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Faculty of Graduate Studies

Simulation Modeling Applications in Organization Management

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This Thesis is submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering Management, Faculty of Graduate Studies, An-Najah National University, Nablus- Palestine.

2013

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ACKNOWLEDGMENT

In the beginning I thank ALLAH and praise Him in a manner that befits the (infinite) number of His creation, and as it pleases Him, for supporting me in the completion of this work. I would like to express my gratitude to my supervisor Dr. Amjed Ghanim for being an outstanding advisor and excellent professor. I am deeply indebted to my committee members, Dr. Mahasen Anabtawi and Dr. Yahya Saleh for their time and effort in reviewing this work.

I am greatly indebted to Sinokrot Global Group for their business case contributions. I'm especially indebted to G.M Mazen Sinokrot, Eng. Muhsen Sinokrot, Eng. Hamzeh Sinokrot and the staff who shared their experiences and insights with me.

My sincere thanks go to Dr. Husam Araman and Dr. Mohamed Othman for providing me with their valuable insights on my research progress.

I am deeply and forever indebted to my parents Adli and Basemah for their love, support and encouragement throughout my entire life. I am also very grateful to my brothers; Eng. Hussein, Mr. Tariq, Mr. Oday, Dr. Abdul Aziz, sister Haneen, and to their lovely families.

Words fail me to express my appreciation to my wife Dr. Heba whose dedication, love and persistent confidence in me, have taken the load off my shoulder. I owe her for being unselfishly letting her intelligence, passions, and ambitions collide with mine.

الاقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان :

Simulation Modeling Applications In Organization Management

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The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Abstract

The purpose of this thesis is to develop simulation models in areas of supply chain, manufacturing systems, and risk management in case of stochastic driving factors, very complex systems, and interrelated factors where analytical or mathematical models are not effective.

To understand the structure of supply chain, manufacturing systems, and risk management models, a simulation model for Sinokrot Company is developed according to a methodology which includes collecting and analyzing data, building the simulation model using ARENA software and Excel sheets, verification and validation, statistical experimented design, and performance analysis.

Many simulation scenarios are developed in order to evaluate: ad hoc system, decisions at all levels to achieve organization objectives such as increase products sales, allocation a specific production line, inventory management, and others.

Besides, this thesis deals with developing optimization-simulation models to design or re-design inventory management parameters in order to minimize inventory costs, inventory level based on lean manufacturing philosophy, and maintain stock-out percentage less than specific point.

Those models are considered as knowledge contribution in these areas where simulation models are recommended to improve ad hoc system. It is concluded that the role of the developed simulation models in improving supply chain, manufacturing system and risk management, is needed where decisions at all level are made based on simulated scenarios or polices in stochastic and complex environment.

CHAPTER 1

INTRODUCTION

The enterprises and companies in the world are now affected by very variable and interrelated multi driving factors as well as the complex environment. The traditional strategic planning tools are not effective to deal with high speed changing and the complex relations among these driving factors; due to some of these tools are static tools in dynamic environment and even dynamic tools cannot provide decisions with confidence or justifications of expected outputs in complex environment. To over-come this problem, many of simulation techniques are used at strategic, tactical and operational levels.

Simulation applications can be used in generating strategic decisions, scenarios, and policies according to ad hoc situation and desired situation (vision). In addition, Simulation applications are used to evaluate each decision supporting to achieve higher level objectives, evaluate the impact of these decisions on the enterprise resources and competitive advantages to evaluate set contingency plans, and analyze the relationships among the system internal and external driving factors.

