

A SIMULATION MODEL FOR FACTORY PRODUCTIVITY MONITORING

CASE STUDY: BRITISH AMERICAN TOBACCO (UGANDA)

By

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DECLARATION

I, David Luleti, hereby declare that this project is my own original work and has to the best of my knowledge never been submitted to any institution of higher learning for any academic award.


Signed.....*DL*.....

Date.....*21/08/2009*.....

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APPROVAL

This project report titled “A Simulation Model For Factory Productivity Monitoring “has been brought to completion under the supervision of the undersigned and is ready to be submitted to the board of examiners.

Sign  Date 21/08/05

KAMUKAMA ISMAIL
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DEDICATION

I dedicate this research to my wife Rehema for her love and care to me and her special concern about my studies through out the time I spent at university.

My dedication also goes to my work mates, Nassimbwa Hamida who ensured that an internet connection was always available to my office which enabled me to carry out part of my research with ease and to Marcel Katabaks for his encouragement and for standing in for me when it was necessary to leave office for studies.

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TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENTS	v
ABSTRACT	vii
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background of the study	1
1.2 Case study description	2
1.3 Problem Statement	2
1.4 Project Objectives	3
1.4.1 General Objective	3
1.4.2 Specific Objectives	3
1.5 Justification of the study	3
1.6 Project scope	3
CHAPTER TWO	4
LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Simulation Models	4
2.3 Applications of Simulation Models	4
2.4 Characteristics of simulation models	5
2.5 Model types and their comparisons	6
2.6 Classification of Simulation Models	6
2.7 Discrete Event Simulation Model	7
2.8 Productivity	8
2.9 Productivity monitoring	8
2.10 Conclusion	9
CHAPTER THREE	10
METHODOLOGY	10

3.1 Overview	10
3.2 System study	10
3.2.1 Reading	10
3.2.2 Interviews.....	10
3.2.3 Questionnaires	10
3.2.4 Observation.....	11
3.3 Analysis	11
Figure 1. Process map	12
3.4 Development of the Model.	13
3.4.1 Determining model requirements.	13
3.5 Testing and validation.....	13
CHAPTER FOUR.....	14
SYSTEM DESIGN AND IMPLEMENTATION.....	14
4.1 Model Design.....	14
Table 2. Production resources, their types and unit of measure.	14
The simulation process	14
4.2 Implementation	20
CHAPTER FIVE	21
FINDINGS, CONCLUSIONS AND RECOMMENDATIONS	21
5.1 Discussion	21
5.2 Conclusion	21
5.3 Recommendations.....	21
REFERENCES.....	22
APPENDICES	23
APPENDIX A	23
Questionnaire	23
APPENDIX B	25
Sample System Codes.....	25

ABSTRACT

This project is about a productivity simulation system for a factory. It is a real time system, which has been designed to monitor productivity by capturing information on all the resources that are used in producing a unit quantity of a product. The resources in this project are people, water, furnace oil and electricity. The value of these resources for a specific period of time is divided by the quantity of product processed or produced in the same period to evaluate the unit cost of production in that period and hence the productivity of the factory can be monitored on an hourly basis. The simulation model is thus made to be an integral process in a processing factory rather than a system that checks performance after a process is complete.

The system therefore works well when there is a system in place that captures all the resources that go into the manufacturing process accurately and on a regular basis.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Computer simulation was developed hand-in-hand with the rapid growth of the computer, following its first large-scale deployment during the Manhattan Project in World War II to model the process of nuclear detonation[1].The Manhattan Project (1942-1946) was the codename for a project conducted during World War II to develop the first atomic bomb[2].Simulation was used to predict the behaviour of plutonium and estimate the extent of damage that a bomb would cause on detonation and this was important in determining the location where a bomb was to be detonated.

Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. Simulation is used in many contexts, including the modeling of natural systems or human systems in order to gain insight into their functioning.

In manufacturing, simulation is used to address issues like need for and the quantity of equipment and personnel. A fairly accurate estimation of the number and type of machines for a particular objective can be made. The number, type, and physical arrangement of transporters, conveyors, and other support equipment (e.g., pallets and fixtures), the location and size of inventory buffers can be established with a high degree of accuracy using simulation. Simulation is used in the evaluation of a change in product volume or mix and in the evaluation of the effect of a new piece of equipment on an existing manufacturing system and also in labour-requirements planning [3]. Simulation is also used in the analysis of throughput, production scheduling and bottle necks which are performance measures that are used in computing productivity of a factory [3].

Simulation models been widely used to improve and validate the designs of a wide range of manufacturing systems. They have been used in facility design, as well as enterprise-wide supply chain modeling. The typical manufacturing model is usually used either to predict system performance or to compare two or more system designs or scenarios. Facility design applications may involve modeling many different aspects of the production facility, including equipment selection/layout, control strategies, material

handling design, buffer sizing, dispatching/scheduling strategies, material management, etc [4].

Currently productivity in most factories is computed at the end of a shift or end of day as there is no model to simulate the changing parameters in the factory, thus prompt monitoring of productivity is difficult. Use of simulation modeling is thus a good process of monitoring productivity in a factory. In this project, simulation modeling is used to represent productivity in a factory amid changing resources and to display the actual productivity against the target productivity.

