the main usages of arena software is to collect simulation data of a particular project. For this case study, the crystal reports vary from Queue time and queue number, Manpower utilization, number of products processed by every station, number of parts arriving at every station. Shown in Figure 4.8 and Figure 4.9 are the crystal report that is useful in the improvements of the production.

7:04:24PM **Category Overview** April 22, 2007

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch 20.Queue	0.00279817	(Correlated)	0.00	0.00974799
Batch 21.Queue	0.00257314	0.000063776	0.00	0.00990067
Batch 22.Queue	0.00258872	(Correlated)	0.00	0.01042067
Batch 23.Queue	0.00284420	(Correlated)	0.00	0.01040131
Batch 24.Queue	0.00267802	0.000114146	0.00	0.01112391
Batch 25.Queue	0.00277129	0.000502447	0.00	0.01083954
Batch 26.Queue	0.00258076	(Correlated)	0.00	0.00982902
Batch 27.Queue	0.00234909	(Correlated)	0.00	0.00880083
Batch 28.Queue	0.00331042	0.000031709	0.00	0.02257537
Batch 29.Queue	0.00307418	0.000238080	0.00	0.01117896
Batch 30.Queue	0.00313208	0.000277130	0.00	0.01264307
Batch 31.Queue	0.00260245	0.000076406	0.00	0.00902366
Batch 32.Queue	0.00203711	0.000024940	0.00	0.00692536
Batch 33.Queue	0.00194363	(Correlated)	0.00	0.00757405
Batch 34.Queue	0.00182932	(Correlated)	0.00	0.00710482
Batch 35.Queue	0.00180049	(Correlated)	0.00	0.00715893
Batch 36.Queue	0.00259621	(Correlated)	0.00	0.01086562
H1.Queue	0.00	0.000000000	0.00	0.00
H15.Queue	0.00	0.000000000	0.00	0.00
H16.Queue	0.00	0.000000000	0.00	0.00
H17.Queue	0.00	0.000000000	0.00	0.00

Figure 4.8 Waiting Time Crystal Report

7:04:24PM **Category Overview** April 22, 2007

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
BendingMachine	0.6553	(Correlated)	0.00	1.0000
H15man	0.6743	0.003987120	0.00	1.0000
H16man	0.7483	(Correlated)	0.00	1.0000
H17man	0.6155	(Correlated)	0.00	1.0000
H19man	0.3547	(Correlated)	0.00	1.0000
H20man	0.5831	(Correlated)	0.00	1.0000
H21man	0.5276	0.072943881	0.00	1.0000
H22man	0.4988	0.069535432	0.00	1.0000
H23man	0.4702	0.066170742	0.00	1.0000
H24man	0.4776	0.067019061	0.00	1.0000
H25man	0.6620	0.091721247	0.00	1.0000
H26man	0.5186	0.072662145	0.00	1.0000
H27man	0.5397	0.076141306	0.00	1.0000
H28man	0.5569	0.078306148	0.00	1.0000
H30man	0.4094	0.057251872	0.00	1.0000
H31man	0.5467	0.076997704	0.00	1.0000
H32man	0.4315	0.060928512	0.00	1.0000
H33man	0.8063	(Correlated)	0.00	1.0000
H34man	0.8019	(Correlated)	0.00	1.0000
H35man	0.7695	(Correlated)	0.00	1.0000
H36man	0.6909	(Correlated)	0.00	1.0000
H37man	0.5992	(Correlated)	0.00	1.0000
H38man	0.5279	(Correlated)	0.00	1.0000
H39man	0.6701	(Correlated)	0.00	1.0000
H40man	0.4886	(Correlated)	0.00	1.0000

Figure 4.9 Manpower Utilization Crystal Report

CHAPTER 5

RESULTS AND DISCUSSION

From the simulation, the output of production is 751 units. This is quite far from the objective that is 930 units. The conveyor speed was set at 55 cm per minute. This shows that the production is not meeting its specified output rate.