Recently, simulation techniques have been used popularly because of the reduction in cost of using user-friendly and powerful simulation software which leads to increase the speed of model building and delivery according to established set of guidelines of simulation referenced to. Zandian. [Zandian, 2004]

1.1 SIMULATION

Simulation can be defined as “the imitation of a dynamic system using a computer model in order to improve system performance”[Harrell, 2004], and simulation tools “provide the modeler with the ability to develop simulations using entities that are natural to the system, appeal to human cognition, and exhibit localized behaviors, which is important for complex systems”.[Booch, 1991]

1.2 STRATEGIC MANAGEMENT AND SIMULATION

Strategic management is the systematic analysis of the factors associated with(the external and the internal environment to provide the basis for maintaining optimum management practices). The objective of strategic management is to achieve better alignment of corporate policies and strategic priorities.

Axelson et al. find the formulation of a strategy that outlines current state (the planned or target state) and the operational planned mechanisms to reach the planned state that should be documented and communicated to different levels in the organization. [Axelson et al., 2004]

Papageorgiou and Hadjis in 2011 assured that the complexity and uncertainty of the organizational environment as well as the continuous change which is manifested in new business models and new value systems make it impossible for the intuitive human mind alone to respond with developing effective strategies.

Simulation can test and investigate effectiveness of various business scenarios prior to their implementation. In this way possible mistakes which can prove detrimental to organizations can be avoided.

Zandian classified the usage of computer simulation in businesses as strategic, tactical, or operational based on the time horizon of the decisions made in the simulation study; the time horizon of strategic decisions which upper management takes covers from three years to five or more years, tactical decisions which middle management takes such as purchasing new machines covers from one year to three years, and operational decisions which lower-level management makes such as scheduling of products or workforce assignments covers from days to weeks. [Zandian, 2004]

On the other hand, Tesfamariam, and Karlsson refer Multiple Criteria Decision Making (MCDM) to make decisions in the presence of multiple, incommensurable, and often conflicting criteria. When dealing with such multiple criteria, it becomes necessary to capture the preferences of these criteria in view of their importance or influence to the overall performance objective. This parameterization of criteria can be accomplished by explicating the management view or perception of the higher level strategic objective in terms of the criteria.

They discuss the relations between current system configurations and operation conditions; top-down analysis and bottom-up analysis. Top-down analysis refers to interpreting down (decomposition) of strategic objectives to operational level parameter, while bottom-up analysis refers to how limited is the present system to meet the requirements and what is the level of reconfiguration needed to improve this., Figure (1.1) shows top-down analysis and bottom-up analysis and multi criteria decision making. [Tesfamariam, and Karlsson, 2005]

1.3 RESEARCH STATMENT

In this thesis, the researcher will build a model that can be used in strategic management. The model will be based on utilizing simulation techniques to evaluate a present and desired situation. Making Decisions process is associated with problem definition, collecting and analyzing data, defending criteria, forming alternatives, and then making decision.

Simulation modeling is used in analyzing behavior of studied system, especially where analytical method cannot provide real solutions or rational results. Simulation can analyze complex system due to interrelated external and internal driving variables (stochastic variables) and at hierarchal levels, such as, plant design and layout at strategic level, purchasing new machine at tactical level, and scheduling and control at operational level. Strategically, plant capacity parameters are led by driving external and internal variables such as expected market share, demand behavior, number of production lines, production rate, and handling material system.

The researcher will build the model based on simulation techniques to be utilized in operational making decisions to ensure these decisions will serve tactical or strategic planes. Also, the researcher will investigate the implementation of the making decision process in one of the Palestinian organizations (Sinokrot Food Company -SFCo). He will investigate the degree to which simulation techniques can be used in making decision.

