Manufacturing, Simulation and Implementation of Concurrent Engineering to Improve Production A Case Study in Palm Oil Industry

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ABSTRACT

The objective of this thesis is to improve the performance of a medium size industrial manufacturing plant by studying the effects of its production line and developing a proposed model of the production stages of the system via computer simulations.

The study has been carried out over an industrial case; Cameroon Development Corporation (C.D.C) is a palm oil manufacturing factory located in Limbe – Cameroon, which intends to invest on upgrading some of the production stages or by constructing another plant in the near future. This study aims to define the requirements and methods of simulation implementation for this selected case to improve its throughput and delivery performance in batch production. The proposed system is basically focused on modeling and simulation of the palm oil production lines of selected case via Activplant computer simulation tool. Then, the existing model is modified to test the several aspects by implementing computer simulation for achieving better performance and effectiveness in continuous production. The result of this simulation study is expected to be useful reference to the factory under study for its process of improvement.

Keywords: Simulation, Modeling, Batch production, Continuous production.

ÖZ

Bu tezin amacı, üretim hattının etkileri eğitimi ve bilgisayar simülasyonları ile sistemin üretim aşamaları önerilen model geliştirilerek endüstriyel üretim tesisi orta boy bir performansını geliştirmektir. Çalışmanın bir sanayi davası yüzünden yapılmıştır; Kamerun Development Corporation (CDC) bir hurma yağı fabrikasında Limbe bulunan - Kamerun, bazı üretim aşamaları ya da yakın gelecekte başka bir bitki oluşturarak yükseltme üzerine yatırım yapmak niyetinde olduğunu. Bu çalışma kendi akışı ve toplu üretim teslimat performansını artırmak için gereksinimleri ve simülasyon uygulama yöntemleri bu seçilmiş için tanımlamak amacındadır. Önerilen sistem temelde modelleme ve seçilmiş davanın hurma yağı üretim hatlarının simülasyon Activplant bilgisayar simülasyon aracı ile odaklanmıştır. Daha sonra, mevcut modelin daha iyi performans ve etkinliğini sürekli üretimde ulaşmak için bilgisayar simülasyonu uygulayarak çeşitli yönleriyle test etmek değiştirilir. Bu simülasyon çalışması sonucu fabrika için yararlı referans iyileştirme ve süreç için çalışma altında olması bekleniyor.

Anahtar Kelimeler: Simülasyon, Modelleme, Parti üretimi, Sürekli üretim.

to my family;

my dad Peter, my mum Elizabeth, my sisters Rosemary, Helen, Therese, my late sister Vivian and my brothers Florentin and Evaristus.

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Abbreviations/symbols	Meaning
--	continuous (So long as there is production)
CO	Conception office
PD	Product Design
WD	Washing and Disinfection
B	Boiling
PM	Production Mill
WT1	Waiting Tank 1
RDDB	Refining, Deodorization, Decolourization and Bleaching
FM	Filtering Machine
WT2	Waiting Tank 2
FC	Filling and Corking
MK	Marketing and sales
C.D.C	Cameroon Development Corporation

Chapter 1

INTRODUCTION

1.1 Problem statement

Around the early nineteen nineties, lots of industries stated to feel the effect of some influences on their product development: innovative, newer technologies, increase in product complexity, and larger industries. Therefore industries were forced to look for new product development methods or alternatives. Population growth is rapidly increasing till the extend that companies can not meet up with the demand. Customers are also having a high taste for new and advanced products which are health wise good. This demands a lot to the companies as they would have to improve on their quality, produce different variety of products at same time or concurrently, so as to meet the customers taste and demand.

1.2 Purpose

Kofie et al. (1998), examined that in third world countries and in developing countries, most companies do not meet the customers or market demand. This is due to the fact that the conception, design of product and manufacturing cycle time is long and time consuming. The main objective of this study is to examine the existing system before designing the proposed model and to propose the best alternative by using applications of computer simulation and thereby contribute to improve the production area of the company. This study is related with a simulation model development for a manufacturing company named Cameroon Development Corporation (C.D.C) which is an agro-industrial company located at Bota - Limbe in south west province, in the Republic of Cameroon. It is a medium size palm oil production factory, performing mass production of refined palm oil for a variety of customers in CEMAC (Economic and Monetary Community of Central Africa) and Africa as a whole. A simulation model has been built to visualize the implementation of computer simulation and concurrent engineering in order to improve its production environment.

1.3 Organization of Thesis

This thesis includes a literature review on manufacturing, Concurrent Engineering (CE) and simulation modeling in chapter two. Chapter three elaborates on the case study which covers the current system, products, data collection and present model of the Cameroon Development Corporation (C.D.C). The proposed method with the implementation of Concurrent Engineering (CE) and simulation can be found in chapter four. The investment appraisal for the proposed model for the C.D.C is examined in chapter five. Lastly chapter six concludes with a discussion of the results and suggestions for future work in this area.

Chapter 2

LITERATURE SURVEY

2.1 Introduction

This chapter is an overview of the current research in areas relevant or important to this thesis. This thesis could be viewed in three areas and the literature relevant to each view was examined. The first is the manufacturing, followed by Concurrent Engineering (CE) and simulation. Several pieces of literature from which no specific ideas were used or drawn for this thesis, but which were extremely necessary to gain the background needed to understand other work being done. The literatures are referenced in the Bibliography, but no formal summary of that work is included.

Chapter two talks on the definition of manufacturing, followed by a brief summary of traditional or serial manufacturing. The advantages and disadvantages of traditional or serial manufacturing are listed. Concurrent engineering and related work in design for manufacture are explained. The advantages and draw backs of concurrent engineering, product development, the myths of product development using concurrent engineering (CE) and the realities of product development by implementing concurrent engineering are examined. The definition of simulation, classification of studies in simulation modeling literature, applications of simulation on small and medium sized enterprises, input data collection and model development, simulation studies for different industries, effect of employee on manufacturing simulation and case studies are explained.

2.2 Definition of Manufacturing

Serope et al. (1994), defines manufacturing as all steps necessary to convert raw materials, components, or parts into finished goods that meet a customer's expectations or specifications. Manufacturing commonly employs a man-machine setup with division of labor in a large scale production. He went further to define manufacturing technology as a field of study focused on improvement of manufacturing processes, techniques, or equipment in order to reduce costs, increase efficiency, enhance reliability, or to incorporate safety and anti-pollution measures.

M.A.E Okure et al. (2006), defines advanced manufacturing as computer-controlled or micro-electronics-based equipment used in the design, manufacture or handling of a product. Typical applications include computer aided design (CAD), computer aided engineering (CAE), flexible machining centers, robots, automated guided vehicles, and automated storage and retrieval systems. These may be linked by communications systems (factory local area networks) into integrated flexible manufacturing systems (FMS) and ultimately into an overall automated factory or computer-integrated manufacturing system (CIM).

2.2.1 Traditional Manufacturing

Rebecca et al. (2002), defined traditional manufacturing also called Serial production is an old production technique where by idea, design, manufacturing, assembly and marketing are done in a sequential or centralized manner. This is still carried out by most companies especially in the third world countries. David et al. (2008), examined that in traditional manufacturing the product design, process planning and production departments are re-strictly separated and this prevents achieving efficient plans that can keep up with the increased product variety or types and shorter delivery dates demanded by customers today. Figure 1 shows the traditional manufacturing work flow model.

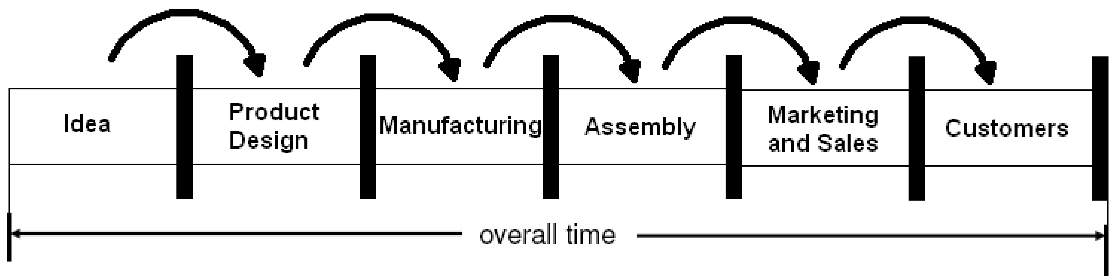

Figure 1: The traditional manufacturing work flow model.

Boothroyd et al. (2002), illustrated that data or work represented by the forward arrows, flowing in the traditional manufacturing work flow model as seen in figure 1.1 above is said to be over the fence. The functions go up the production pattern with little or no feedback. That means from the conception or idea right up to the customers there is no feed back, as seen by the direction of the arrows on the figure 1. Examining this brings us to the point of the overall time (OT) and total time to market (TM) conception. The overall time (OT) is the time taken in the traditional work flow model for a product(s) to leave from the idea bureau to the customers. This directly gives us the total time to market (TM) for the product(s).

David et al. (2009), stated that the overall time (OT) that's the time from idea to customers is directly proportional to the total time to market (TM).

$$OT \sim TM$$

Baback et al. (1999), examined the traditional manufacturing technique carried out in the design office by most industries in the third world and developing countries which is the sequential design approach. Information flows from one person to the next with little or no feedback. Figure 2 illustrates the sequential design.

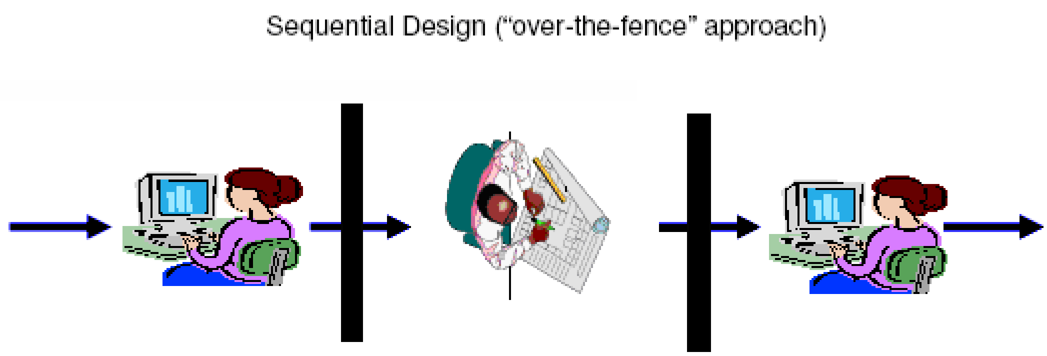

Figure 2: Sequencial design carried our in the design office.

Sam Mannan et al. (2007), also examined that another method carried out in the design office in some companies is the centralized design. With this system, decisions are taken by a single person. Information flows only between the design manager or head and each of the design technicians. As the design manager confirms a design, he sends it directly to the production sector. Note should be taken that information does not flow among the design technicians as illustrated in figure 3.

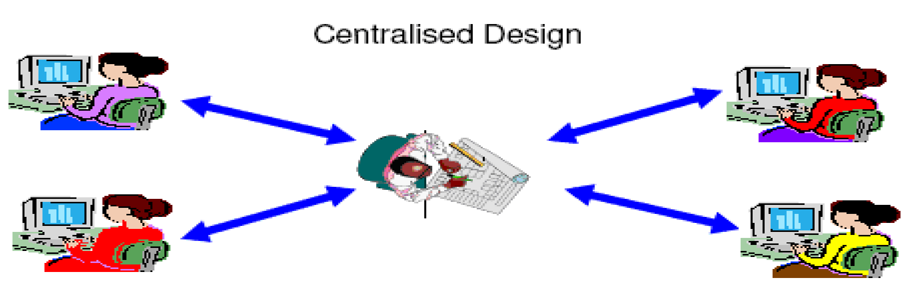

Figure 3: Centralized design carried out in companies.

2.2.2 Advantages and disadvantages of traditional manufacturing.

The advantages and disadvantages of traditional manufacturing are summarized in table

Table 1: Advantages and disadvantages of traditional manufacturing.

Advantages	**Disadvantages**
The production time still Maintains	Cycle Time Too Long
Improve operator's expertise	Facility Intensive
	Cost High
	Convergence Not Assured
	The centralized design is disadvantageous, for the central design manager may take wrong decisions that may hinder manufacturing.
	With the sequential design, there is no feed back.

2.3 Concurrent Engineering

Sandra et al. (2009), defined concurrent engineering (C.E) as a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support.

David et al. (2008), described concurrent engineering as the practice of concurrently developing products and their design and manufacturing processes. If the existing processes are to be utilized, then the product and the processes must be developed concurrently. Here, this requires knowing much about manufacturing processes and one of the best ways to do this is to develop products in multifunctional teams.

Rong-Shean et al. (1997), investigated that design for manufacturing (DFM) and concurrent engineering (CE) are proven design methodologies that work for any size company, be it small, medium or large size companies. Typically, concurrent engineering involves the formation of cross-functional teams, which allows engineers and managers of different disciplines to work together simultaneously in developing product and process design.

This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from concept through disposal, including quality, cost, productivity, speed (time to market and response time), and user requirements (include functional and reliability).

Portioli et al. (2003) examined the extent to which Concurrent Engineering best practices are being used effectively in companies. Companies both in Belgium and in Italy were investigated using a Concurrent Engineering compliance checklist. The paper comments on usage patterns in both countries and compares them. Specific information per sector is also included. Finally, the positive impact of formal Concurrent Engineering programs is proven by the data.