1.2 Case study description

The British American Tobacco Uganda factory where this research was carried out processes leaf tobacco and turns it out in a form that is ready for manufacturing of cigarettes. It is located on Plot 69/72, Jinja Road in Kampala and was constructed in 1952. The various processes in this factory require resources like water, steam, electricity, machinery and labour to turn out a finished product. The costs of these resources are later computed to analyze productivity against the volume of tobacco processed. The system is manual where the quantities of water, steam, electricity and furnace fuel are read from the meters. Computation of productivity is done once a week. This is not reliable because errors that may come up in the course of the week before computation is done cannot be detected and corrected.

1.3 Problem Statement

Most of the factories and other businesses lack customized software tools to efficiently monitor productivity. Current monitoring is done manually based on weekly computations. These take a lot of time, they are tedious and error prone. In addition some variables in the environment are dynamic, all rendering the methods unreliable. Manual methods have a weakness in that correction of unproductive processes is not detected quickly enough [5].

1.4 Project Objectives

1.4.1 General Objective

To enhance planning and decision making through reliable monitoring of factory productivity.

1.4.2 Specific Objectives

- (i) To carry out a study about the current monitoring methods used and identify inefficiencies.
- (ii) To analyze and identify the necessary variables used in monitoring productivity.
- (iii) To develop a model that evaluates the costs of production for efficient monitoring
- (iv) To test and validate the developed model

1.5 Justification of the study

Lack of a monitoring system for productivity delays decision making in improving on the use of resources and leads to wasteful processes taking long to be corrected.

A productivity simulation model monitors productivity and quickens decision making in the use of resources in a factory. This enables staff and management take corrective action early enough when resource utilization becomes uneconomical..

1.6 Project scope

The project focuses on the development of a model that accepts necessary data and simulates the data to observe relationships between variables in the operational environment. The model excludes security or data processing, storage and output of periodic reporting. The model developed is desktop able to run on Windows Xp operating system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter describes what simulation models are and the kind of problems they solve. It also describes the characteristics of simulation models, examples of existing modes, types, architecture and how they are built. Lastly the chapter looks at the advantages and disadvantages of simulation models and finally productivity monitoring and the tools used in its monitoring.

2.2 Simulation Models

A simulation model is a mathematical model that calculates the impact of uncertain inputs and decisions we make on outcomes that we care about, such as profit and loss, investment returns, environmental consequences, productivity and the like. Such a model can be created by writing code in a programming language, statements in a simulation modeling language, or formulas in a Microsoft Excel spreadsheet [6]. A simulation model may also be called a computer model or a computational model and is further described as a computer program, or network of computers, that attempts to simulate an abstract model of a particular system [6].

Regardless of how it is expressed, a simulation model will include inputs, intermediate calculations as required and outputs. The inputs are uncertain numbers, called uncertain variables. The outputs depend on the inputs and are called uncertain functions.

2.3 Applications of Simulation Models

In a manufacturing environment a simulation model allows a manager or engineer to obtain a system wide view of the effect of local changes to the manufacturing system [6]. If a change is made at a particular work station, its impact on the performance of this station may be predictable. On the other hand it may be difficult to determine ahead of time the impact of this change on the performance of the overall system. Here is an example of a scenario that can be foreseen by simulation modeling. Suppose that a work station with one machine has insufficient capacity to handle its work load.(processing rate being less than arrival rate of parts). Suppose that it has been determined that adding a second machine will alleviate the capacity shortage at this station. However the

additional machine will also increase the throughput of parts from this station. This increased throughput will in turn show up as increased arrival rates to downstream work stations which may cause new capacity shortages to occur. A simulation model will solve this problem by simulating the behaviour of the entire process.

There are other benefits from using simulation models for manufacturing analyses. These include increased throughput. Throughput means parts produced per unit of time. Use of simulation models also leads to decreased times in system of parts, increased utilizations of machines or workers, increased on-time deliveries of products to customers and reduced capital requirements or operating expenses. Information gathered to build the simulation model will promote a greater understanding of the system which often produces other benefits.

2.4 Characteristics of simulation models

Flexibility: A simulation model offers a flexible approach. Once a model is developed with a reasonably flexible structure it can be modified to include new features. Frequently only in put data need be changed for the same model to be able to evaluate alternatives; remodelling a system using analytical approach would take a much longer period [7].

Study of transient behaviour: Most systems are very complex and since analytical models can only be created using simplifying assumptions often they can at best predict only steady state situations. In reality however, a manufacturing process involves various parts being continuously released into the system at short regular intervals. In such a situation it is sometimes necessary to analyze the transient behaviour of the system. Computer simulation in many cases is the only viable tool to perform this task.

Communication. One of the advantages of computer simulation is the ability to animate the process under investigation.. Animation results in benefits for the model builder. Beneficial communication between the model builder and the model user and benefits in presentation to users and managers . Because of the increased ease of communication that animation allows the model user can be actively involved with the simulation throughout the model development cycle. This leads to significant improvements in the model and in the benefits the user derives from it. A graphics display can give a very good idea

of the logical behaviour of the simulated process. The programmer therefore benefits by being by being able to follow the logical consequences of state changes in the system. Well designed graphics can aid effective experimentation with the model for it is easy to sport whether a particular experiment is fruitful by watching a dynamic graphics display..

2.5 Model types and their comparisons

The table below summarizes the types of models used and how they compare.