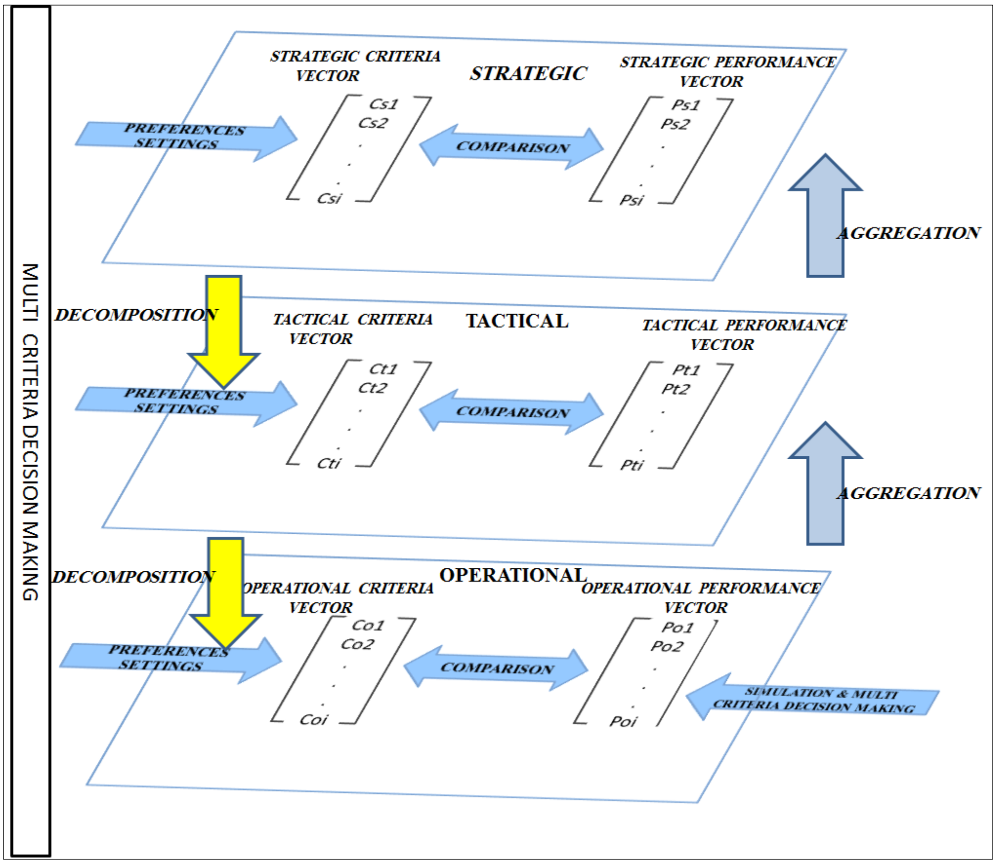


Figure (1.1) MCDM and strategic, tactical, operational levels [Tesfamariam, and Karlsson, 2005]

He will build some simulation models based on ad hoc Sinokrot system and scenarios or decisions. This thesis will be finalized with optimization simulation models; where they are used to determine the optimum raw material inventory parameters which based on either optimum order-quantity inventory system or optimum fixed reviewing time.

1.4 RESEARCH OBJECTIVES

1. Develop simulated planning management tool that will enable mangers to evaluate Ad-hoc and desired situation when managers deal with multi-criteria decisions and behavior of interrelated internal and external variables.
2. Evaluate the integrity and compatibility of the model.
3. Evaluate the implementation of making decision process in local organization (Sinokrot Food Company as case study), and the degree to which they utilize simulation techniques in making decision.
4. Evaluate desired scenarios or decisions that are taken before implementation.
5. Build optimized simulation models in inventory management.

1.5 RESEARCH (IMPORTANCE)

Strategic management model can be a good tool in strategy formulation, implementation and evaluation when mangers face semi-steady behavior of internal variables such as: number of production lines, production rates of production lines, number of working hours, waiting times, inventory parameters, works in process, production time, number of workers, scheduling in addition to the external driving variables such as: demand variables, market share, competitors, delivery and transportation, raw materials prices and so on.

Simulation modeling is powerful tool used in complex system; where interrelated internal and external driving force variables are stochastic.

The importance of this thesis is dealing with real case (Sinokrot Food Company) where the researcher will evaluate ad hoc system, proposed scenarios and decisions, and he will design optimization methodology used in inventory management. The last methodology can be applied in determining optimum parameters of any inventory in the world.