From Figure 5.1 below is shown the number of parts waiting at the production stations. Stations 18, 33 and 44 have the most number of parts waiting or in other terms bottleneck are occurring. This line jam can affect the rate of production. Thus line balancing has to be carried out to smoother the production.

Number Waiting	Average
Access 22.Queue	0.01355391
Access 23.Queue	0.00
Access 24.Queue	0.01451763
Access 25.Queue	0.01241461
Access 26.Queue	0.00000164
Access 27.Queue	0.01375681
Access 28.Queue	0.01339268
Access 29.Queue	60.4942
Access 30.Queue	13.3195
Access 31.Queue	106.99
Access 32.Queue	0.01001308
Access 33.Queue	0.00004035
Access 34.Queue	0.00000101
Access 35.Queue	0.00
Access 36.Queue	0.00
Access conv.Queue	0.00000073

Figure 5.1 Before the Line Balancing

Number Waiting	Average
Access 22.Queue	0.01433104
Access 23.Queue	0.00
Access 24.Queue	0.01291618
Access 25.Queue	0.03722789
Access 26.Queue	0.00000118
Access 27.Queue	0.01595790
Access 28.Queue	0.01282692
Access 29.Queue	3.0279
Access 30.Queue	0.1939
Access 31.Queue	0.00804895
Access 32.Queue	0.01487290
Access 33.Queue	0.0948
Access 34.Queue	0.00000229
Access 35.Queue	0.00000162
Access 36.Queue	0.00000069
Accessconv.Queue	0.00000067

Figure 5.2 After line balancing exercise

After line balancing exercise was conducted, the parts waiting has been reduced in numbers to be less than 10 parts waiting at every station. This is an example of a smooth production.

Improvements were made in terms of regulating the parts supply. There are 16 parts coming into the whole production. A variable increase and decrease in parts arrival rate was implemented.

Table 5.1 Inter Arrival Rate of Parts

Station	Part Arrival	Improved Part Arrival	Percentage Difference
H1	0.65 , 0.653	0.65 , 0.653	0
H2	0.648 , 0.647	0.5832 , 0.5823	+10% , +10%
H4	0.6528	0.6202	+5%
H5	0.648	0.6156	+5%
H8	0.667	0.667	0
H11	0.65	0.65	0
H12	0.6458	0.5812	+10%
H14	0.65	0.52	+20%
H18	0.65	1.36	-110%
H33	0.54	0.66	-22%
H44	0.4688	0.75	-60%
H50	0.667	0.5336	+20%
H58	0.667	0.4002	+40%
H59	0.7407	0.444	+60%
H60	0.7	0.42	+60%
H61	0.7	0.42	+60%

(Positive percentage means increased part arrival rate and vice versa.)

The throughput after increased part supply increased from 751 units to 1215 units. This shows that there is a significant increase in the production rate. Before the increase of the parts supply, the 61 stations do not show 100% productivity. The station, being humans might have only about 70 % utilization rate. But now, the average utilization rate is shown in Table 5.2.

Table 5.2 Utilization Rate of Manpower

Station (Manpower)	Utilization	Utilization (After Improvement)
H1	0.64	0.6369
H2	0.62	0.6573
H3	0.53	0.5570
H4	0.62	0.6543
H5	0.80	0.8417
H6	0.82	0.8683
H7	0.43	0.4583
H8	0.44	0.4557
H9	0.45	0.4608
H10	0.55	0.5964
H11	0.62	0.6305
H12	0.75	0.7941
H13	0.84	0.8921
H14	0.70	0.8052
H15	0.58	0.6743
H16	0.65	0.7483
H17	0.53	0.6155
H18	0.68	0.6553
H19	0.37	0.3547
H20	0.61	0.5831
H21	0.55	0.5276
H22	0.52	0.4988
H23	0.49	0.4702
H24	0.50	0.4776
H25	0.69	0.6620
H26	0.54	0.5186
H27	0.56	0.5397
H28	0.58	0.5569
H30	0.42	0.4094
H31	0.57	0.5467
H32	0.45	0.4315
H33	0.91	0.8063
H34	0.91	0.8019
H35	0.87	0.7695
H36	0.78	0.6909
H37	0.68	0.5992
H38	0.60	0.5279
H39	0.76	0.6701
H40	0.55	0.4886
H41	0.74	0.6627
H42	0.61	0.5422
H43	0.58	0.5129
H44	0.65	0.6065
H45	0.67	0.6201
H46	0.54	0.5064
H47	0.95	0.8888
H48	0.58	0.5462
H49	0.45	0.4195
H50	0.42	0.4552
H51	0.50	0.5511
H52	0.21	0.2289
H53	0.75	0.8168
H54	0.53	0.5787
H55	0.53	0.5832