Klaus et al. (1996), presented a holistic approach to concurrent engineering and its implementation which is under development by the Brite-EuRam funded PACE consortium. PACE stands for a ‘Practical Approach to Concurrent Engineering’. It is a pan-European project consisting of a consortium of eight partners (four industrial and four academic research institutions) from four European countries (UK, Germany, Denmark and Portugal). The primary aim of PACE is to provide a holistic technology transfer infrastructure enabling the effective and efficient change and improvement of present engineering practices towards concurrent engineering principles. At the outset the question of what is meant by a conceptual model is discussed, together with what it should contain and how it should be structured. This is followed by a description of how the PACE conceptual model was derived and why the consortium considers that it encapsulates the pertinent issues of CE. The most well-known existing models are reviewed, examined and critiqued. Through analysis of previous case studies and in the authors' experience, many companies consider that there are difficulties with existing models for CE implementation. It was felt that none of them presented the full picture in terms of what constitutes CE and what bearing it will have on companies that decide to go ahead with implementation. The authors and the PACE consortium believe that the conceptual model will be unique due to its high level of industrial relevance. This section is augmented by the developments to date on the Knowledge Platform environment and its user interface. The final section of the paper focuses on the issues relating to a generic concurrent engineering implementation support framework. A methodology defining the introduction of CE-based product engineering processes is outlined. This is generic in nature but designed to be adaptable to specific company needs. Implementing CE successfully requires a huge cultural change in an organization. The framework presented in the paper is especially aimed at showing how to implement CE in an ordinary company i.e. not using a 'super-motivated' project team. It is based on the steps of change management in the specific context of CE and provides a structure for implementation, drawing on literature and experiences of the PACE industrial partners.

2.3.1 Advantages and disadvantages of Concurrent Engineering (CE)

Larry et al. (2005), investigated that concurrent engineering despite its numerous advantages, still has some draw backs. The table 2, briefly states the advantages and disadvantages of concurrent engineering.

Table 2: Advantages and disadvantages of Concurrent Engineering (CE).

Advantages	**Disadvantages**
Design time reduction	Discontinuity along partition boundaries
Low risk of high-level ECO impact	Conflicting net type rules and definitions
Maximized resources	Optimize packaging of gated devices
Global collaboration	
Multiple engineers working on same parallel schematic database	
Hierarchical	
Conflict resolution	
Peer-to-peer updates	
Use of physical partitions	
Synchronization of partitions with master layout	
Reuse methodology with a block based design approach	
Outsourcing	
Project distribution	

2.3.2 Product development

Anil et al. (2008), examined that to improve production in a company, we are simply talking of product development and to realize this, concurrent engineering (CE) which is a potential approach has to be implemented.

Escola et al, (2006) examined that, there are different perspectives among the design and development research community. Past research shows that there are at least four common perspectives addressing this issue. Furthermore, there are significant differences among papers within each of the perspectives, not only in the methodology used and assumptions made, but also in the conceptualization of how product development is executed. Project management, concurrent engineering and methodologies of engineering design are examples of those perspectives and are usually treated as isolated disciplines. However, there are many interactions among the tasks related to them. Interactions, common tasks and concepts are investigated.

2.3.3 The myths and realities of product development by implementing concurrent engineering.

The myths and realities of product development by implementing concurrent engineering are listed below;

The myths of product development using concurrent engineering include;

- Developing products faster, proceeding soon on the detail design, then software coding and enhance deadlines to keep design release and meet customers demand on schedule.

- To customize products, take all orders and use an ad hoc approach, marking up the existing drawings or having a separate engineering group which perform custom engineering on individual products as needed
- Anderson et al. (2008), stated that after the product is designed, the cost can be easily reduced by cost reduction efforts.
- To achieve quality, find out what’s wrong and fix it.

The realities of product development by implementing concurrent engineering are;

- One of the effective ways to achieve quality is to design it and then build it in.
- Another effective way to customize products is by the concurrent design of versatile product families and flexible processes, which is known as mass customization.
- The only measure of time-to-market is the time to stable, trouble free production and that depends on getting the design right the first time.
- Lastly, by early concept decisions, cost is designed into the product and it is difficult to remove in later stages.

2.4 Comparison between traditional manufacturing (TM) and concurrent engineering (CE)

C.A.Maynard (2003) investigated the comparison between traditional manufacturing (TM) and concurrent engineering (CE). He stated that;

Traditional manufacturing (TM) approach also known as "serial manufacturing", towards development had been largely sequential in nature, i.e. each discipline performs its own individual function and passed the results to the next discipline in the serial chain. Typically, there is very little or no interaction at all among various disciplines.

Thus this leads to problems later in the development cycle. The most obvious barrier is the separation of various functions. Once a new product design is verified, by either simulation or hardware proto-typing or both, it is tossed "over the wall" to manufacturing, test, quality, and service engineers for review. Continual changes usually must be made as problems are usually discovered later in the process. This will invariably adds to overall development cost and time to market.

In contrast, concurrent engineering (CE) approach encourages teamwork and it harnesses the expertise from all the disciplines that are involved to work closely together in parallel right from the early stage of the product design and development stage. In order for effective teamwork, sharing of ideas and goals had to go beyond immediate assignments and departmental loyalties. Trade-offs regarding ease of production, testing and servicing are made along with product performance, size, weight, parts and cost trade-offs. When a design is verified, it is already manufacturable, testable, serviceable and of high quality. Hence, multiple iterations on the product changes commonly found in sequential process is eliminated. This will minimize the time from concept to release for a product.

In terms of product quality, traditional manufacturing emphasis is more on correction than prevention. Design errors are detected only during manufacturing rather than eliminated during the design stage and preventing them from occurring in the production stage. This process inevitably leads to rework. Generally manufacturing becomes more expensive due to the additional number of tests and checks required. Concurrent engineering, working in parallel or concurrent activities, allows multi-disciplinary teams to rectify any problems at the earliest stage. This will prevent any design problems to surface later in the process and help to reduce the number of checks and test required at later process.

In traditional manufacturing, information flow is mostly one way and is severely restricted as it is stored on many media in many locations. As a result, insufficient information is exchanged among various groups. Mean while information sharing is vital for effective concurrent engineering implementation. Organization would be unified with mechanism for storage, control and retrieval of all information and data relevant to the product. All functions would have access to these resources. Information exchanges among all teams are strongly encouraged.

2.5 Definition of Simulation

Banks et al. (2000), defines simulation as the imitation of the operation of a real world process or system over time. The purpose of simulation experiments is to understand the behaviour of the system. During the mid 19^{th} century, simulation was first used in the industry and FORTRAN was one of the programming languages that were used to build simulation models. During the 1960s, simulation such as SIMSCRIPT ad GPSS were used in manufacturing industry. Around the early 1980s, new simulation languages such as SLAM and SIMAN were developed and came into use. During the 1980s and early 1990s, new graphical model development tools such as Witness, ProModel, Arena, iThink, Quest, Activplant were introduced to provide more flexibility on simulation, such as graphical tools, user friendly and flow chart based programs for the engineers and business analysts. In the first halve of the 1990s, “object-oriented modeling and analysis" has influenced simulation and several simulation languages such as ModSim and Simple++ are introduced.

Mitchell et al. (1998), reports an approach by combining virtual prototyping (VP) with design by manufacturing simulation techniques. By constructing virtual prototypes, accurate assessments of mass producibility and customer acceptance will enable better informed design of customized products. The primary goal of VP for customized product development is to provide a multidisciplinary design definition and rapid prototyping environment for concept development and a tailored, scenario-based simulation environment for concept evaluation within a single facility. This design environment facilitates the capture and utilization of information generated during the design phase, and the simultaneous generation, at design time, of manufacturing, materials, costing, and scheduling data, together with visual evaluation of customer perception on target products, hence supporting the implementation of concurrent engineering.

2.6 Classification of studies in Simulation Modeling Literature

The classification of studies is divided into six main categories as listed below;

- Application of simulation on small and medium sized companies,
- Input data collection and model development,
- Simulation studies for different industries,
- Effect of employee on manufacturing simulation
- Case studies.

Of these categories in the classification, the application of simulation on small and medium sized enterprises is the most interesting for this study, because Cameroon Development Corporation (C.D.C) is a medium size palm oil production factory. In the factory, human factors take the prominence when producing the products. However, human performance can be a working life problem in some cases, while improving overall system performance such as increasing quality of production. Therefore, managers should be ware of the potential human performance shortfalls to find a reasonable solution for those pitfalls. At the point, CIM implementation can be a good solution to apply automation for some production lines in the factory.

2.6.1 Application of Simulation on Small and Medium Sized Enterprises

Molina et al. (2003), worked on a research project in the study named Extended Enterprise Demonstration Factory program, which is enabled to create reference models, methodologies and tools for building and implementation of the main idea of extended enterprise in Mexican industries (SMEs). With that project, they identified the best manufacturing practice of integrated modelling and simulation environment based methodology. This methodology consists of five phases: (1) evaluation of the enterprise performance; is face to assess possible strategies for improvement, (2) modelling and simulation of AS-IS core process; to identify which improvements should be applied to current enterprise, (3) selection of best manufacturing practices for core process enhancement, (4) modelling and simulation of TO-BE core process; to evaluate impact of the best practices practice in the process, (5) evaluation of manufacturing practices implementation in terms of their impacts and benefits. A simulation tool SIMETRICS, Aris Tool set, Quest and Activplant were used to support this study.

Dewhurst et al. (2001), presented a case and a methodology, which are related with structured system analysis and modelling and simulation of a manufacturing plant to analyze, and application of the manufacturing system. First, a business process modelling approach (BMA) was applied; but the system represented dynamic system, and then simulation approach was applied to provide information for planning and to improve the performance of manufacturing system. Then, proposed methodology (integrated with strategic, tactical, operational and project planning) was carried out to two small and medium sized enterprises. The proposed methodology demonstrated feasibility by applying BPM and simulation approaches.

There is also a paper that is related to an application of small and medium size manufacturers as a case study in literature. Silva et al. (2000), presented a case study to simulate the overall productivity of an existing factory, which produces chest freezers. They accomplished some improvements, for instance daily throughput rate was increased by 66 percent.

2.6.2 Input Data Collection and Model Development

Generally, a good simulation study should consist of some essential parts, such as literature review, system definition, statistically sufficient data collection, model development, verification and validation of the model, modelling the proposed redesigns, and a good experimental design together with a powerful statistical analysis of the simulation results to conclude the study. Those parts can be taken into account as a whole, especially, input data collection and model development sections gain a vital importance and need a sensitive work because they constitute the first part of the study and contribute to the productivity of the study. Lack of it will prevent smooth development of the study and may cause some serious representation problems.

Perera et al. (2000), presented a methodology on batch manufacturing, which is based on IDEF (Integrated computer aided manufacturing DEFinition) family of tools for rapid identification and input data collection. Methodology consists of three main elements, which are functional model library, reference data model, and mapping table. Functional model library is developed by using IDEF0 for functional analysis; it is like a history of the model. Reference data model is developed by using IDEFIX, which is an entity relationship diagram with their primary and foreign keys between the various kinds of components that is in the system, such as machine, operator, part, and operations. Lastly mapping table is an interface between the functional model library and reference data model. This mapping table is represented by the modules of Activplant (a visual interactive simulation package) or any other simulation software package. Also, proposed methodology prevents waste of time during data collection, and can be adapted to some specific manufacturing areas, such as aerospace and automobile industries.

Dogan et al. (1997), modified and analyzed a kind of hardwood sawmill in upper Peninsula of Northern Michigan by using Quest simulation software to determine the cutting of logs, and improvement of efficiency of sawmill, and lastly maximize the annual rate of the profits. When developing the model some descriptive information was needed about the machines, processes, etc. For these reasons, they considered seven distinct data to identify the system, which are material characteristic distributions, processing times, setup times, downtimes, process flow probabilities, material divergence distributions, and conveyor characteristics (speeds and capacities). Also, simulation model was developed based on two phases. During the first phase, current machine (trimmer machine) was changed with the new one to analyze the machine's processing rate. In the second phase of the study, they expanded the area of the sawmill, which included a storage area, called the green chain area.

2.6.3 Simulation Studies for Different Industries

There are a lot of simulation studies on case studies in the literature, because most of the manufacturing systems contain complex units, for which there is no well formulated analytical approach. For this reason, it is desirable for simulation packages used in manufacturing to be flexible. Therefore, experimentation by simulation models has been widely used in different industries such as, chemical, food, textile, and manufacturing environment.

Kline et al. (1992), introduced a method, which is simulation/animation method that demonstrates the application and utility of furniture rough mill system for the eastern region of the United States. Simulation was used to assist in identifying and solving problems, and animation was used to reduce the time for model development. In that case, to represent the rough mill, they described six primary objects with their characteristics to develop the model, which are (1) station objects; to define the workstations, storage area or transfer point in the system, (2) route objects; to define the route between the stations, (3) entity objects; to represent which kind of materials are used in the system, (4) queue objects; to define an in-process storage area for material until the queue capacity is exceeded, (5) resource objects; to represent the operators and materials handling equipment for operating the machines and move the materials from one station to another, (6) system variable objects; is used to store information about the system. All of those objects were used for simulation/animation to reduce significantly the amount of time used in model development.

Huda et al (2002), performed a research of application of simulation modelling and analysis for high-speed combined continuous and discrete food processing industry, and this manufacturing sector was modeled by using Activplant simulation software package. The proposed model can be carried out using different production scenarios to examine and decrease the bottleneck in any production schedules for testing the feasibility of the proposed improvement. Huda and Chung (2002) explained the details of their model with an illustrative real world example.

Dilay et al. (2006), introduced a new optimization study with a mathematical model to simulate the energetic behaviour of a pasteurization tunnel used in a beer production process in the food industry. The proposed methodology acts as an efficient tool to analyze different features of pasteurization tunnel. Also this study geometric optimization of beer pasteurization tunnel was found to be a successful study and could be applied to simulation, design, and optimization of any industrial process. The mathematical model can be examined in detail with experimental validation and numerical results.

Dengiz et al. (2006), proposed DSS (decision support system) analysis for simulation modelling of a diamond tool production line of a company in Ankara, Turkey. The aim of this study was to evaluate and understand the system performance and maximize the throughput rate of the system by using a meta-model put together with an optimization module. In this case study, the aim of DSS application, it provides flexibility with different scenarios to the current system, which can be changed or adapted to condition of manufacturing technology changes according to company's objectives. Also, the aim of meta-modelling is for reducing the cost of simulation such as queue length of a station in the system as a bottleneck is reduced to very low number as well as the total operating cost and cycle time are reduced too. It is very typical in the literature that they performed all steps of a simulation study.