1.6 METHODOLOGY

The researcher will follow the traditional engineering approach in problem solving. (For more details, please see section 2.7: Simulation Procedure), and time frame of this thesis is shown in Table (1.1).

Table (1.1): Thesis Time Frame

#	Stage	Time Frame
1	Define Objective, Scope, and Requirements	2 weeks
2	Collect and Analyze System Data	6 months
3	Build the Model	1 month
4	Verify and Validate the Model	1 month
5	Conduct Experiments	2 weeks
6	Analysis Scenario, Decisions and optimization Models	2 months
5	Present the Results	2 weeks

1.7 RESEARCH TOOLS

To achieve the previously mentioned objectives, the researcher will use the following tools:

1. Define objectives, scope and requirements: by conducting interviews with Sinokrot Food Company, represented by GM, production manager, and sales manager.
2. Data collection: by conducting interviews with GM, production manager, sales manager, maintenance technician, quality assurance manager, laboratory technicians, production supervisors, and inventory manager, by using historical data when is available, and by watching and monitoring the processes in the company.
3. Data analysis: by using Stat-Fit software which provides good statistical analysis and statistical experiments design besides to MS. Excel sheets.
4. Building model: there are many simulation software packages can be used to build the desired simulation model, such as ARENA, SIMULAT8, GOLDSIM, ProModel and others. The researcher uses ARENA software (student version) because it is a simulation environment consisting of module templates and augmented by a visual front end. ARENA is suitable to deal with heretical systems such as main models and sub-models and so on.

1.8 ORGANIZATION OF THE THISES

The thesis begins with introduction chapter to provide the reader with what the thesis is about in general, how the researcher will deal with thesis problem, introductory of simulation and tools.

The second chapter “SIMULATION” is to give well-defined simulation, types of simulation, related topics such as analytical modeling versus simulation modeling, simulation role, simulation advantages and disadvantages and simulation methodology.

The researcher goes over to mention previous contributions in 3 main fields; namely supply chain management, production management, and risk management. Then, the researcher will answer the question of relationship between this thesis and previous contributions.

To achieve cited objectives, chapter 4 case study (Sinokrot Food Company) is presented. The researcher described Sinokrot system. Then, simulation models were built according to simulation methodology. After that scenarios and decisions were analyzed. Optimization simulation models were also presented. Finally, the researcher ends the thesis with thesis conclusions, recommendations and future work.

Detailed Sinokrot system, collected data, analyzed data results, and details of the simulation models are presented in the appendices.

CHAPTER 2

SIMULATION

2.1 SYSTEM, MODEL, AND SIMULATION

Simulation is powerful tool to model studied system. Real dynamic of systems includes manufacturing, supply chain, information system, management systems and so on. Model is representative of the real system, while the simulation is mimic modeling of the system. All of these terminologies will be explained in the following sections.

2.1.1 SYSTEM

Blanchard defines the system as a collection of elements that function together to achieve a desired goal. [Blanchard, 1991] The systems have three types of variables according to C. Harrell et al. [Harrellet al., 2004] as following:

1. Decision variables (input or independent variables) which affect the behavior of the system.
2. Response variables (performance or output variables) which measure the performance of the system in response to particular decision.
3. State variables which indicate the status of the system at any specific point in time such as the current number of entities waiting to be processed or the current status (busy, idle, or down such as unscheduled maintenance) of a particular resource.

2.1.2 MODEL

White and Ingalls define the model as simplified abstractions, which embrace only the scope and level of detail needed to satisfy specific study objectives. Models are employed when investigation of the actual system is impractical or prohibitive. This might be because direct investigation is expensive, slow, disruptive, unsafe, or even illegal. Indeed, models can be used to study systems that exist only in concept. [White, and Ingalls, 2009]

El- Haik and Al-Aomar classify models as following [El- Haik and Al-Aomar, 2006]:

- Physical Models are tangible prototypes of actual products or processes.
- Graphical Models are abstractions of actual products or processes using graphical tools.
- Mathematical models(Mathematical modeling) is the process of representing system behavior with formulas or mathematical equations
- Computer Models are numerical, graphical, and logical representation of a system (a product or a process) that utilizes the capability of a computer in fast computations, large capacity, consistency, animation, and accuracy.