H56	0.35	0.3850
H57	0.44	0.4851
H58	0.65	0.8930
H59	0.34	0.5240
H60	0.52	0.8220
H61	0.29	0.4769
Throughput	744	1208

Note: 1.0 represents 100% utilization of manpower

The manpower utilization has increased slightly. From Table 5.2 we can see that some stations have higher utilization than others. For a more detailed improvement, manpower can be added at these stations to improve the productivity and reduce downtime resulting from manpower fatigue.

The increase of the production is really high but cannot be increased further because it means that the part is coming in at a very fast rate and it will take up more workspace at each station. We want only a minimal increase to meet the objective without unnecessarily spend money on expanding the floor.

From the simulation, it can be seen that we have a bottleneck in some parts of the parts supply. By observing the crystal report at the parts waiting time, the station that has the most parts waiting can be determined for line balancing.

The parts supply for these three stations have to be slowed down and the increase must not be more than 40%. Increment of parts supply more than 40% will be over the budget for the factory operations. So the simulation is done now with only 40% of increase and lower increment for the bottleneck stations

The number of parts waiting at the supply is dramatically reduced. Number of throughput is 1215 units which are very high and we can lower it down to get a clean operation without waiting parts at any station.

The model allows several "what if" scenarios to be simulated. For example the manufacturing system was improved by increasing and decreasing the parts supply arrival time of the 16 parts arrival. The conveyor speed is increased from 45 to 55 cm. Output is increased by 62%.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

The simulation has showed that the production throughput can be increased without additional cost. Through method of line balancing, the production was increased from 751 units to 1215 units which is a total average increase of 62%.

In this simulation the 61 stations are modeled and the arrival times of different parts are decreased and increased to achieve a smooth production without an excessive number of parts waiting. The number of parts waiting is limited to below ten parts per station. The conveyor belt speed is increased from 55 cm per minute from 45 cm per minute.

The bottlenecks or line jams are identified at station 18, 33 and 44. The improvements made have incurred zero cost of addition of manpower or machines. This is very favourable to the company. The manpower utilization is also increased just slightly. From the simulation, line jams or gaps can be determined as well as the cause of it. The simulation process takes less time than improvements done manually by observation or hand calculation.

For future development or expansion, a solution is to rearrange the layout of the production floor. Maybe a parallel production flow would increase more throughputs. The production floor can be made into two floor, ground floor and upper floor using suspended conveyor. From the simulation data, the stations which have more than a 70% utilization rate can be added with extra manpower to redistribute the work accordingly.

The model has to be constantly run and the results in the crystal report should be taken into account. Further improvements of the simulation also include reporting the numbers of utilization in the form of Microsoft Excel sheet. The advantage is that the data is then mobile no need of the Arena Software to view the data. This can be done using Visual Basic for Applications found in Arena. For formal presentation, Microsoft Power Point slide has been integrated in the model simulation and can be enhanced with sounds and visual effects.

As a conclusion, the objective of this project to improve throughput of the production has been achieved. The project has also shown that Arena can be used to improve a plant's performance and implement changes without compromising current operation and extra cost. The key to improvement is to recognize problematic areas to apply line balancing techniques. Computer simulation has improved time and production rate.