2.6.4 Effect of Employee on Manufacturing Simulation

Nowadays, in highly competitive industries, manual labor is still significant in manufacturing environment; especially in assembly lines, although most of the industries have shifted to and design tools during the last 20 years. Therefore, human performance should be taken into consideration with most of the experts and analysts when modelling a system that has a manual labor substructure.

Baines, et al. (2004) carried out two human performance models, studied at Ford Motor Company for simulating the production system, which are age related performance theory and circadian rhythm (cr) related performance theory. The first model states "as human gets older (after age of 30), their working performance gets worse, as well as the throughput rate of the production decreases". The second model deals with time of day and age, which are very important and can affect human performance strongly.

Erensal et al (2005), performed a case study base o two human performance models, which is applied by Baines et al. (2004), and developed a simulation model by using

Automated simulation software for two stations on a manual assembly line by applying four experiments and considering some factors of job assignments, which are age, skill requirement job, and operation time. In experimental design, subcontracting and human effects are considered as two different values for each experiment that is used either together or not. The proposed model with applied human performance models is verified through the simulation results.

Freudenberg et al. (1998), simulated the team work in manufacturing systems, where there basic components are used to model the workers, which are the workers themselves, time management of workers, and a controlling facility holding the disposition strategies and information. When developing the worker specification, different working structures are considered which consists of several characteristics such as (1) integration of functions and tasks; it is related with qualification of the worker who is available for appropriate job, (2) cooperation and communication; is communication between the workers for cooperation, (3) autonomous control and inspection, (4) integration of qualification and the model developed by using GPSS/H and Proof™ as a simulation language. Although worker specification simplified to create the personal oriented simulation models, it did not give a general solution to this approach.

2.6.5 Case Studies

Silva et al. (2000), performed a case study, which is an application of a simulation modelling and analysis into medium size enterprise, which is one of the chest freezers manufacturers in industry. The aim of this study is to make acceptable change to the current manufacturing system operations such as to produce a new machine to replace two press machines in order to obtain the maximum throughput rate and finding an appropriate solution to bottlenecks in the system. For that reason, to evaluate impact of proposed simulation model on the overall performance of the company, they developed a model by using Activplant simulation software for four different products. According to the simulation results, throughput rate of these products are increased by 66% units per day, respectively.

Szczerbicki (2000), worked on a steel manufacturing area as real world study of a bar mill. When developing the model by using SLAMSYSTEM simulation modelling environment, author faced with two problems, which were (1) the lead time of the products was too long because of their processing times, (2) the dispatching performance was too low because of the lead times. In order to solve both problems, three acceptable solutions were found, which are (1) to increase the dispatching performance to 95% to determine ways to reduced the lead times, (2) to improve the schedule to obtain targeted lead time and dispatching performance, (3) to calculate the optimum number of workers at steel processing stations. Some distinct scenarios were tried within a lead time of 7 days and consequently a bottleneck was found. Two recommendations were suggested to improve the performance of the system; which are changes in the rolling sequence and changes in the allocation of operators.

Greasley (1999), worked on a case study, which is related with a local manufacturing company located in the UK producing aluminium gas cylinders for the global market. Purpose of the case study was to increase the available recourse usage and determine the queuing problems in the current system and minimize it to acceptable line, which are saw, billet preparation, etch, extrusion, heat treatment, machining, pressure test, and painting, respectively by using Quest visual interactive modelling (VIM) system to analyze and find a feasible solution for the available problems such as removing the bottlenecks in the current manufacturing area. As a result, the proposed model is high quality example to demonstrate "what-if" analysis and if the required simulation skills are present, the technique will be very useful in the analysis of the complexity of modern manufacturing systems.

Additionally, there are other papers, which are related with implementations and methodologies of case studies in the literature, and this is mentioned under the different subsection in this chapter. Briefly, they can be itemized as;

- Dewhurst et al. (2001), proposed a methodology for small and medium size enterprises and it can be easily adapted on business process modelling approach (BPM) and simulation approaches to reach the feasibility.

- Eransal et al. (2005), carried out a case study based on two human performance models. In that model, subcontracting and human effects are considered as two different values for each experiment that is use either together or not. Simulation results are verified by the proposed model with applied human performance models.

- Dengiz et al. (2006), applied DSS (decision support system) analysis to provide flexibility under a number of different scenarios to the current system, which can be changed or very easily adapted to condition of new situations such as manufacturing technology changes according to its desires and needs.

Chapter 3

CASE STUDY

3.1 System Definition

With the system definition phase, setting the characteristics of the system will be stated and problem formulation will be made. Shannon (1975) defined six major system characteristics, which are (1) change, (2) environment, (3) counterintuitive behavior, (4) drift to low performance, (5) interdependency, and lastly (6) organization. All of those characteristics should be examined one by one with respect to the objective of the study, which are identified with the formulation of the problem.

Shannon (1975) defined the first characteristic change, that it is related with how often and how much the system will change during the course or a simulation study and it should be estimated over a period of time. Changes in the system can also affect the study objectives. A system's environment contains all input variables that can significantly affect its state. For instance, for a traffic intersection system, the inter-arrival time of vehicles can be thought as an input variable. Counterintuitive behavior should be tried to identify for consideration in defining the system, but it is not easy to do that with the people who do not have expert knowledge about the simulation study. System can show a drift to low performance due to the determination of its components such as machines in a manufacturing system over a period of time. If the system shows this characteristic, it should be integrated within the model representation. Interdependency and organization characteristics of the system should be examined before starting the real system modeling. In a complex system, many events take place and affect each other. Therefore, the system is decomposed into subsystems and subsystems into other subsystems to resolve the complexity. This decomposition can be done by examining how system elements (components) are organized.

3.1.1 System Description

Before developing a model, knowing the characteristics and attributes of the system and describing its operation is of great importance, to expose a fine simulation study. In this section, description of the manufacturing systems and its types, refined palm oil extraction operations in manufacturing systems, and the current or present system of the Cameroon development corporation (C.D.C) is introduced and examined in this section.

3.1.2 Manufacturing Systems

Hitomi (1996), defined manufacturing system as the conversion process of the resources of production, particularly the raw materials, into the finished products, aiming at maximum productivity. There are four major types of manufacturing systems, which are (1) custom manufacturing, (2) intermittent and batch manufacturing, (3) continuous manufacturing, (4) flexible manufacturing. Custom manufacturing is known to be the most conventional manufacturing system. This system is suitable for “custom-made” products to make special products according to customer specifications, for instance clothing (a tailor made dress for a customer) and furniture and just one person made the entire order. Intermittent and batch manufacturing refers to the case of small and medium production, where there is a balance between production volume and product variety. Here, unlike the “one-of-a-kind” philosophy of custom manufacturing, production is made in batches. In continuous manufacturing, the parts move down a manufacturing line. At each station in a line, a worker completes a specific operation as soon as possible because product takes the shape as it moves along the line. For continuous manufacturing the idea is to minimize production costs and eliminate laborer skill requirements on a moving assembly line shop configuration. This can be achieved by offering limited variety to customer and high volume of production to justify the shop floor layout investment and minimize unit production costs. Flexible manufacturing system (FMS) is a comparatively new system and uses complex machines in the manufacturing area. It can produce a small batch like a batch manufacturing but also uses continuous manufacturing actions. Flexible manufacturing requires a computer controlled shop with integrated design and production control software. FMS shops ca deliver a wide range of products, but unlike conventional job shops (custom manufacturing) unit production costs are affordable because of eliminated set up times, inexpensive and integrated product-process designs, efficiency of inventory control, scheduling and production control. The C.D.C produces its products using batch production (intermittent) manufacturing, which is further discussed in section 3.1.4.

3.1.3 Palm oil Extraction Process in Manufacturing Systems

Palm oil extraction is the process of squeezing palm oil out of a mixture of oil, moisture, fiber, and nuts by applying mechanical pressure on the digested mash with the aid of an oil extraction machine or press. The raw palm is distilled or boiled in a distillation chambers before fed into the extraction machine. Crude palm oil is produced. Fiber and nuts follow a different pattern. This method is called the “wet” method. The C.D.C is using the “wet” method. The figure 4a shows the palm fruit plantation in Bota, Limber-South West province, Cameroon. Figure 4a shows palm fruit in cone, which has been harvested from the palm plantation. Figure 4b illustrates the detailed cross-section of the palm fruit. The palm oil gotten after the extraction process is shown in figure 4c. Figure 4d shows the extra-refined palm oil.

Figure 4a: Palm fruit in cone.

Figure 4b: Cross-section of palm fruit

Figure 4c: Palm oil from extraction.

Figure 4d: Extra-refined palm oil.

Figure 4 (a,b,c,d): shows the palm fruit before and after production.

3.1.4 Current System of the Cameroon Development Corporation (C.D.C).

The Cameroon development corporation (C.D.C) is a medium size industry performing mass production of palm oil of different qualities for a variety of customers in Europe, Africa and CEMAC (Economic and Monetary Community of Central Africa) zone which consist of Cameroon, Chad, Central Africa Republic, Gabon, and Congo Republic. The factory is operated throughout the whole day (24 hours), employing 3 shifts. The morning shift is set between 8 pm and 4 pm, the noon shift is set between 4 pm and 12 pm and lastly the night shift is between 12 pm and 8 pm.

The common product is palm oil, but they are of different variety such as; 0% cholesterol, 25% cholesterol, 50% cholesterol, 75% cholesterol and 100% cholesterol, which are for variety of customers. The company employs a total number of 200 people; 180 shop floor workers, 10 foremen, and management which consist of 10 members who are divided to work in 3 shifts. Additionally, the annual turn over of the factory is $ 50 million approximately with an extraction machine capacity of 50,000 metric tons annually. Despite the extraction machine capacity, C.D.C produces just about 30,000 metric tons annually. The quantity of production (Index of production) in metric tons in the past years is shown in figure 5. (2008 revenue data of C.D.C).

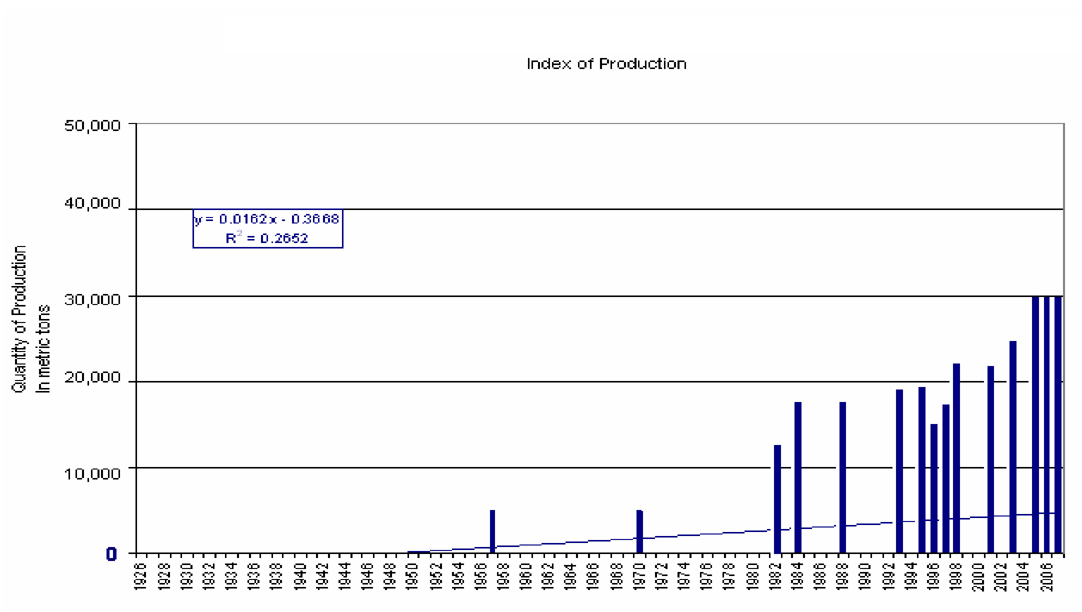

Figure 5: Illustrates the index of production for the past years

The process begins with the raw materials (palm fruit) arriving from C.D.C palm fruit plantations where the fruit must have been removed from the cones. The idea or conception office has the customer's product requirement (The quality recommended). It is being analyzes and forwarded to the design bureau or office where the quality (cholesterol percentage, brightness, etc) is determined, raw materials checked if available, if not it returns to the idea office and if available it goes to the washing and disinfection sector where the palm fruits are washed and disinfected to kill insects and germs. The disinfected fruits go directly to the boiling and sector via a conveyor. In the boiling sector, the palm fruits are boiled at a temperature of 100 ^{o}C for a period of 1 hour and the boiled water is drained. The palm fruit is now moist and this would help facilitate extrusion. Moist palm fruits are sent to the production mill where the palm oil screw press squeezes the moist palm fruits, separating the crude palm oil from the mesh or chaffs (palm fruit waste). The mesh is being used in another sector for the production of fertilizers. The crude palm oil produced is simultaneously sent to a waiting tank. This waiting tank needs to be full before the crude palm oil can be sent to the next stage which is refining. This is because crude palm oil can not be processed in bits. For if processed in bits, this would increase the production cost tremendously. As soon as the waiting tank is full of crude, it is then pumped to the refining cylog (process tank). Basically there are four processes carried out in the cylog (RDDB); (1) refining (R), which is the removal of moisture and impurities which is 0.15% in crude palm oil, (2) deodorization (D) is another process and is the removal of the crude palm oil smell, (3) decolourization (D) is the removal of the thick red coloration of the crude palm oil, and (4) bleaching (B) is the decomposition or breakdown of free fatty acids (FFA) and gums

(Phospholipids and phosphotides) into simpler forms which is 3-5% in crude palm oil. Note should be taken that the time period for processing crude palm oil (RDDB) in the cylog depends on the quality of oil to be produced. The refined palm oil from the cylog goes straight away to the filtering machine passing through a control point. This point controls if the palm oil has been refined well. If “YES”, then it continues to the filtering machine and if “NO” it is sent for cancellation and then to the waiting tank to be re-processed with the incoming crude palm oil. In the filtering machine, the refined palm oil is filtered so as to prevent impurities such as dirt, fatty acids and gums from passing to the next stage. The refined and filtered palm oil is simultaneously sent to a waiting tank, passing through another control point. For if the palm oil is not well filtered (“NO”) it is cancelled and sent to the waiting tank to be re-processed with incoming crude palm oil. It can not be sent to the RDDB cylog because it is permanently closed when refining is carried out. If the palm oil is well filtered, it sent to another waiting tank where it is simultaneously sent for filling and corking. The refined and filtered palm oil is then filled into bottles or containers. If not well filled or corked (“NO”), it is sent back to the refined and filtered palm oil waiting tank to be refilled and corked with incoming refined and filtered palm oil. If well filled and corked (“YES”) it is sent to the customers for sales and consumption. Figure 6 below illustrates the current processes carried out in the C.D.C when producing any of the products.