2.1.3 SIMULATION

In English, the simulation can be defined as a way" to reproduce the conditions of a situation, as means of a model, for study or testing or training etc." [Oxford American Dictionary, 1980] Harrell et al. defined simulation as the "imitation of a dynamic system using a computer model in order to evaluate and improve system performance." [Harrell et al, 2004], Kelton et al. refer it to a board collection of methods and applications to mimic the behavior of real systems" [Kelton et al., 2001], on the other hand, Bangsow defined simulation as the reproduction of a real system with its dynamic processes in a model. The aim is to reach transferable findings for the reality. In a wider sense, simulation means preparing, implementing, and evaluating specific experiments with a simulation model. [Bangsow, 2010]

In this thesis, simulation can be defined as a mimic methodology uses computer technology or software to model a system which deals with complexity of stochastic input data and interrelated (interdependent) internal and external variables besides to multi criteria making decision in order to study the system behavior based on determined parameters, test desired situations or scenarios, detect system problems, develop the system, optimize system efficiency and effectiveness.

The system from simulation perspective consists of entities, activities, resources, and controls. As shown in Figure (2.1) these elements define the “who, what, where, when, and how of entity processing. Entities such as customers are items processed through performing activities in the system by means called resources which perform the activities, while the control is how, when, and where activities are performed such as routing sequences, work schedules, instruction sheets, and task prioritization.

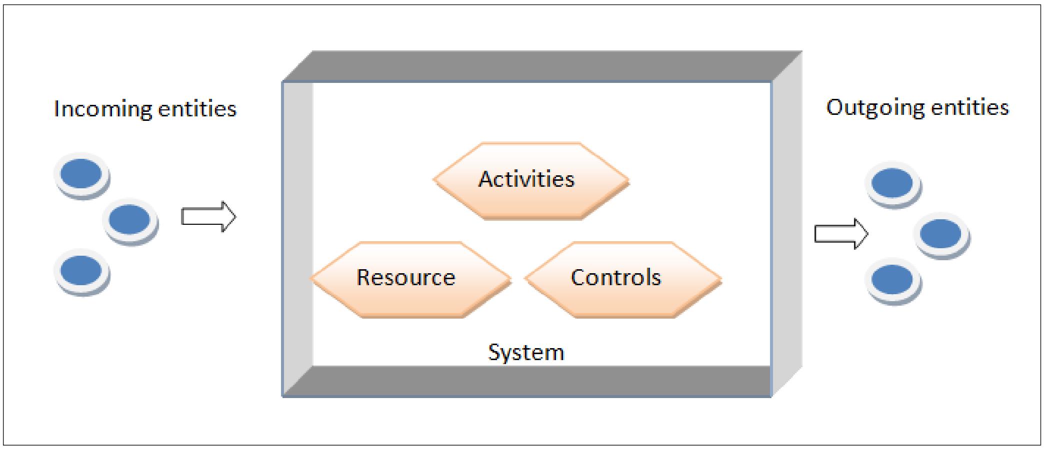


Figure (2.1): Elements of a system from simulation prospective, [Harrell et al, 2004]

2.2 TYPES OF SIMULATION

White and Ingalls categorize simulation types as the following [White, and Ingalls, 2009]:

- **Static versus Dynamic**

Static simulation is one that is not based on time, where the dynamic simulation includes the passage of time. It looks at state changes as they occur over time. According to this description, simulation system of the case study in this thesis is considered as dynamic simulation system.

- **Stochastic Versus Deterministic**

Simulations -in which one or more variables are random- are referred to as stochastic or probabilistic simulations. A stochastic simulation produces output itself random and therefore gives only one data point of how the system might behave, while simulations which have no input components that are random are said to be deterministic. Based on this description, simulation system in this thesis is considered as stochastic simulation system.