	Model types			
	descriptive	physical	analytical	procedural
Method of prediction	judgement	manipulation	mathematical	simulation
Method of optimization	-----	experiment	mathematical	experiment
Cost	low	high	medium	high
Ease of communication	poor	good	poor	excellent
limitation	Not repeatable	Cannot represent information process	Only able to cope with simplified cases	Optimal solution not guaranteed

Table 1: Simulation Model types and their comparisons (Adapted from [8])

2.6 Classification of Simulation Models

Any type of simulation model may further be classified as one of the three classes depending on the nature of variables under observation. The first class is the Static vs Dynamic Simulation Model. A static simulation model is a representation of a system at a particular time, or one that may be used to represent a system in which time simply plays no role; a typical example being a Monte Carlo model. A dynamic simulation model represents a system as it evolves over time, such as a conveyor system in a factory. The second class is the Deterministic vs. Stochastic Simulation Model. If a simulation model

does not contain any probabilistic (i.e. random) components, it is called deterministic; an example being a complicated system of differential equations describing a chemical reaction. In deterministic models the output is determined once the set of input quantities and relationships in the model have been specified, even though it might take a lot of computer time to evaluate what it is. Systems modelled as having at least some random input components give rise to stochastic simulation models. Most queuing and inventory systems are modelled stochastically. The output of these models is only an estimate of the true characteristics of the model. The third class is the Continuous vs. Discrete Simulation Model. Discrete event concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. A continuous event has variables that smoothly change without breaks in between i.e. in a smooth graphical manner. In this project the Discrete Event Simulation Model was used.

2.7 Discrete Event Simulation Model

The following components are found in most discrete event simulation models using the next event time advance approach programmed in a general purpose language [8].

- (i) System state: The collection of state variables necessary to describe the system at a particular time.
- (ii) Simulation clock: A variable giving the current value of simulated time.
- (iii) Event list: A list containing the next time when each type of event will occur.
- (iv) Initialization routine: A subprogram to initialize the simulation model at time 0.
- (v) Timing routine: A subprogram that determines the next event from the event list and then advances the simulation clock to the time when that event is to occur.
- (vi) Event routine: A subprogram that updates the system state when a particular type of event occurs, if there is one event routine for each event type.

(vii) Library routines: A set of subprograms used to generate random observations from probability distributions that were determined as part of the simulation model.

(viii) Report generator: A subprogram that computes estimates (from the statistical counters) of the desired measures of performance and produces a report when the simulation ends.

(ix) Main program: A subprogram that invokes the timing routine to determine the next event and then transfers control to the corresponding event routine to update the system state appropriately. The main program may also check for termination and invoke the report generator when the simulation is over.

2.8 Productivity

Productivity is defined in many ways. It is an output, yield or efficiency [1].

But broadly speaking productivity is a measure of the efficiency of production. The parameters used in measuring productivity are therefore volume or weight of manufactured product and value of resources that go into its manufacture. The resources are diverse, depending on the product but some of the mandatory ones are energy, machinery or manpower or both, and time. These resources cost money and the more of them go into a unit product, the more costly it becomes. The need to monitor resource input into a product, especially one that is dynamic, that is to say one with changing requirements, cannot be over emphasized.

2.9 Productivity monitoring

There are several methods of checking a factory's productivity [9].

The traditional method is to manufacture a specific amount of product in a known amount of time. Then one records the measurable resources used in its manufacture such as the man hours people have spent on the product and therefore the labour costs, the energy e.g. coal, electricity or gas, water and others. The value of these individual resources is evaluated and summed up. Productivity is then computed from these values using well defined formulae.

Some costs that go into manufacture of products can only be computed, or approximated but are not easily measured. An example is the tear and wear of machinery used in

manufacturing. Every time a machine is used in a manufacturing process there is an amount of depreciation it suffers and this depreciation is deemed as a cost in the manufacturing process. But there is no accurate method of measuring depreciation. It can best be computed using certain accounting formulae.

2.10 Conclusion

A modern approach is to monitor resource utilization online. [10] This involves metering most utilities like water, electricity, gas etc using digital meters. Digital meters, though more expensive than analogue ones have a comparative advantage of sending a signal that can be manipulated by a computer for various purposes, especially in a field of engineering called process control, using one of the industrial software like Simantic Step ver 7 for instance [10] . Once this data is captured on line it can be used in frequent computations of productivity to simulate a productivity monitoring model.

In this project the system to simulate productivity was designed based on data that is collected on an hourly basis.

CHAPTER THREE

METHODOLOGY

3.1 Overview

The methods used to understand the system were mainly through a study of existing literature, conducting interviews and using questionnaires. Observation of the processes was also done.

3.2 System study

3.2.1 Reading

Copies of the various documents like books, magazines and catalogues kept at the case study library were looked at. A list of these books can be found in appendix A. This revealed the previous and current methods of productivity computing and monitoring.

There also exists a database on process maps and work risk assessments, which details every process in the factory. This was also looked at in details. The advantage of this method was that it exposed previous stages of system development and the methods formally used in developing the system. The limitation of this method was that the authors of most of this literature could not be reached to answer some of the questions.

3.2.2 Interviews

Oral interviews were conducted with the system users. These were the factory operations manager, the factory mechanical engineer, the factory electrical engineer, the factory operatives, the data clerks and the cost accountant. This gave a clear understanding of the operation of the present system. The advantage of this method was that explanations of the system operation were made very clear. Its current inefficiencies were exposed and the improvements required were made explained. The disadvantage of this method was that some interviewees took a long time to find time to be interviewed because of their busy schedules.