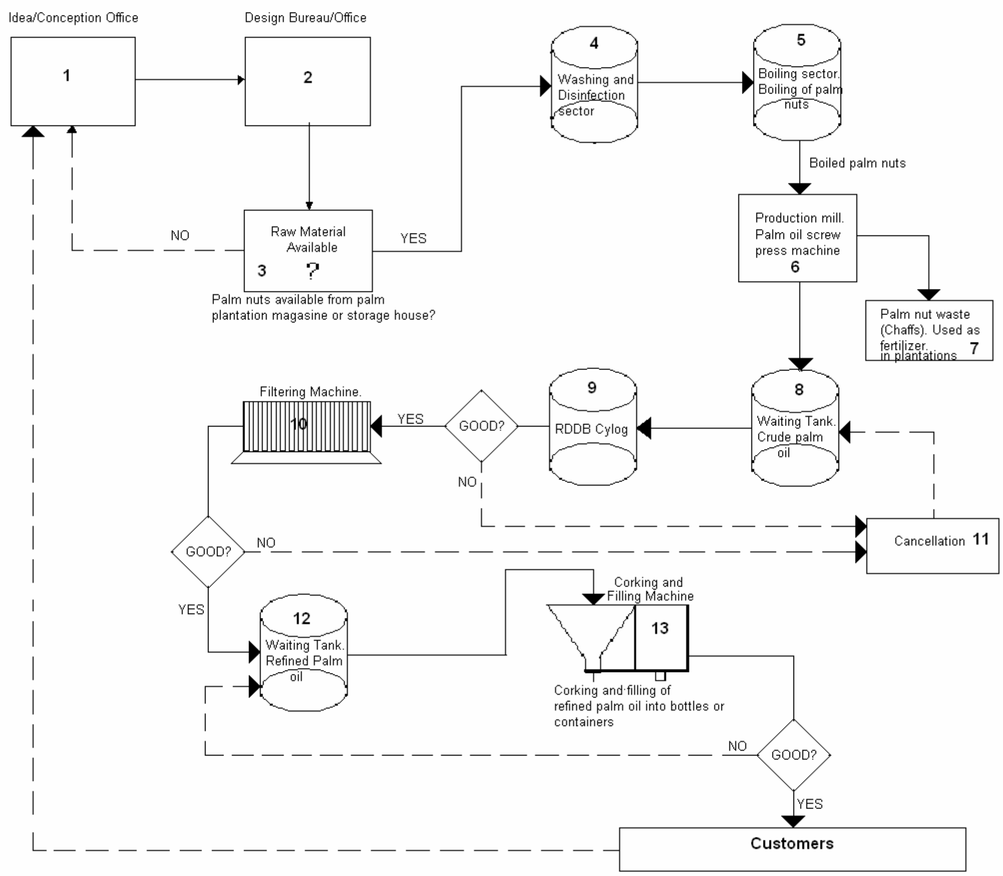

Figure 6: Current flow chart of processes in the C.D.C.

Table 3 shows the list of block numbers and their meaning or function on figure 3.3.

Table 3: List of block numbers and their meaning or function.

Number	Meaning
1	Idea/Conception Bureau or office
2	Design office
3	Palm nuts available from palm plantation storage house
4	Washing and disinfection of nuts
5	Boiling of palm nuts
6	Production mill
7	Palm nuts waste
8	Waiting tank 1(Crude palm oil)
9	RDDB(Refining, Deodorizations, Decolourization bleaching) Cylog
10	Filtering machine (filtering of palm oil)
11	Cancellation and repeat action
12	Waiting tank 2. Refined palm oil
13	Corking and filling machine

Table 4 illustrates the operation sequence, timing and delivery status of products in the Cameroon development corporation (C.D.C).

Table 4: Operation sequence, timing and delivery status of products.

Product Type	**List of operations**	**Time Hours**	**On time Delivery (OD)**	**Delayed Delivery (DD)**	**Total Cycle time/product in hours**
1 0% cholesterol	CO PD WD B PM WT1 RDDB FM WT2 FC MK	1 1 1 2 -- -- 10 -- -- -- --		✓	15
2 25% cholesterol	CO PD WD B PM WT1 RDDB FM WT2 FC MK	1 1 1 2 -- -- 8 -- -- -- --		✓	13
3 50% cholesterol	CO PD WD B PM WT1 RDDB FM WT2 FC MK	1 1 1 2 -- -- 6 -- -- -- --		✓	11
4 75% cholesterol	CO PD WD B PM WT1 RDDB FM WT2 FC MK	1 1 1 2 -- -- 4 -- -- -- --	✓		9
5 90-100% cholesterol	CO PD WD B PM WT1 RDDB FM WT2 FC MK	1 1 1 2 -- -- 2 -- -- -- --	✓		7

3.1.5 Calculation of on time delivery and delayed delivery percentages

The on time delivery (OD) of a product is the time taken for that product to complete the total cycle time (From idea/conception to customers) in hours to meet the delivery date or schedule. It is measured in percentages (%). Based on the current production line in figure 6 and the operation sequence, timing and delivery status of products in table 4, the on time and delayed delivery percentages are calculated.

It is calculated by using the formula;

$$OD = \frac{X}{U_T} * 100\ \%$$ (Alemu et al 2009)

Where;

X = Total number of on time delivery (OD) of product

U_T = Total number of products

From table 4;

On Time Delivery (OD) $= \frac{2}{5} X\ 100 = 40\ \%$

Delayed delivery (DD) occurs when a product is being delivered at any time over and above its expected delivery schedule.

It is calculated by using the formula;

$$DD = \frac{Y}{U_T} * 100\ \%$$ (Alemu et al 2009)

Where;

Y = Total number of delayed delivery (DD) of products

U_T = Total number of products

From table 4;

Delayed Delivery (DD) = $\frac{3}{5}$ X 100 = 60 %

The production of crude oil done by the oil extraction press is continuous but that of the refining (RDB) cylog is sequential per product due to the difference in cholesterol percentages there by causing the cycle time too long for products that need to be well refined (For example 0% cholesterol free palm oil) and hence not meeting the costumers demand on time. It is viewed that 60% of the company's products are not delivered on time to the customer and only 40% of products are delivered on time. It is shown that much has to be done to increase the percentage of products delivered on time, thereby reducing the percentage of delivery delay of the products.

3.2 Problem definition

After cross examination of the processes carried out in C.D.C. for the production of refined palm oil as shown on figure 6, it is viewed that the problem of delayed delivery of the various products is from the production line. This is because of sequential production being carried out whereby one type or variety of product is refined, filtered, filled and corked (Total cycle time is complete) before the next product can be produced. This problem begins from the refining cylog (RDDB cylog) and there is just one production line. Two or more products of different cholesterol percentages can not be refined at the same time. The downtime is high since much time is taken to trace faults. Therefore, the delayed delivery percentage of products (60%) has to be reduces tremendously, while the on time delivery percentage of products (40%) has to drastically increase so as to meet the market demand of Europe, Africa and the CEMAC zone

(Economic and Monetary Community of Central African States). Much work has to be done to improve the production and a proposed model would be seen illustrated.

3.3 Proposed Model

After the cross examination of the current system and its problems in the C.D.C, a new and appropriate model for improving the production sector was proposed. Concurrent engineering was implemented in the propose model and a simulation is performed.

Since the C.D.C produces five deferent products of different cholesterol percentages, five production lines are to be used in the proposed model, since the demand for the products are extremely high. Data below shows the quantity of refined palm oil required per product in each production;

0% cholesterol = 28,000 liters (28 tons) per day

25% cholesterol = 32,000 liters per day

50% cholesterol = 36,000 liters per day

75% cholesterol = 60,000 liters per day

100% cholesterol = 80,000 liters per day

Total = 118,000 liters in 12 hours and 236,000 liters (236 tons) in 24 hours.

3.4 Implementation of concurrent engineering (CE) in the proposed model

With the proposed model, concurrent engineering was implemented. Five production lines are added so that more that all the five product types can be refined, filtered, filled and corked (Concurrently), thereby increasing the on time delivery and meeting the require scheduled time since the sequential production is not rampant here. Each product is produced continuously for 24hours so as to meet the huge market demand of the products. The proposed system design is shown in figure 7. It illustrates the proposed system that can be used to produce these five products of different cholesterol percentages. From the proposed model, it is viewed that each product is produced individually per line. Note should be taken that, when the cycle time of a product is finished, a new production of that same product proceeds. This is due to the huge amount of products being demanded by the consumption market (CEMAC, African, Asia, Europe and the Americas). The meaning or function of the numbers on each block is illustrated in table 3. Table 4 shows the operation sequence, timing and delivery status of each product in the proposed model.

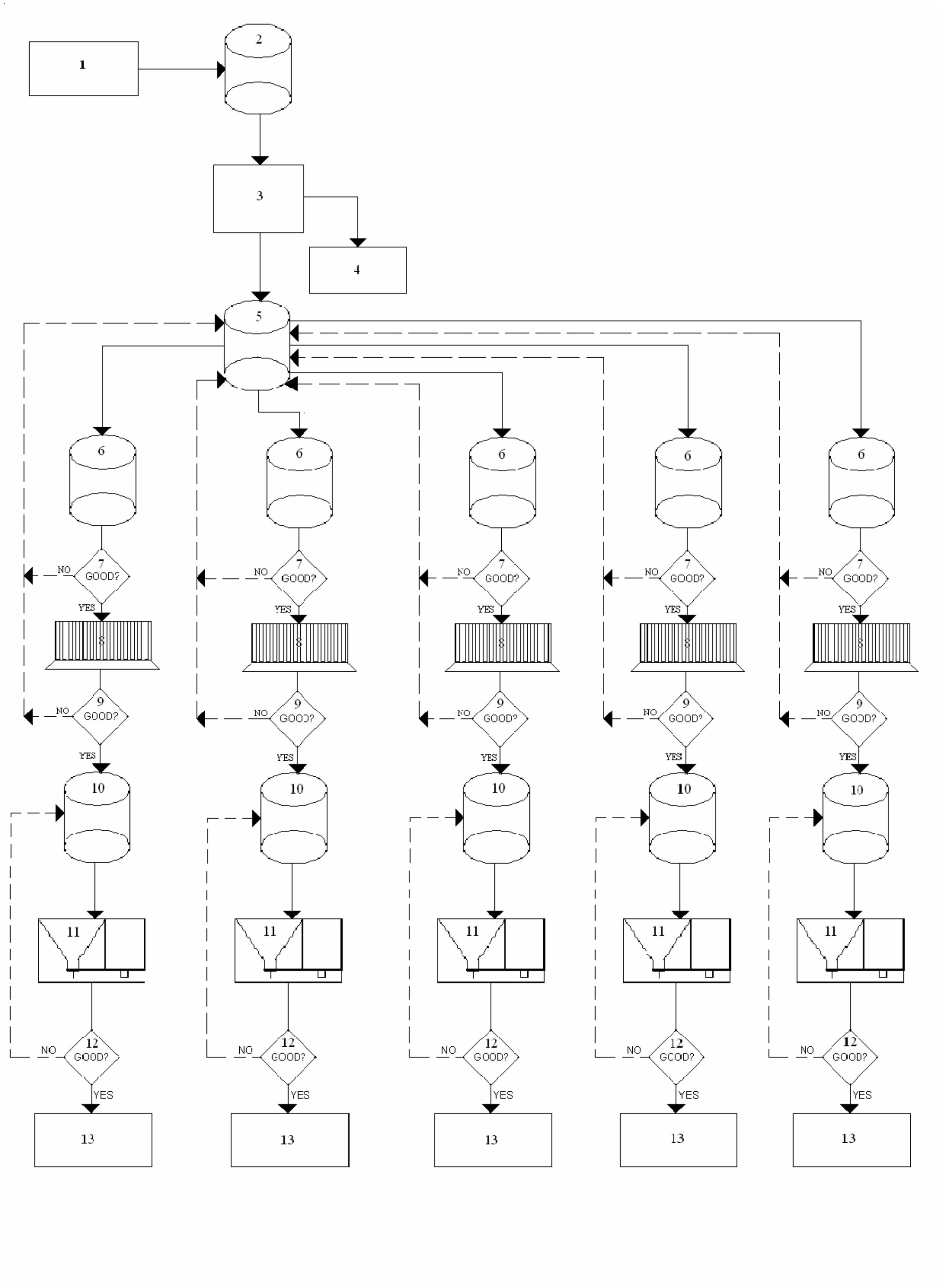

Figure 7: Proposed system design for the C.D.C.

Table below shows the list of numbers and their meaning on figure 5.

Table 5: List of block numbers and their meaning or function.