- **Discrete Event Versus Continuous Simulation**

A discrete event simulation is one in which state changes occur at discrete points in time as triggered by events. In continuous simulation, state variables changes continuously with respect to time and therefore referred to as continuous (change state variables such as level of oil in an oil tanker that is being either loaded or unloaded). The simulation system of the case study is considered discrete event simulation.

So the case study (Sinokrot Food Company) is dynamic, stochastic, and discrete event Simulation.

- **Analytical Modeling Versus Simulation Modeling**

Altiok and Melamed differentiated between analytical and simulation solutions or performance measures, where the analytical models calls for the solution of mathematical problem, the derivation of mathematical formulas, or more generally, algorithmic procedures. The solution is then used to obtain performance measures of interest.

On the other hand, “a simulation model calls for running (executing) a simulation program to produce sample histories. A set of statistics computed from these histories is then used to form performance measures of interest.”[Altiok, and Melamed, 2007]

In this thesis, it is focused on simulation system because of system complexity referred to stochastic variability and interrelated (interdependencies) of the system variables, where analytical modeling cannot deal with what appears in the case study.

2.3 ROLE OF SIMULATION

El- Haik and Al-Aomar clarify the role of simulation by first justifying the use of simulation both technically and economically and then presenting the spectrum of simulation applications to various industries in the manufacturing and service sectors. The role can be summarized in the following points [El- Haik and Al-Aomar, 2006]:

A. Simulation Justification

1. Technical Justifications

- Simulation capabilities are unique and powerful in system representation, performance estimation, and improvement.

- Simulation is often utilized when the behavior of a system is complex, stochastic (rather than deterministic), and dynamic (rather than static).
- Analytical methods, such as queuing systems, inventory models, and Markovian models -which are commonly used to analyze production systems-often, fail to provide statistics on system performance when real-world conditions intensify to overwhelm and exceed the system approximating assumptions.
- Decision support encountering critical stages of design so that designers reveal insurmountable problems that could result in project cancellation, and save cost, effort, and time.

2. Economical Justifications

- Although simulation studies might be costly and time consuming in some cases, the benefits and savings obtained from such studies often recover the simulation cost and avoid much further costs.
- Simulation can reduce cost, risk, and improve analysts' understanding of the system under study.

B. Simulation Applications

- Wide spectrum of simulation applications to all aspects of science and technology
- Utilizing simulation in practical situations and designing queuing systems, communication networks, economic forecasting, and strategies and tactics.

2.4 SIMULATION ADVANTAGES

Zandian remarks simulation advantages in the following points [Zandian, 2004]:

- **Increase in Global Competition**

In the last 20 years, almost all businesses have provided products and services globally, so that pressures exerted on them to increase their competitiveness by using simulation tools for testing implementations of continuous productivity improvement, process reengineering, and the best alternative system design.

- **Cost Reduction Efforts**

Simulation modeling becomes an essential tool to increase the robustness of the system relative to internal and external disturbances in design of lean or agile systems to increase production rates and flexibility while reducing the investments in inventories, equipment, and labor.

- **Improved Making Decision**

Simulation modeling has been proved as an effective tool in training managers because they can understand the effects of their decisions on the important performance metrics of the system. And also “Simulation avoids the expensive, time-consuming, and disruptive nature of traditional trial-and-error techniques.”[Harrell et al, 2004]

- **Effective Problem Diagnosis**

Simulation models can solve a problem at different levels of details and complexity with the credibility management requires for effective use in real-life situations rather than other analytical tools such as mathematical techniques, artificial intelligence, statistical techniques, and root cause analysis techniques, which either require too many simplistic assumptions to solve the problem or are too complex to be explained credibly to management.

- **Prediction and Explanation Capabilities**

Simulation modeling provides both prediction and explanation of a system's performance under different conditions. In addition to predicting what the system's performance will be for a set of conditions, the user can also comprehend the reasons why the system produces those results and behaves in a certain way.