3.2.3 Questionnaires

This method was used to get information from a large number of factory employees who did not have time for oral interviews because of their work schedules. The method had the advantage of getting a large number of people interviewed, including those who report for duty at odd hours. The disadvantage was that some interviewees were reluctant

to return the questionnaires while others wanted to take too long to return them.(see appendix B for questions).

3.2.4 Observation.

This method was used to know the physical lay out of the factory, the distances between the areas where various activities were carried out and the problems encountered by operatives in using the current system. The method made it easy to get interaction with the system users. Its limitation was the long time taken to make observations and some people required lengthy explanations of why the processes were being studied.

3.3 Analysis

From the system study the following inefficiencies were identified.

There was no duty roster for taking meter readings of utilities in the factory. Taking these readings was thus not regular and sometimes the readings were only estimated. This led to inaccurate computation of productivity.

The meter readings whose data is used in computing productivity are taken long after the process has ended. This renders the taking of corrective action not possible in case it is identified that one or more resource utilization is higher than expected. . Quantities of resources used were being recorded but their value in monetary terms was not. There was thus no immediate way of knowing the exact costs being spent on a specific resource in a specific period.

Use was made of process maps which show the sequence of operations and materials used in the factory. The process maps however, do not show the quantities of resources used at the various stages of the process.

Below is a process map showing different stages of processing and the resources required at each stage.

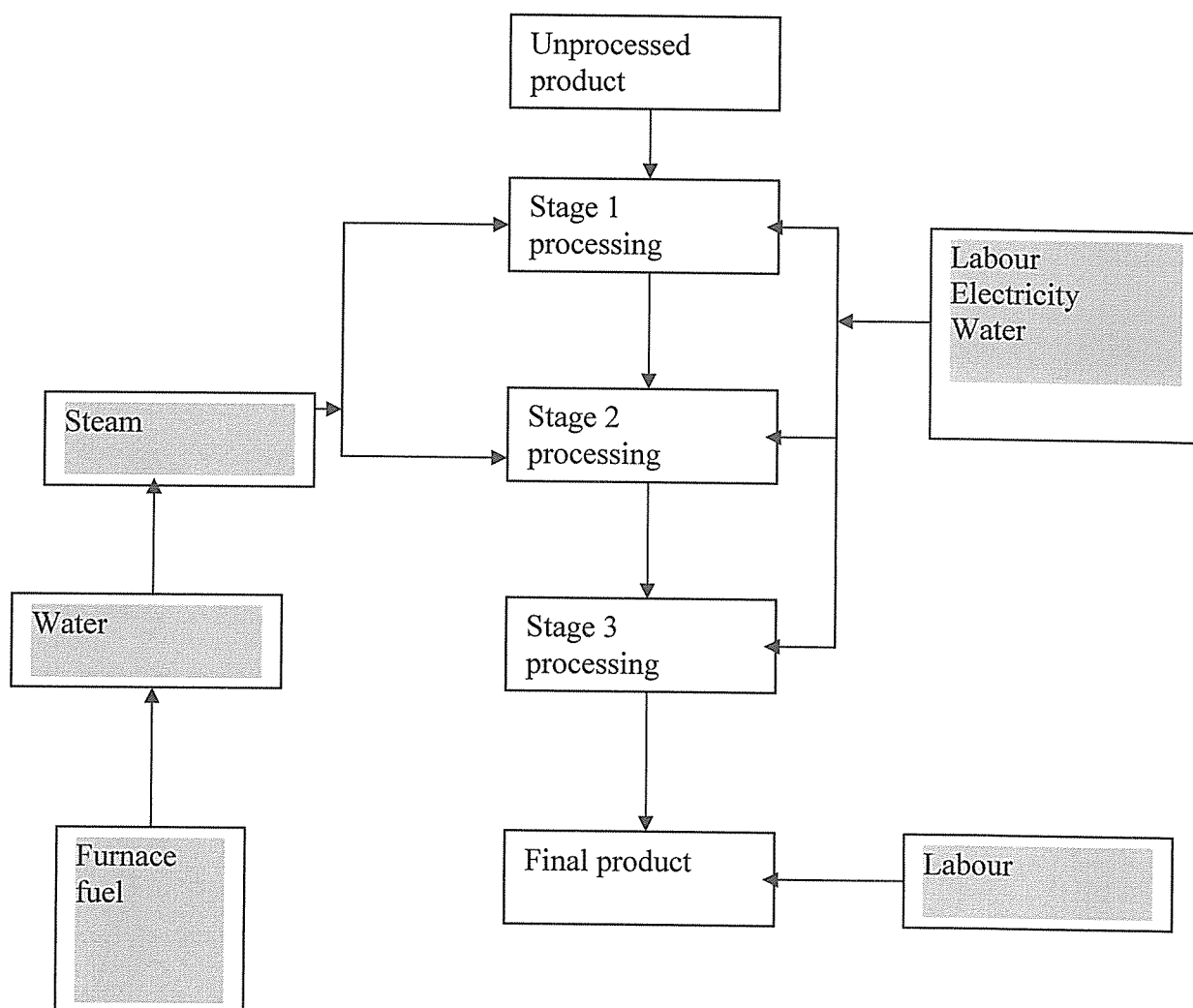


Figure 1. Process map

Explanation of the process map:

The rectangles represent the various stages the process flows from the raw material to the finished product. The shaded rectangles represent the resources that go into the processes to get out the finished product. These are the resources which the system monitors and computes their total value per unit of finished product to give productivity. In this case the product is tobacco and is given in Kilograms processed in a specific period, typically, one week. Productivity is calculated as cost of processing a Kilogram of tobacco.