Number	Meaning
1	Idea and design bureau
2	Washing, disinfection and Boiling of palm nuts of nuts
3	Production mill
4	Palm nuts waste used as fertilizer in plantations
5	Waiting tank (Crude palm oil)
6	RDDB (Refining, Deodorizations, Decolourization bleaching) Cylog. This is where the % of cholesterol is brought to its required amount.
7	Is the RDDB good? If Yes; it goes to the next step. If No; It goes back to the Waiting tank to be re-processed with incoming crude.
8	Filtering machine (filtering of palm oil)
9	Is the filtering of the refined palm oil good? If Yes; it goes to the next step. If No; It goes back to the Waiting tank to be re-processed with incoming crude.
10	Waiting tank. Refined palm oil
11	Filling and Corking Machine
12	Is the filling and corking done properly? If Yes; It goes to the next step. If No; It goes back to the waiting tank 10, to be refilled and corked with incoming refined palm oil
13	Customers

Table 6 illustrates the operation sequence, timing and delivery status of products in the C.D.C.

Table 6: Operation sequence, timing and delivery status of products.

Product Type	**List of operations**	**Time Hours. Total time=T**	**On time Delivery (OD)**	**Delayed Delivery (DD)**	**Before time delivery** (BD)
1 0% cholesterol	1 2 3 4 5 6 7 8 9 11 12 13	1 2 -- -- -- 10 -- -- -- -- -- -- **T=13**	✓		
2 25% cholesterol	1 2 3 4 5 6 7 8 9 11 12 13	1 2 -- -- -- 8 -- -- -- -- -- -- **T=11**	✓		
3 50% cholesterol	1 2 3 4 5 6 7 8 9 11 12 13	1 2 -- -- -- 6 -- -- -- -- -- -- **T=9**		✓	
4 75% cholesterol	1 2 3 4 5 6 7 8 9 11 12 13	1 2 -- -- -- 4 -- -- -- -- -- -- **T=7**			✓
5 90-100% cholesterol	1 2 3 4 5 6 7 8 9 11 12 13	1 2 -- -- -- 2 -- -- -- -- -- -- **T=5**			✓

3.5. Calculation of on time delivery, delayed delivery and before time delivery percentages

The on time delivery, delayed delivery and before time delivery percentages are calculated based on the proposed model in figure 7 and the operation sequence, timing and delivery status of products in table 6.

On Time Delivery (OD) = $\frac{X}{U_T} * 100\ \%$ (Alemu et al 2009)

On Time Delivery (OD) = $\frac{2}{5} X\ 100 = 40\ \%$

Delayed Delivery (DD) = $\frac{Y}{U_T} * 100\ \%$ (Alemu et al 2009)

Delayed Delivery (DD) = $\frac{1}{5} X\ 100 = 20\ \%$

Before time Delivery (BD) = $\frac{2}{5} X\ 100 = 40\ \%$ (Alemu et al 2009)

Before time delivery (BD) occurs when a product (s) is being delivered at any time before the expected delivery schedule.

Total Delivery percentage = OD + BD (Alemu et al 2009)

= 40 % + 40 %

= 80 %

With the implementation of concurrent engineering all the five product type of different cholesterol percentages can be produced concurrently and this simultaneously enforces the "on time delivery" and hence meeting the customers demand. With the implementation of concurrent engineering by creating multi-production lines in the C.D.C's production sector, the percentage of on-time delivery is 40%, that of before time delivery is 40% and the percentage of delay delivery is reduced to 20%. The overall cycle time in hours for the five products is reduced since batch production is no more, thereby minimizing cost and time, and meeting the customers demand.

With the aid of simulation in the proposed model, it is viewed that, the down time (Time period when there is fault or break down, till when it is solved) would be low. This is simply because when there is fault or break down, the buffers indicate the line and machine that the fault is coming from.

Chapter 4

PROPOSED MODEL

4.1. Simulation of the proposed model

Simulation here is to demonstrate the manufacturability of the proposed model. The simulation program used here is called activplant (Activating intelligent manufacturing). This would give us the throughput of the system.

Throughput is the maximum overall equipment effectiveness (OEE) that a line can produce, based on the performance of each station on the line. If any station is constrained and delivering less-than-optimum output, the throughput capability of the entire line cannot exceed the throughput capability of that particular station.

4.1.2 Activplant software

Activplant software is a platform for meaningful manufacturing and business intelligence. The Activplant family of products provides a strong foundation for manufacturers who need to focus on strategies for moving their enterprise forward. At Activplant, we believe that data in itself does not provide manufacturing and business intelligence (MBI). MBI can only come from collecting the right data, analyzing it, and processing it in a way that enables personnel, from the shop floor to the management office, to make the best possible decisions. Activplant's software makes the promise of manufacturing and business intelligence a reality. Refer to appendix 1 for more on Activplant software.

The proposed model was developed by collecting data (Operation sequence, timing delivery status of products quantity produced) from the old model including the demand and target to be met and not forgetting the number of lines (Single production line) and its production stages. The program Activplant Insight for Excel is opened and you go to file menu and click function editor. The data is input into the Activplant Insight for Excel-function editor which is an ActivEssentials platform (Refer to appendix A). When the required data is input in the spreadsheets provided, click preview and save the document (See figure 8). The Activplant simulation software is opened. On the insert menu, we click insert file and select the file name (C.D.C) and it is inserted into the Activplant simulation platform. The model is automatically updated by clicking the update button. This takes some minutes, depending on the quantity of data input but for this particular case, the run time was 3 minutes. The plant opens and the throughput simulation for the proposed model of the C.D.C is viewed.

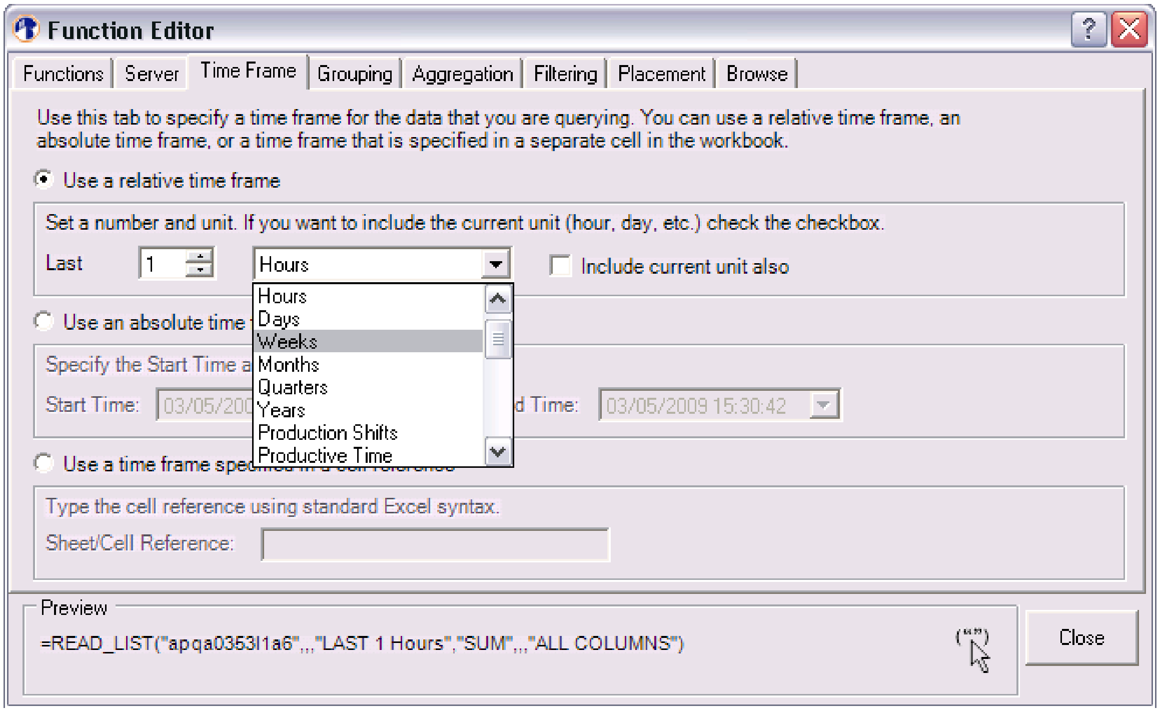

Figure 8: Acivplant Insight for Excel-function editor

You can specify shifts, batches, product codes or lots within particular time frames for targeted reports. Filters that exclude certain data, such as all data for a shift or all data on a product can be created.

Two different experiments have been conducted for the proposed model. One without failure and the other with failure.

Figure 9 shows the throughput simulation of the proposed C.D.C. production lines without failure. The percentage of availability of the raw materials (palm nuts) is 95%. For example in line 1, station 1 reads 94.1 %, station 2 - 94.0 %, station 3 - 94.1 %, station 4 - 94.3 % and station 5 - 95.0 %. The production board shows attainment level - 98 %, FTT (First time through quality) - 96% and OEE (Overall equipment effectiveness) - 89 %. The amount of refined palm oil produced is 12300 liters and the target is 14000 liters. Buffer reads 0.0 meaning that no station along that production line has a problem or delivering less-than-optimum output resulting to a good and effective throughput. The throughput of all the other production lines is shown in figure 4.1 below. Line 5 has reads attainment - 99.9, FTT - 99 and OEE - 94, production level 21700 liters with target 20000 liters. Line 5 has the highest throughput out come as seen on figure 4.1. The total amount of refined palm oil produced in a day from the simulation results of the proposed model is 84,100 litters.

Figure 10 illustrates the throughput simulation of proposed C.D.C. production lines with failure or faulty station(s) in lines. The buffer 3 reads 3.2. This tells us that in line 3, station 2 has a fault or breakdown. Station 2 reads 64.6 % showing that it is delivering less-than-optimum output. Attainment reads 46.5 and the throughput (OEE) reads 44.1%, which goes support the statement "the throughput of the entire line cannot exceed the throughput of that particular station". 7144 liters of refined palm oil is produced, which is a drop down in production. The buffer 5 reads 5.5 meaning that line 5, station 2 has a problem. Station 5 reads 75.5 % with attainment - 66 % and OEE - 56.4 %. 12238 liters of refined palm oil is produced. With this system, problems or faults can be easily identified and repaired for production to continue. This goes to reduce the down time (The total time of zero production due to break down at a station(s) in a production line).

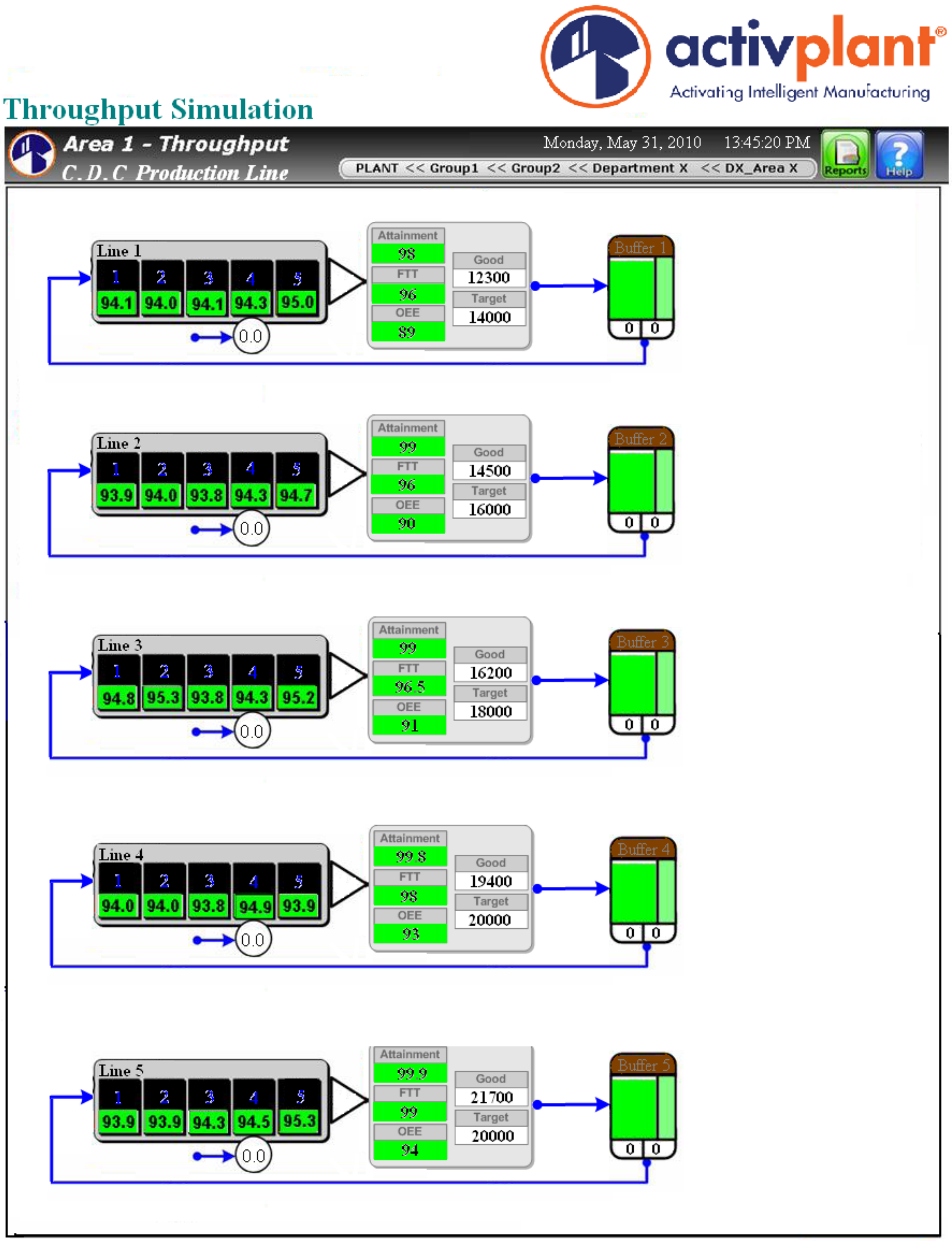

Figure 9: Throughput simulation of proposed C.D.C. production lines.