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APPENDIX

Visual Basic Program for Menu at Start of Simulation

```
Private Sub CommandButton1_Click()

Dim m As Model
Dim theMod1 As Module
Dim theMod2 As Module
Dim theMod3 As Module
Dim theMod4 As Module
Dim theMod5 As Module
Dim theMod6 As Module
Dim theMod7 As Module
Dim theMod8 As Module
Dim theMod9 As Module
Dim theMod10 As Module
Dim theMod11 As Module
Dim theMod12 As Module
Dim theMod13 As Module
Dim theMod14 As Module
Dim theMod15 As Module
Dim theMod16 As Module
Dim theMod17 As Module
Dim theMod18 As Module

Dim a As Long
Dim b As Long
Dim c As Long
Dim d As Long
Dim e As Long
Dim f As Long
Dim g As Long
Dim h As Long
Dim i As Long
Dim j As Long
Dim k As Long
Dim l As Long
Dim n As Long
Dim o As Long
Dim p As Long
Dim q As Long
Dim r As Long
Dim s As Long
```

```
Set m = ThisDocument.Model
'.......................................................................................
a = m.Modules.Find(smFindTag, "Process1")
Set theMod1 = m.Modules(a)

theMod1.Data("Value") = TextBox1.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
b = m.Modules.Find(smFindTag, "Process2")
Set theMod2 = m.Modules(b)
theMod2.Data("Value") = TextBox4.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
c = m.Modules.Find(smFindTag, "Process3")
Set theMod3 = m.Modules(c)
theMod3.Data("Value") = TextBox2.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
d = m.Modules.Find(smFindTag, "Process4")
Set theMod4 = m.Modules(d)
theMod4.Data("Value") = TextBox5.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
e = m.Modules.Find(smFindTag, "Process5")
Set theMod5 = m.Modules(e)
theMod5.Data("Value") = TextBox6.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
f = m.Modules.Find(smFindTag, "Process6")
Set theMod6 = m.Modules(f)
theMod6.Data("Value") = TextBox7.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
g = m.Modules.Find(smFindTag, "Process7")
Set theMod7 = m.Modules(g)
theMod7.Data("Value") = TextBox7.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
h = m.Modules.Find(smFindTag, "Process8")
Set theMod8 = m.Modules(h)
theMod8.Data("Value") = TextBox9.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
i = m.Modules.Find(smFindTag, "Process9")
Set theMod9 = m.Modules(i)
theMod9.Data("Value") = TextBox9.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
j = m.Modules.Find(smFindTag, "Process10")
```

```
Set theMod10 = m.Modules(j)
theMod10.Data("Value") = TextBox10.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
k = m.Modules.Find(smFindTag, "Process11")
Set theMod11 = m.Modules(k)
theMod11.Data("Value") = TextBox11.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
l = m.Modules.Find(smFindTag, "Process12")
Set theMod12 = m.Modules(l)
theMod12.Data("Value") = TextBox12.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
n = m.Modules.Find(smFindTag, "Process13")
Set theMod13 = m.Modules(n)
theMod13.Data("Value") = TextBox13.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
o = m.Modules.Find(smFindTag, "Process14")
Set theMod14 = m.Modules(o)
theMod14.Data("Value") = TextBox14.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
p = m.Modules.Find(smFindTag, "Process15")
Set theMod15 = m.Modules(p)
theMod15.Data("Value") = TextBox15.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
q = m.Modules.Find(smFindTag, "Process16")
Set theMod16 = m.Modules(q)
theMod16.Data("Value") = TextBox16.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
r = m.Modules.Find(smFindTag, "Process17")
Set theMod17 = m.Modules(r)
theMod17.Data("Value") = TextBox17.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
s = m.Modules.Find(smFindTag, "Process18")
Set theMod18 = m.Modules(s)
theMod18.Data("Value") = TextBox19.value 'takes the value stored in the textbox, "TextBox1" and,
'through automation, places it into the module operand named "Value".
Me.Hide 'to hide the userform after click ok
End Sub
Private Sub TextBox1_Change()
theMod1.Data("Value") = TextBox1.value
End Sub
```