From the above analysis, to overcome the problems mentioned, it was necessary to develop a model that simulates productivity.

3.4 Development of the Model.

3.4.1 Determining model requirements.

From system study and system analysis, it was concluded that a model to solve the problems had to have the following capabilities:

- (i) The model was required to have a conversion table turning quantities of resources utilized at various stages into costs.
- (ii) The model was required to compute productivity
- (iii) The model was required to compare the computed productivity against a set target.
- (iv) The model was required to simulate productivity when any one of the input parameters changed.
- (v) The model was required to display the results in a visual form.
- (vi) A computer with Microsoft Windows XP, 1.70 GHz, and 248 MB of RAM was needed.

The model was developed on the Monte Carlo Software platform. The Monte Carlo methods are a class of computational algorithms that rely on repeated random sampling to compute their results. Monte Carlo methods are often used when simulating physical and mathematical systems. Because of their reliance on repeated computation and random or pseudo-random numbers, Monte Carlo methods are most suited to calculation by a computer. Monte Carlo methods are used when it is unfeasible or impossible to compute an exact result with a deterministic algorithm [1]. The software was used to design a model that accepts input data which is the resource utilization and outputs productivity. This achieved the third objective.

3.5 Testing and validation.

Performance of the developed model was tested against design specifications. For the same data input, a comparison was made between the manual system output and the Simulation Model output. This achieved the last objective.

CHAPTER FOUR

SYSTEM DESIGN AND IMPLEMENTATION

4.1 Model Design

Information got from the data collection phase was used here to create a logical design of the simulation model.

Resources that make up production costs were arranged together as in example below.

Resource	Type	Unit of measure
People	Labour	Man hours
Tobacco	Raw material	Kilogram
Water	Utility	Litre
Furnace fuel	Utility	Litres
Electricity	Utility	Kilowatt hours
Steam	Utility	Cubic Centimeter

Table 2. Production resources, their types and unit of measure.

The simulation process

Productivity p is calculated as the total cost of production (c) in shillings divided by the weight (w) in Kilograms of product produced.

i.e. $p=c/w$ and is computed in Shillings per Kilogram

c and w are a set of variable inputs to give p .

To simulate all possible values of p for varying in puts of c and w the following steps are followed.

Step 1: Create a parametric model, $y = f(x_1, x_2, \dots, x_n)$.

Step 2: Generate a set of random inputs, x_1, x_2, \dots, x_n .

Step 3: Evaluate the model and store the results as y

Step 4: Repeat steps 2 and 3 for $i = 1$ to n .

Step 5: Analyze the results using histograms, summary statistics, confidence intervals, etc.

Step 1 Parametric model, $p = f(c,w)$

Hourly costs (c)

Resource	Unit cost (Shs)
Water(h)	2
Electricity (e)	300
Furnace fuel (f)	500
Labour (l)	1250
Total	

Parametrically $c=2h + 300e + 500f + 1250l$ where h, e, f, l are amounts of water, electricity, furnace fuel and labour costs used every hour.

$$p = (2h + 300e + 500f + 1250l)/w$$

Step 2 Set of random inputs. These are generated from table of resource usage as in table below

Minimum hourly usages are figures that are arrived at over a period of time while using the system. The maximum hourly usage is read from the meters by the user. Labour is the number of laborers The program is a desk top application so these figures are entered in an excel sheet