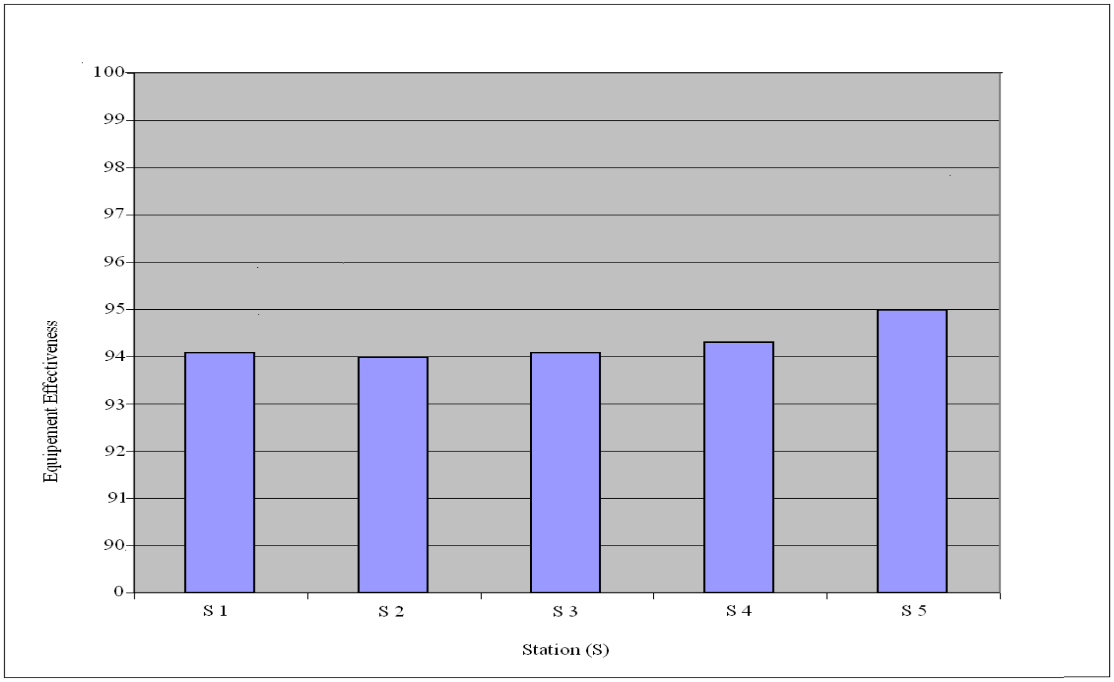

Figure 10: Equipment effectiveness of production line 1.

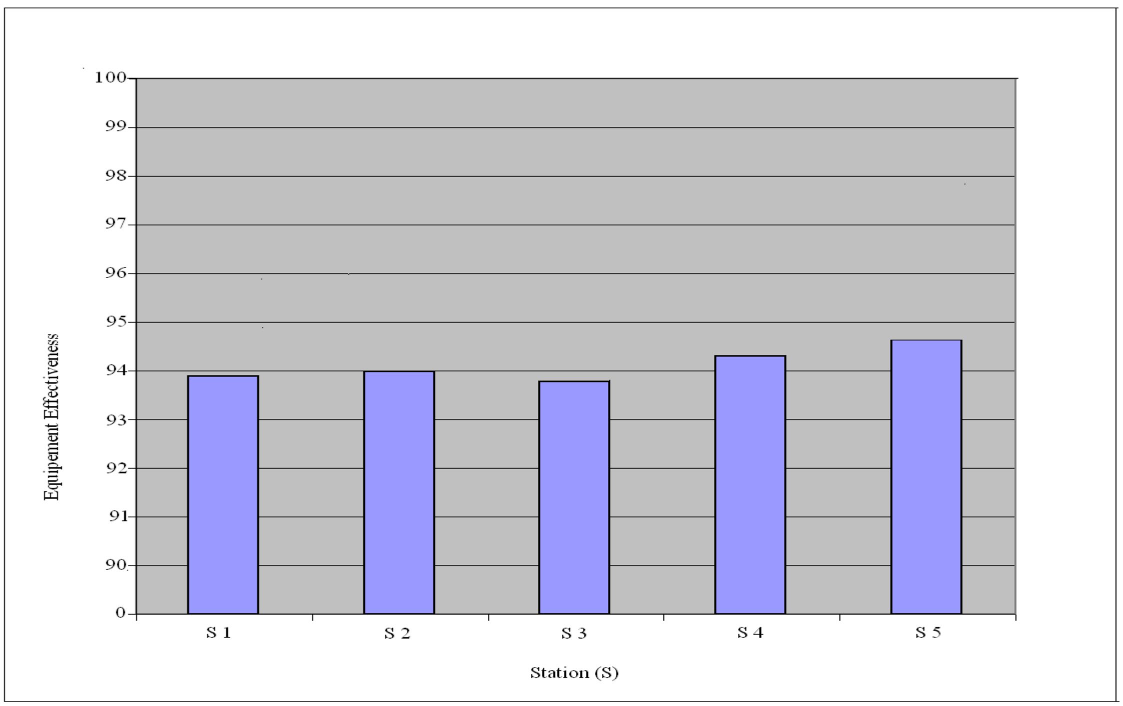

Figure 11: Equipment effectiveness of production line 2.

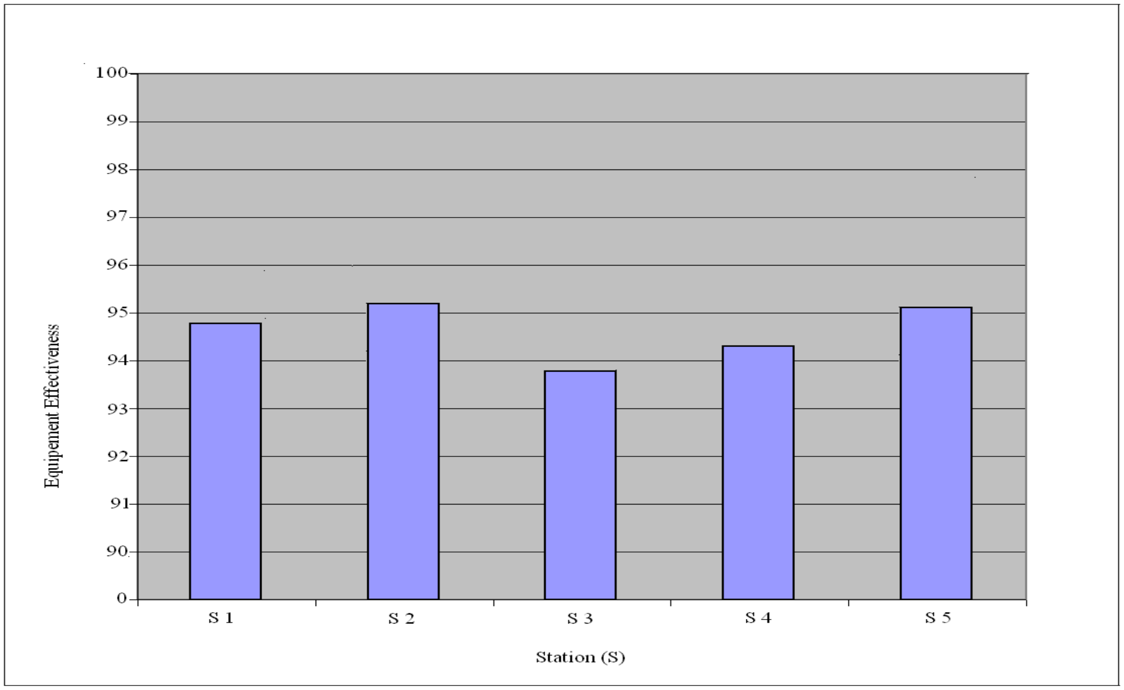

Figure 12: Equipment effectiveness of production line 3

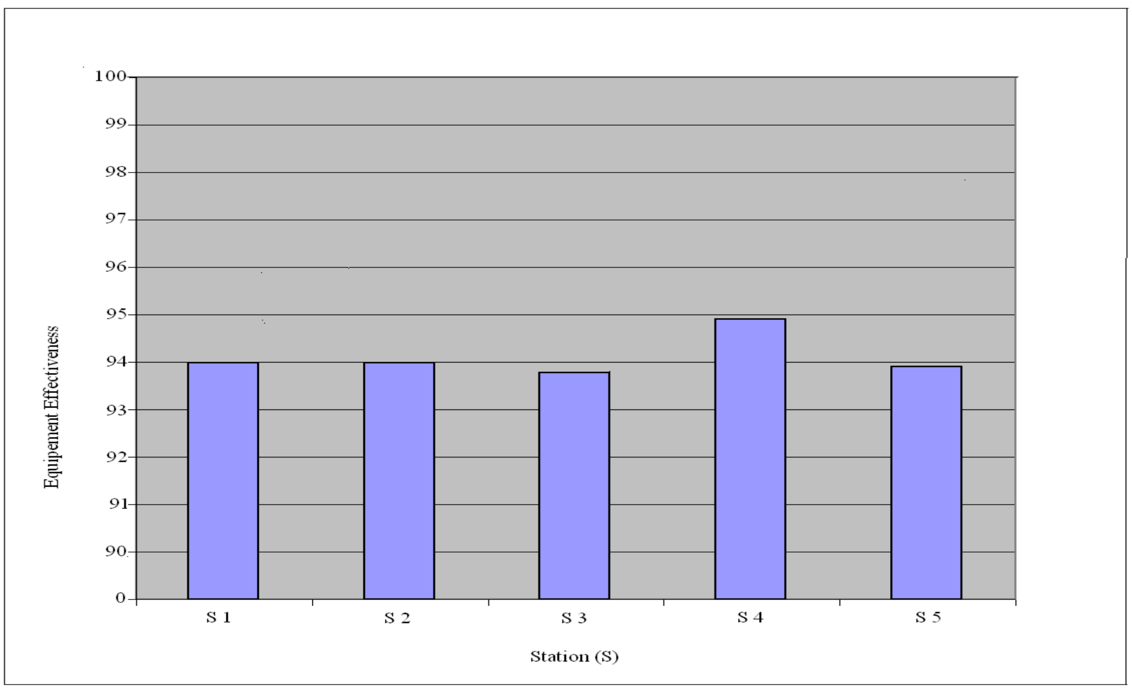

Figure 13: Equipment effectiveness of production line 4.

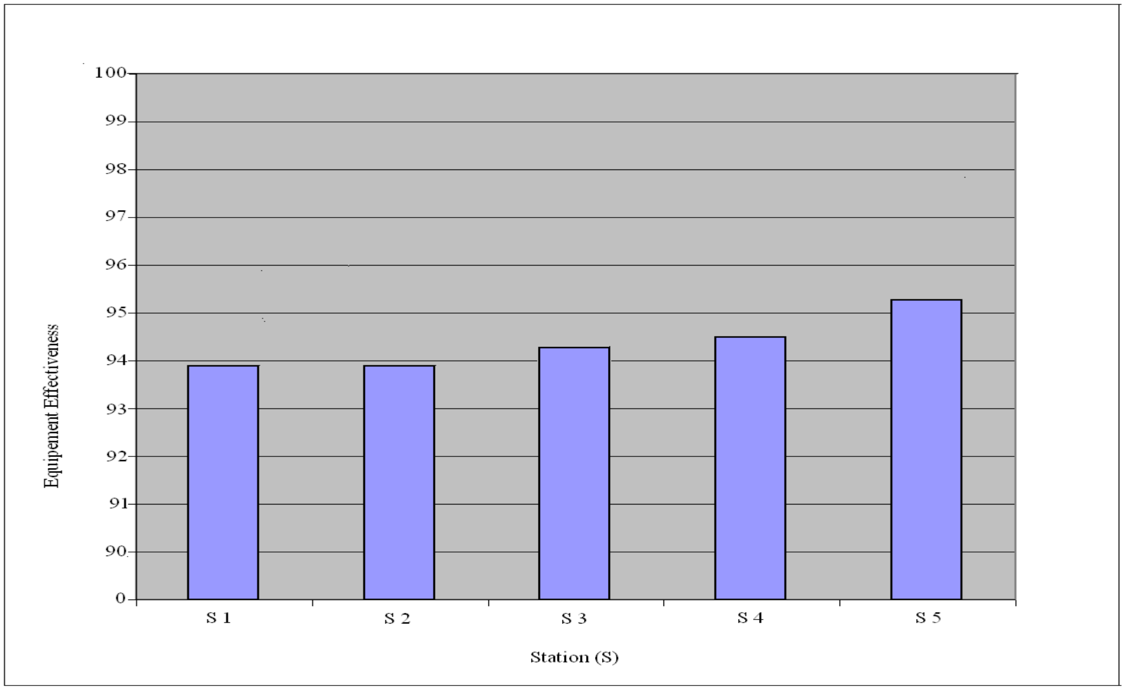

Figure 14: Equipment effectiveness of production line 5

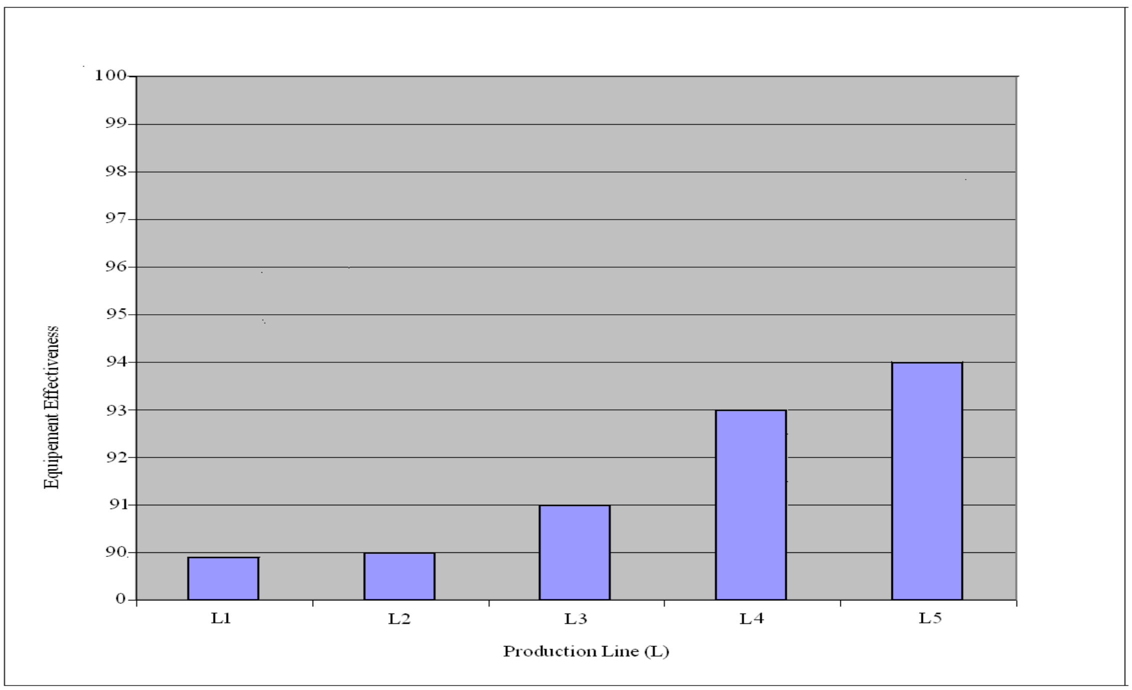

Figure 15: Equipment effectiveness of all 5 production lines

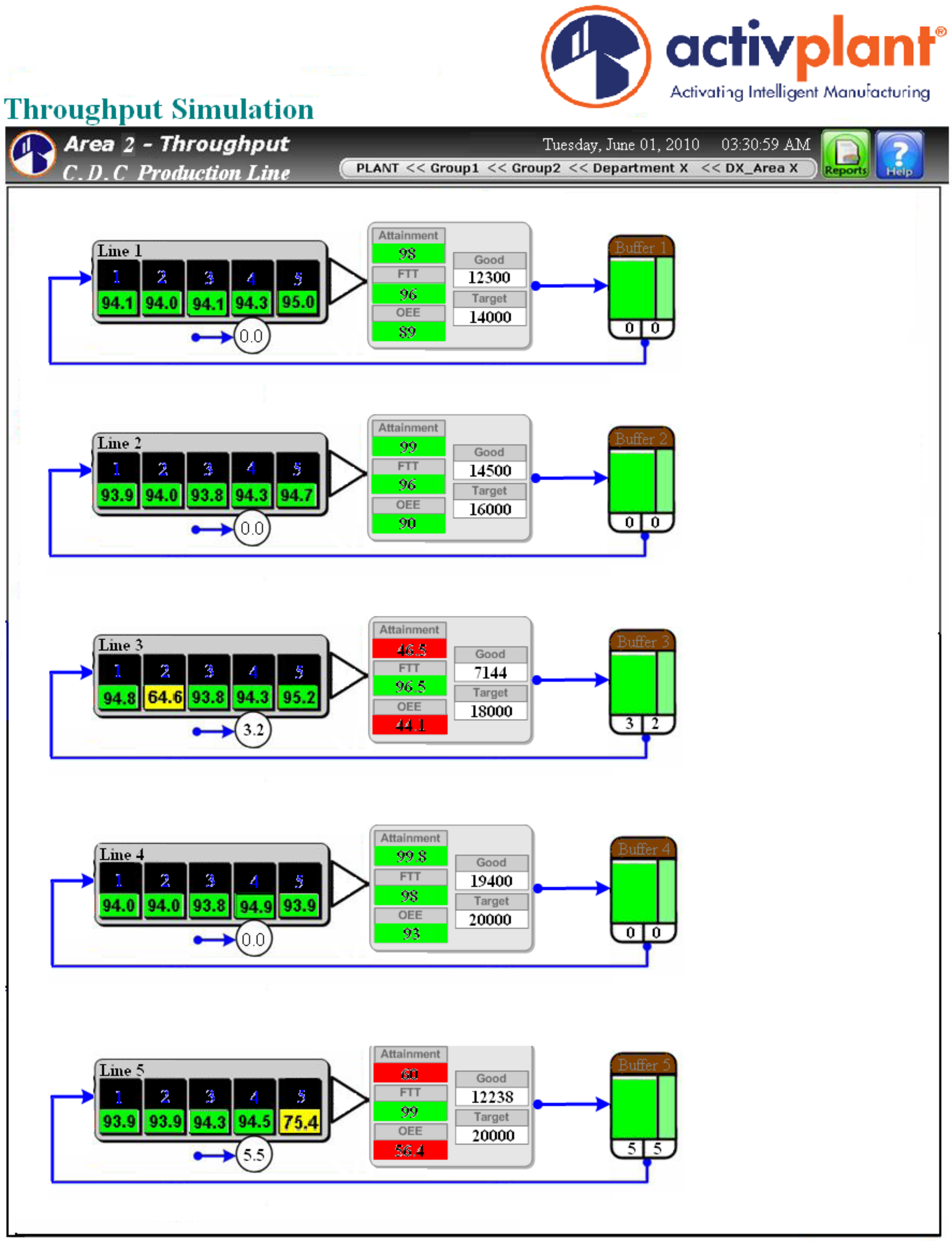

Figure 16: Throughput simulation of proposed C.D.C. production lines with faults.

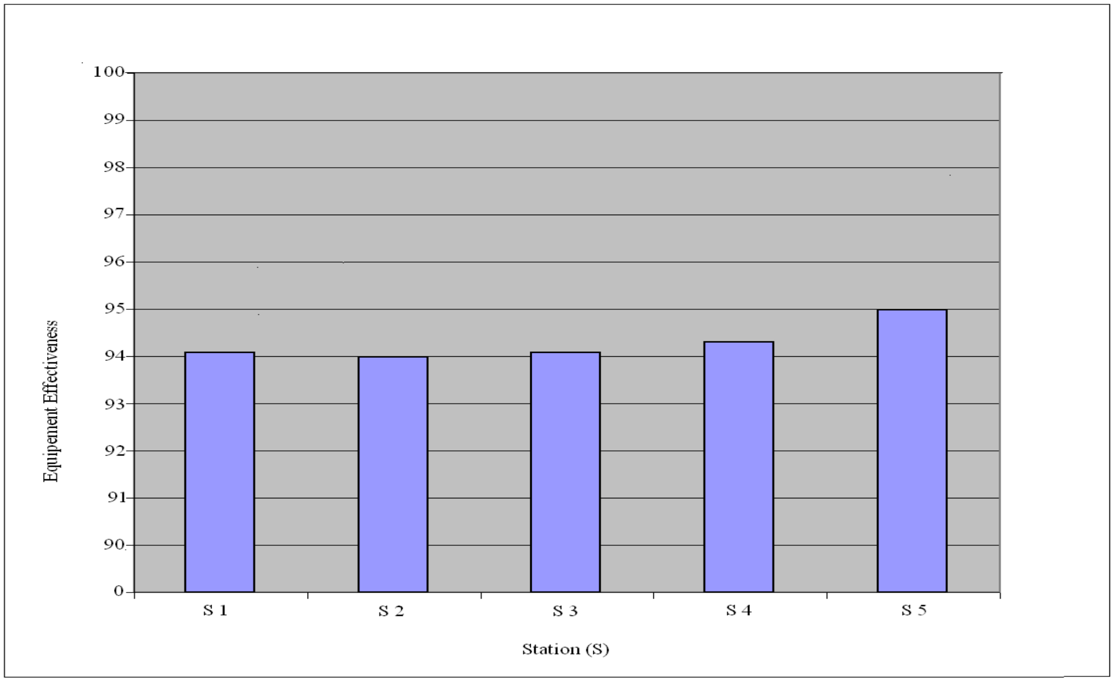

Figure 17: Equipment effectiveness of production line 1.

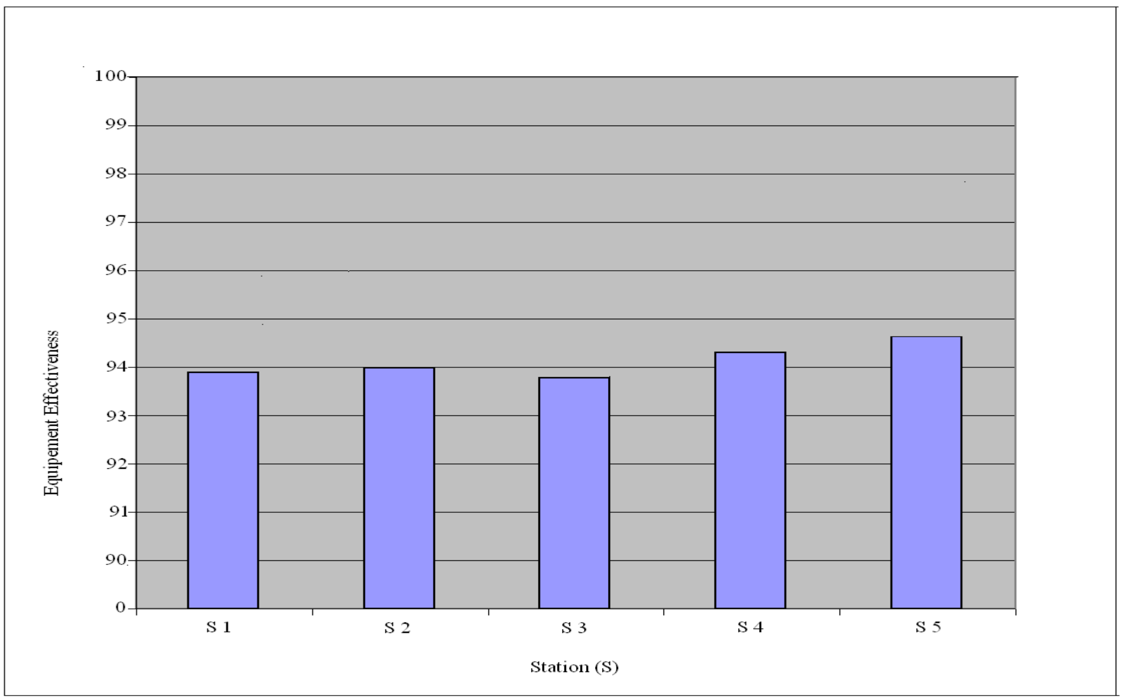

Figure 18: Equipment effectiveness of production line 2.

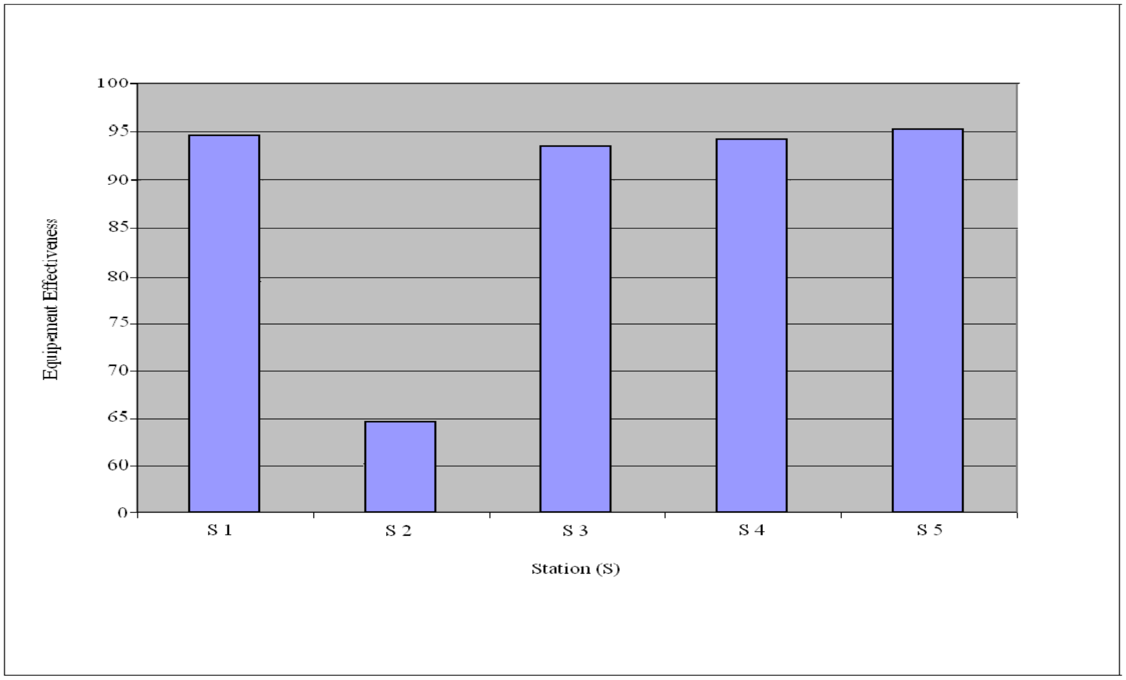

Figure 19: Equipment effectiveness of production line 3.