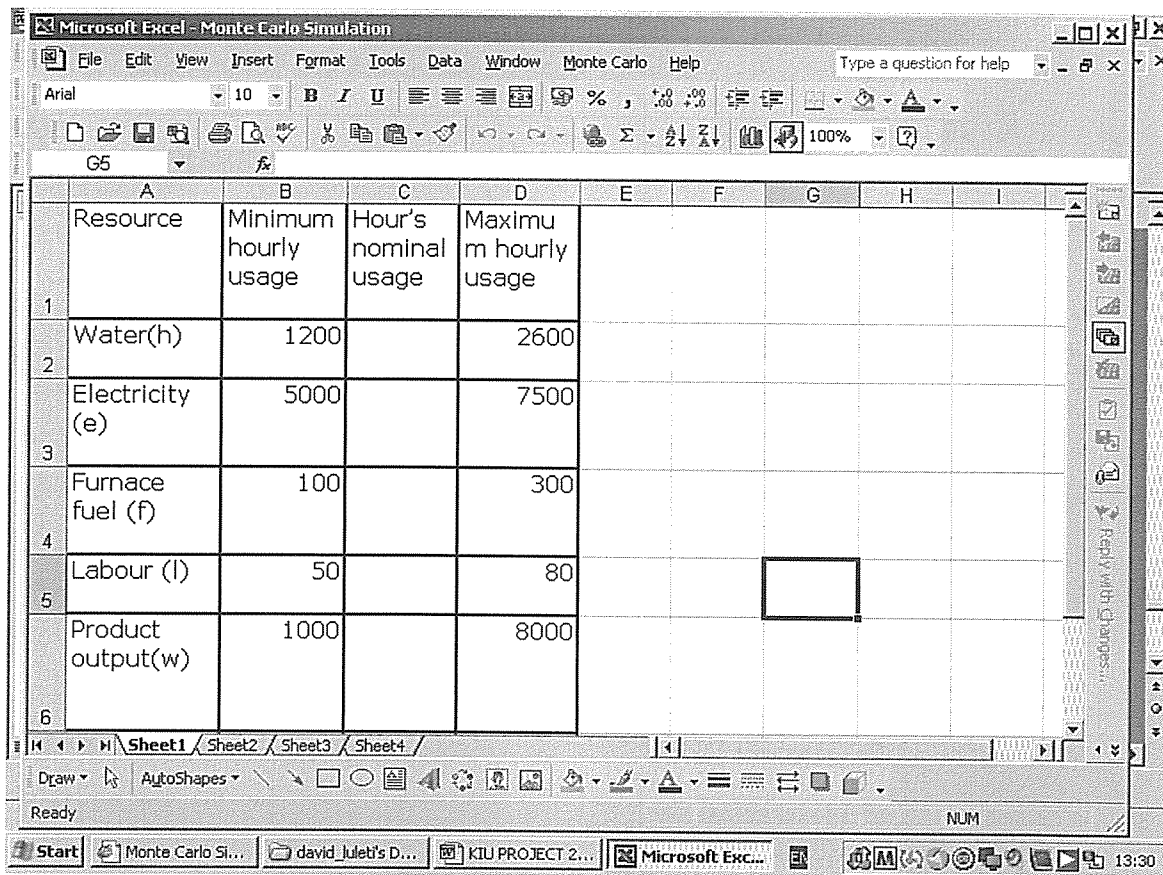
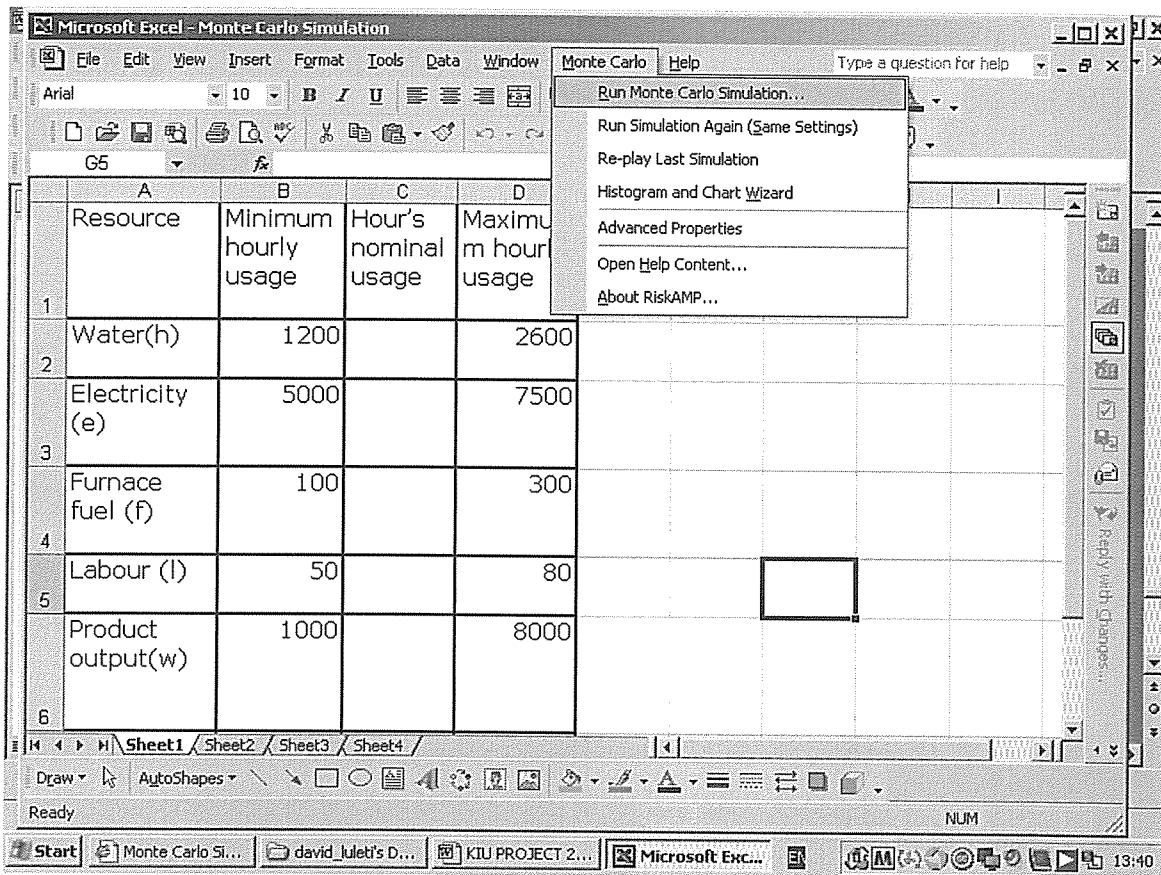


Figure 3. Entering resource utilization figures.