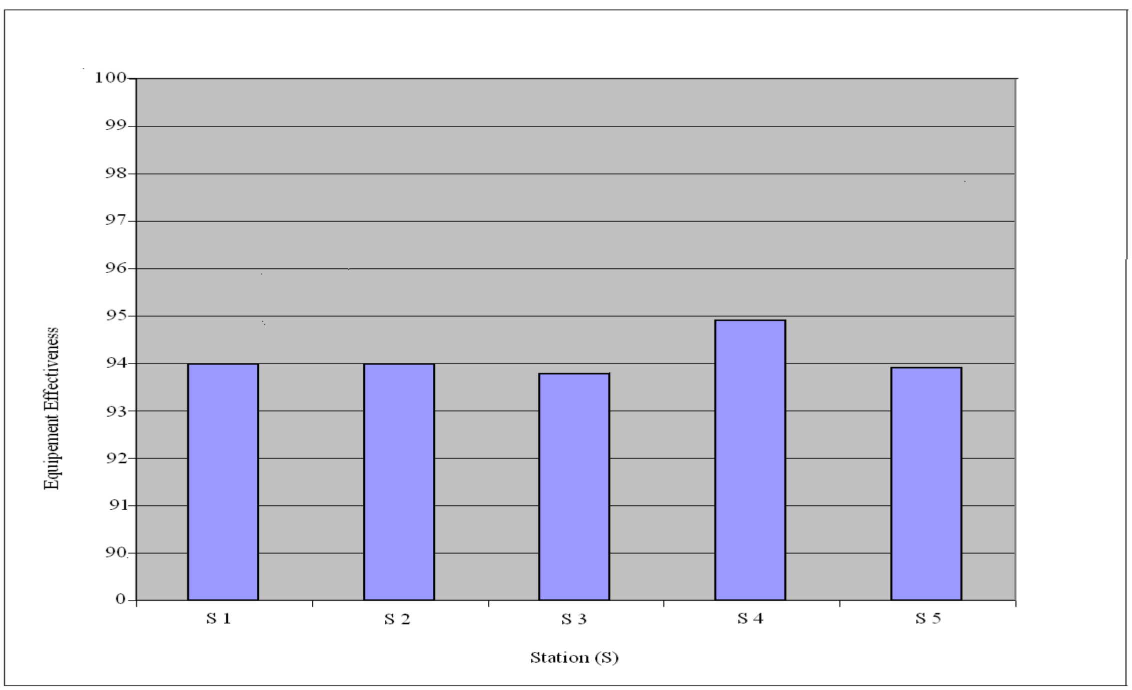

Figure 20: Equipment effectiveness of production line 4.

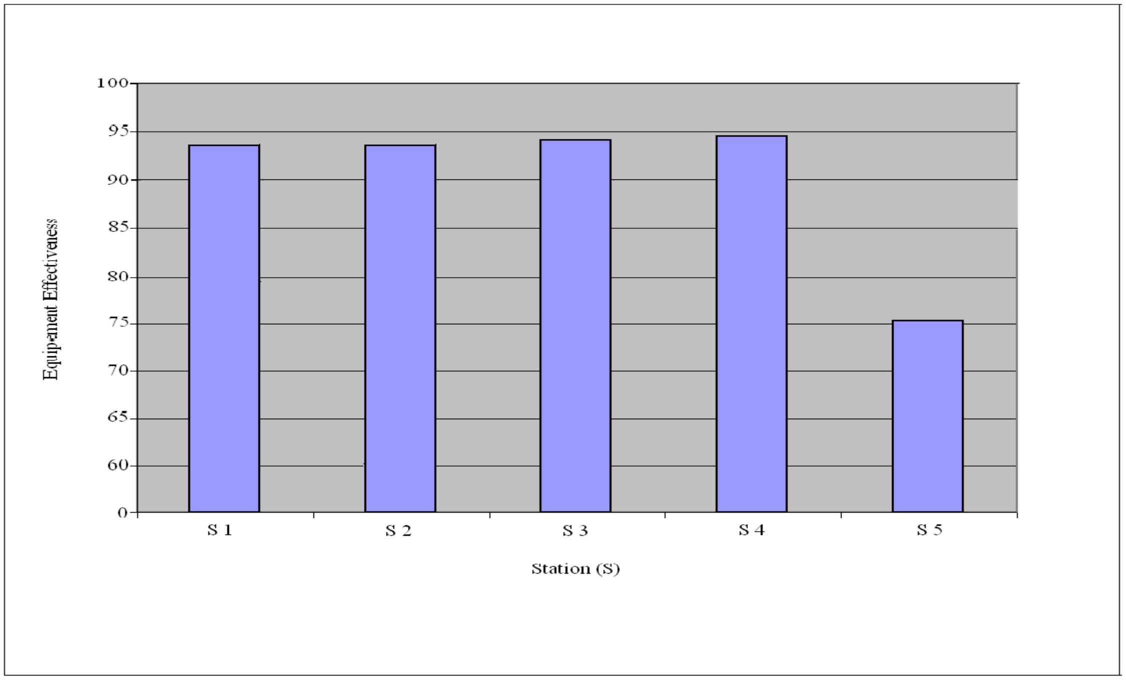

Figure 21: Equipment effectiveness of production line 5.

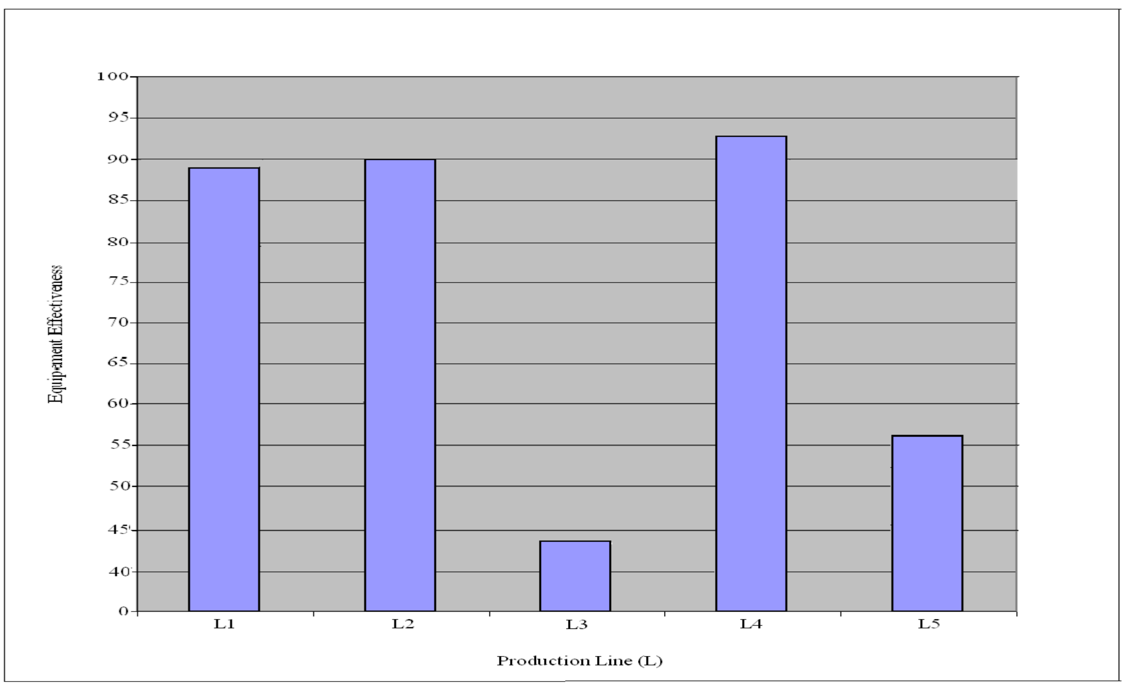

Figure 22: Equipment effectiveness of all 5 production lines.

Chapter 5

INVESTMENT APPRAISAL FOR THE C.D.C. PROPOSED MODEL

5.1 Definition of investment appraisal

Stephen Fox 2008 defined investment appraisal as the activity responsible for carrying out a cost benefit analysis to justify capital expenditure for a new or changed system. With investment appraisal, it is easy for us to know the payback time for our proposed model. Payback time is literally the amount of time required for the cash inflows from a capital investment project to equal the cash outflows.

Payback period = Overall cost of machines / Annual Machine profit (Stephen Fox 2008)

It is necessary to know after our simulation of the proposed model, how much the Cameroon Development Corporation (C.D.C.) would spend to acquire such a plant and knowing the pay back time of the proposed investment.

Note should be taken that, the costing being done are approximations and may very from time to time due to currency rates. The estimated annual income for the proposed model relative to the simulation results is $ 100,000,000 (Target of 50,000 metric tons a year X 500francs [$ 1] = $ 50,000,000,000). The cost of implementing the proposed model that has been simulated is examined in table 7.

The prices of the machines were gotten from Ningbo Xinjiang Import and Export Co.

Ltd No.659 Ren Min Rd, JiangBei, Ningbo , China.

Table 7: The cost of implementing the proposed model for the C.D.C.

Itinerary	Type of Machines				
Cost in $	1 Waiting tank	2 Filtering machine	3 Cylog Tank	4 Corking and filling machine	5 Buffer
Machine cost	$50,000	$150,000	$80,000	$30,000	$20,000
Cost of installation	$10,000		$15,000	$5000	$5000
Maintenance cost	$5000		$10,000	$3000	$5000
Total	$65,000	$150,000	$105,000	$38,000	$30,000
Miscellaneous (pipes, pumps, cables, heating coils etc). for the complete line	$50,000				
Extension cost for the complete line	$100,000				
Overall Total	**$ 538,000**				
Annual Machine profit (Average)	$ 134,500 Annually (Quater of $ 538,000)				

Therefore the total cost for 5 lines (Investment cost) = $ 538,000 X 5

= **$ 2,690,000**

Table 8 shows the production capacity of the present system and the simulated proposed model of for the Cameroon Development Corporation (C.D.C). The annual income is also illustrated and the payback time calculated.

Table 8: Production capacity and income of the present system and the proposed model.

Model itinerary	Production capacity (In metric tons)	Annual income ($)
Present system	30,000	50,000,000
Proposed model.	50,000	100,000,000

Payback period = Overall cost of machines / Annual Machine profit (Average or Shared)

(Stephen Fox 2008)

$$\text{Payback period} = \frac{\$\ 538{,}000}{\$\ 134{,}500}$$

Payback period = 4 years

Therefore, with the help of data from the simulation, price quotation from Ningbo Xinjiang Import and Export Co. Ltd and implementing economics, it has been calculated that the payback period for the doing this investment is four years.

Chapter 6

DISCUSSION OF THE SIMULATION RESULTS AND CONCLUSION

In this study we have shown how to use simulation modeling to solve real-life problems in manufacturing systems to achieve improvements within current resource constraints or using new proposal resources.

In this study, system analysis results enable us to understand the components of the real system and their contribution on the performance measures. This was the learning objective of the simulation study. This is very important for the top management of the company for running after performance improvements. Firstly, the system and its behavior were examined to identify which stage creates bottleneck in the system. Then a proposed model was designed, concurrent engineering implemented and the designed model simulated to demonstrate the manufacturability of the system.

In the old model, batch production was carried out. One type of product is manufactured first, stopped and then the next. Due to the continuous high demand of the five product types in the market, the five production lines were used for continuous production of the five products in other to meet the approximate target of 238,000 liters a day.

The proposed system showed how simulation was used to help a small and medium size enterprise when it is equipped with more production lines to produce the different types of products. The increase in production lines will tremendously increase productivity especially in this case where there are enough raw materials and a vast market to supply with different product types (Products with different cholesterol percentages). The buffers are for spontaneous fault detection within each production line, which helps to reduce the downtime (The total time of zero production due to break down at a station(s) in a production line), simultaneously increasing product quality and meeting the customer's demand.

With the help of simulation to check the effectiveness of the proposed model, some of the data is being used to carry out the investment appraisal of the new system. The pay back period is gotten which is four years. The amount used for the payback is the average or shared revenue for the machines. Depreciation has also been sorted out.

For future work in this area, there is much to be done since the demand for palm oil is greatly needed for the production of bio-fuel. Since the world population is increasing, palm oil offers an outstanding opportunity to provide a sustainable source of food ingredients and nutrition for much of the world's population. We believe that a significant effort on quality assurance and sustainability is now essential to enable this opportunity to be fully realized for the future.

In conclusion, the factory's goals were fully met to obtain the best solution by implementing concurrent engineering in the proposed design and simulating it to check the performance of the model. The investment appraisal carried out for the proposed model has also helped us to know the cost and payback period if this system is implemented. If the suggested modifications to factory's manufacturing operations are implemented by considering the results of the simulation study and the investment appraisal, factory can improve its production. Therefore, the results of this thesis study are expected to be useful reference for small and medium size enterprises, especially to the factory under study for its process of improvements.

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APPENDIX

Appendix A: Activplant Software

Activplant software is a platform for meaningful manufacturing and business intelligence. The Activplant family of products provides a strong foundation for manufacturers who need to focus on strategies for moving their enterprise forward. At Activplant, we believe that data in itself does not provide manufacturing and business intelligence (MBI). MBI can only come from collecting the right data, analyzing it, and processing it in a way that enables personnel, from the shop floor to the management office, to make the best possible decisions. Activplant's software makes the promise of manufacturing and business intelligence a reality. The Activplant software is made up of ActivEssentials platform. The ActivEssentials Platform is the multi-component system at the heart of the Activplant solution. Depending on your needs, ActivEssentials scales easily to meet the needs of your organization. We have deployed our platform in production environments that build complex assemblies with hundreds of machines and in others that use just a few yet produce thousands of units per hour. If necessary, this scalable solution is distributable across several servers. Built on Microsoft technology, the Platform requires Windows servers, SQL Server and Microsoft web servers. This platform contains the Activplant Insight for Excel and Throughput simulation. Activplant Insight for Excel is a Microsoft Excel add-in that provides a “live link” from Excel spreadsheets to ActivEssentials shop floor data. This provides you with the ability to create spreadsheets that not only pull data directly from plant operations, but spreadsheets that can be automatically updated with the latest information with the push of a button. Today, manufacturers face a very difficult environment, where their very ability to survive will depend on their willingness to adapt and explore new possibilities. To meet these challenges, it is crucial that you have up-to-date information about every aspect of your manufacturing operations. This data must be accurate, easy to access, and customized to meet the needs of your particular enterprise. Insight for Excel provides you with the information you need to pursue the continuous improvement projects that ultimately allow you to become leaner and more efficient. The Activplant Throughput Analyzer provides a software solution to finding production constraints, a solution that has otherwise eluded manufacturers. Whether it be on production lines that produce complex assemblies, or on lines that run at high speed with relatively few manufacturing steps, the challenge has always been to find the equipment that constrains your manufacturing potential. You know you can get more from what you have, but you can't unlock the puzzle. Throughput Analyzer users have experienced throughput gains in the order of 10%–25%.