The Monte Carlo Simulator is then selected



Running the Monte Carlo Simulation

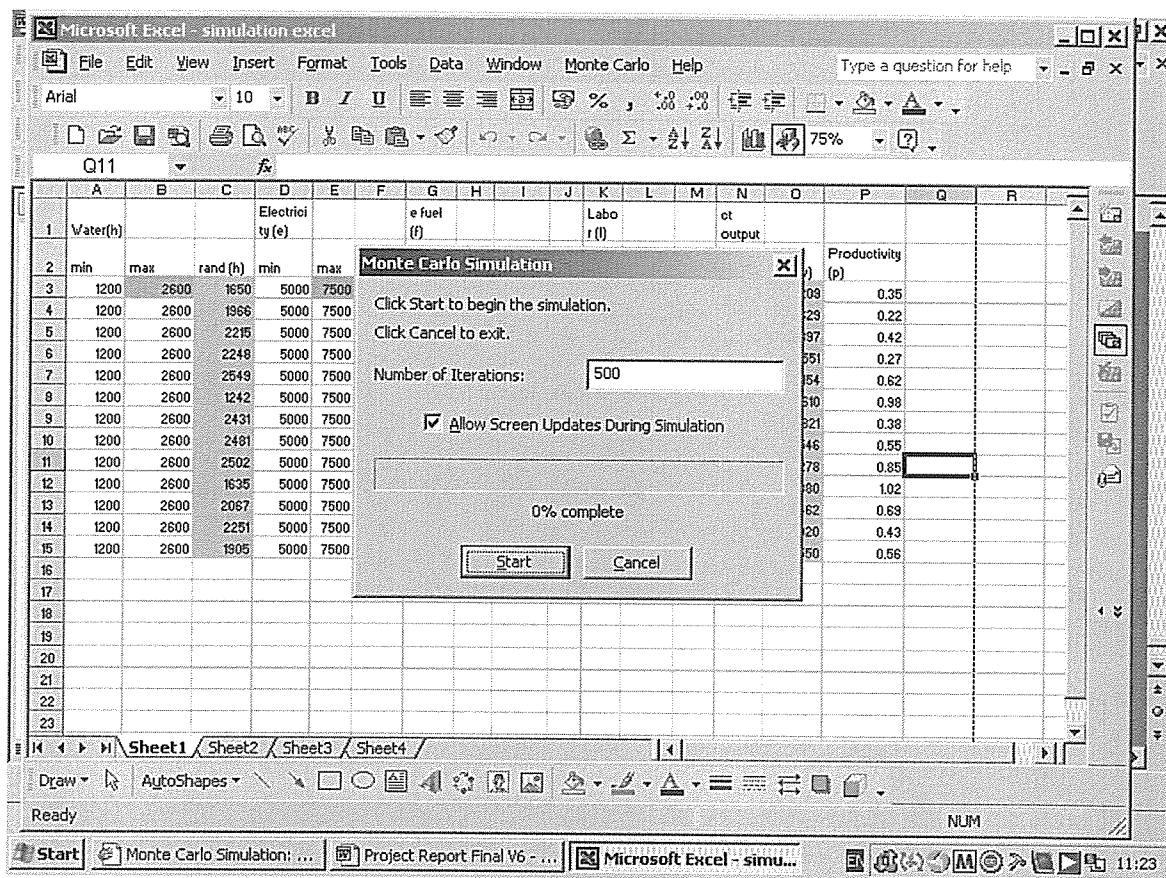


Figure 4. Running the Monte Carlo Simulation.

Display of results

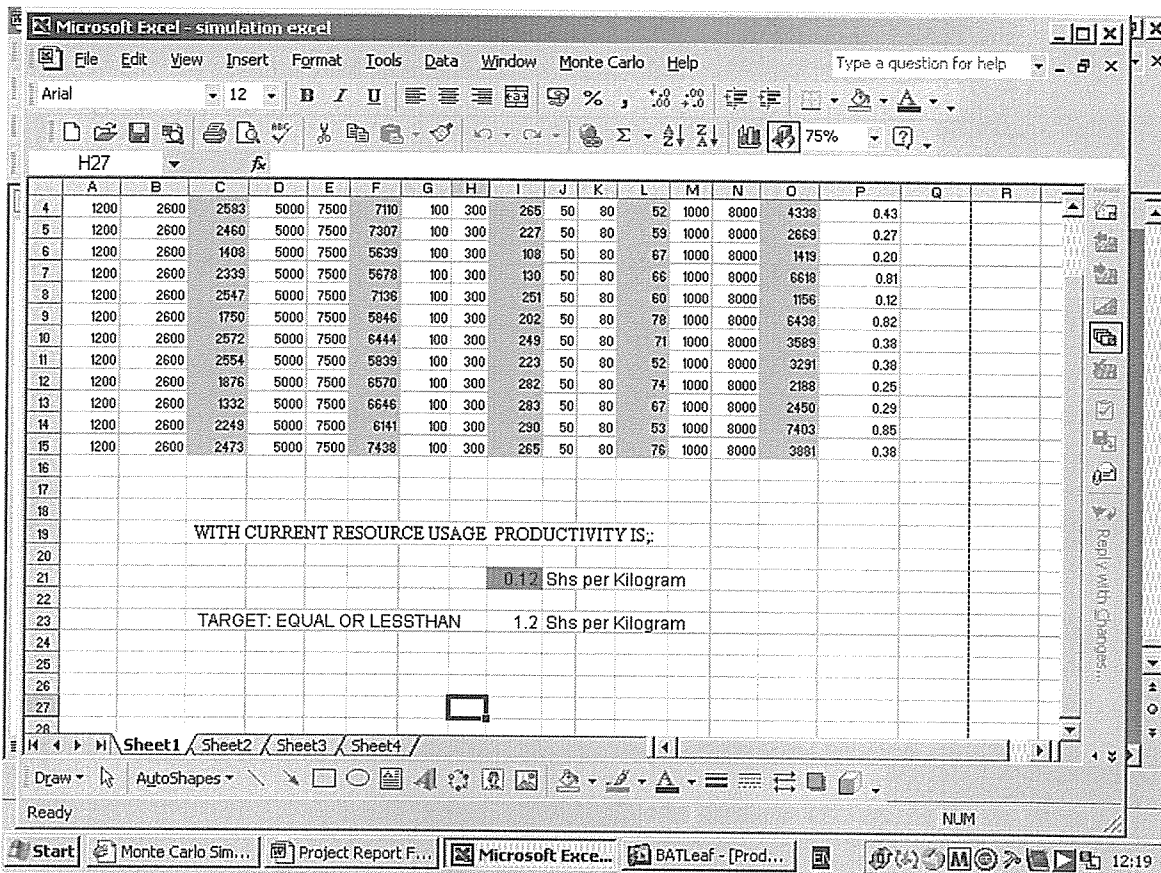


Figure 5. Display of results

The output giving a range of possible outputs for fluctuating inputs The actual output for the hour is displayed in the message.

4.2 Implementation

The system captures all the resources utilized in an hour and the amount of resources utilized in the same period. It then simulates productivity and displays results in a graphical form.

The system compares the simulated productivity and compares it against a set target and warns against under performance. The data is input manually as it was not possible to link meter readings to the system electrically due to the high cost of cabling that would be required to connect the meters to the computers. The output information is displayed in a graphical form on the screen of the computer or in print form.

This software is installed on a computer running windows XP.

CHAPTER FIVE

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

The important issue the study has revealed is that most factories lack a quick way of monitoring productivity but once a system is put in place then productivity is improved since it is well monitored.

The faster people know how they are performing in a manufacturing environment, the more motivated they become and therefore it is important they monitor their performance using systems like this model.

5.2 Conclusion

Though this project is basically academic research, the researcher strongly believe that it is a useful beginning to solve the problem of data storage and retrieval for processing production.

The ideal system however is to develop an inline monitoring system which eliminates manual input of data, though this is expensive

There were a few problems faced during the research but I am glad they were overcome. Some of them were:

- a) The limited time within which the project report was required impose limits on designing other modules, which could have helped in achieving many other objectives.
- b) Being the first time to design an interface of a kind in Monte Carlo software which I had to learn.

5.3 Recommendations

The researcher recommends that this model should be widely used and further developed to capture data online. Companies should invest in productivity improvement as this is the most effective way of keeping themselves in competitive business. Engineering departments in factories should encourage their staff to design tailored software for their processes.

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APPENDICES

APPENDIX A

Questionnaire

Purpose: To explore the use of resources in the factory and their monitoring

Employee Details

What section do you work in?

- ☐ Primary manufacturing
- ☐ Secondary manufacturing
- ☐ Packing
- ☐ Ware housing

How many years have been with the company?

- ☐ 0-2 years
- ☐ 2-5 years
- ☐ Over 5 years

What work do you do?

- ☐ Management function
- ☐ Supervisory function
- ☐ Technician
- ☐ Clerical
- ☐ General labour
- ☐ Other

Resource Utilization

What resources are used in your section?

- ☐ Electricity
- ☐ Water
- ☐ Steam
- ☐ Furnace fuel
- ☐ None of these

Do you ever take a meter reading for:

	Yes	no
Electricity	<input type="checkbox"/>	<input type="checkbox"/>
Water	<input type="checkbox"/>	<input type="checkbox"/>
Furnace fuel	<input type="checkbox"/>	<input type="checkbox"/>

Is there a log book for recording electricity usage in our section ? Yes ☐ No ☐

Is there a log book for recording water usage in your section? Yes ☐ No ☐

Is there a log book for recording furnace fuel usage in your section? Yes ☐ No ☐

Is there a log book for labour utilization in your section Yes ☐ No ☐

Productivity monitoring

Please answer the following briefly

Does your job description require you to know productivity for your company

If yes state who computes productivity for you and how often

Are you satisfied with the frequency of computation?

If not how often do you want productivity computed?

How do you get the results of the computations?

Thank you!

APPENDIX B

Sample System Codes

Production costs(). Montecarlo

Inputs : Array(water,electricity,furnace_fuel,labour).

Multipliers (unit costs)

Costs(c) =

[min_water+random()*(max_water-min_water)]

+ [min_furnace_fuel+random()*(max_furnace_fuel-min_furnace_fuel)]

+ min_labour+random()*(max_labour-min_labour)

+ min_electricity+random()*(max_electricity-min_electricity)]/

production_volume (w)

[min_water+random()*(max_water-min_water)]

+ [min_furnace_fuel+random()*(max_furnace_fuel-min_furnace_fuel)]

+ min_labour+random()*(max_labour-min_labour)

+ min_electricity+random()*(max_electricity-min_electricity)]/production_volume (w)