- **Risk Analysis**

Flangagan and Norman mention probability analysis as a powerful tool in investigating problems which do not have a single value solution. Simulation is the most easily used form of probability analysis. It makes the assumption that parameters subject to risk and uncertainty can be described by probability distributions. [Flangagan and Norman, 1999]

C. Chung added the following points [C. Chung et al, 2004]:

- **Experimentation in Compressed Time**

Because the model is simulated on a computer, experimental simulation runs may be made in compressed time and so that multiple replications of each simulation run can easily be run to increase the statistical reliability of the analysis. Thus, systems that were previously impossible to be analyzed robustly can now be studied.

- **Reduced Analytic Requirements**

Before the existence of computer simulation, only simple systems that involved probabilistic elements could be analyzed by the average practitioner. More complex systems were strictly the domain of the mathematician or operations research analyst. In addition, systems could be analyzed only with a static approach at a given point in time. In contrast, the advent of simulation methodologies has allowed practitioners to study systems dynamically in real time during simulation runs.

- **Easily Demonstrated Models**

The use of animation during a presentation can help establish model credibility. Animation can also be used to describe the operation and interaction of the system processes simultaneously. This includes dynamically demonstrating how the system model handles different situations.

2.5 DISADVATAGES OF SIMULATION

According to [Chung et al., 2004] simulation modeling has specific disadvantages, given as follows:

- **Simulation Cannot Give Accurate Results When the Input Data Are Inaccurate (garbage-in-garbage-out (GIGO))**

The results obtained from simulation models are as good as the model

Data inputs, assumptions, and logical design. Data collection is considered the most difficult part of the simulation process.

- **Simulation Cannot Provide Easy Answers to Complex Problems**

If the system analysis has many components and interactions, the best alternative operating or resource policy is likely to consider each element of the system. It is possible to make simplifying assumptions for the purpose of developing a reasonable model in a reasonable amount of time. However, if critical elements of the system are ignored, then any operating or resource policy is likely to be less effective.

- **Simulation Alone Cannot Solve Problems**

Simulation provides the management with potential solutions to solve the problem. Potential solutions are developed but are never or only poorly implemented because of organizational inertia or political considerations.

2.6 WHEN SIMULATION IS APPROPRIATE

According to Harrel et al. [Harrell et al, 2004], Simulation is appropriate if the following criteria hold true:

- An operational (logical or quantitative) decision is being made.
- The process being analyzed is well defined and repetitive.
- Activities and events are interdependent and variable.
- The cost impact of decision is greater than the cost of doing the simulation.
- The cost of experiment in the actual system is greater than the cost of simulating it.

In this thesis, simulation modeling is an appropriate analysis tool for the case study (Sinokrot Food Company) because of well-defined and repetitive process such as production, interdependency variables such as produced quantities, break down times and frequency, availability of raw materials, readiness of production lines, and also logic operational is used in scheduling production. Besides the cost of simulation in negligible when it is compared to actual system costs.

2.7 SIMULATION METHODOLOGY

Simulation analyst follows a generic and systematic approach for applying a simulation study effectively. This approach is atypical engineering methodology for system design, problem solving, or system improvement. It consists of common stages for performing the simulation study as shown in the figure (2.2).

Harrell et al mention the following steps [Harrell et al., 2004]:

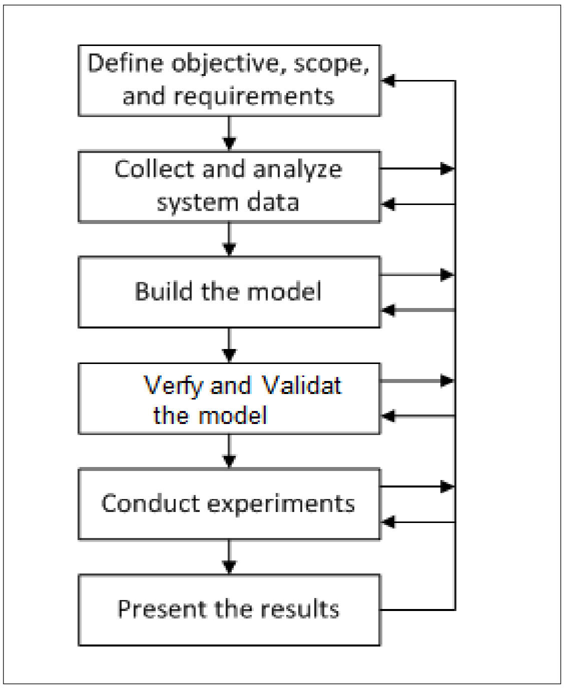


Figure (2.2): Iterative nature of simulation,[Harrell et al., 2004]

2.7.1 STEP 1: DEFINING OBJECTIVE, SCOPE, AND REQUIREMENTS

Simulation objectives can be grouped into the following general categories:

- Performance analysis – What is the all-around performance of the system in terms of resource utilization, flow time, output rate, etc.
- Capacity or constraint analysis – What is the production capacity of the system and where are the bottlenecks?

- Configuration comparison –How well does one system configuration meet performance objectives compared to another?
- Optimization –When are the settings for particular decision variables best achieve desired performance goals?
- Sensitivity analysis – Which decision variables are the most influential on performance measures, and how influential are they?
- Visualization –How can system dynamics be most effectively visualized?

An important part of the scope is a specification of the models that will be built (as-is model), when evaluating improvements to an existing system; it is often desirable to model the current system first. This is called an “as-is” model. Results from the as-is model are statistically compared with output of the real-world system to validate the simulation model. This as-is model can then be used as a benchmark or baseline to compare the results of “to-be” models. With the scope of work defined, resources, budget and time requirements can be determined for the project.

2.7.2 STEP 2: COLLECTING AND ANALYZING SYSTEM DATA

The steps of gathering data should follow this sequence:

- Determine data requirements and identify data sources.
- Collect the data (such as entity flow).
- Make assumption where necessary.
- Analyze the data (such as distribution fitting).

- Document and approve the data.

2.7.3 STEP 3: BUILDING THE MODEL

The conceptual model is the result of the data-gathering effort and is a formulation in one's mind (supplemented with notes and diagrams) of how a particular system operates. Building a simulation model requires that this conceptual model to be converted to a simulation model. The simulation model consists of structural elements (entities, location, resources) and operational elements (routings, operations, entity arrivals, entity and resource movement)

2.7.4 STEP 4: VERIFYING AND VALIDATING THE MODEL

"Verification is the process of determining whether the simulation model correctly reflects the conceptual model." [Harrell, 2004] or verification is "ensuring that the simulation model has all the necessary components and that the model actually runs. In reality, it is interested in getting the model not just to run but to run the way we want it to. In other words, it is interested in ensuring that the model operates as intended. Another way to look at the verification processes is to consider it as: Building the model correctly."[Chung et al., 2004]

"Validation is focused on the correspondence between model and reality: are the simulation results consistent with the system being analyzed? Did we build the right model? Based on the results obtained during this phase, the model and its implementation might need refinement."[Wainer, 2009]

Harrell et al. argue the use of combination of techniques when a validating a model such as watching the animation, comparing with actual system, comparing with other model, conducting degeneracy and extreme condition tests, checking for face validity, testing against historical data, performing sensitivity analysis techniques, running traces, and conducting tests. [Harrell et al., 2004]

2.7.5 STEP 5: CONDUCTING SIMULATION EXPERIMENTS

When executing the simulation model by following the goals stated in the conceptual model, it is needed to evaluate the outputs of the simulator, and using statistical correlation to determine a precision level for the performance metrics. "This phase starts with the design of the experiments, using different techniques. Some of these techniques include sensitivity analysis, optimization, variance reduction (to optimize the results from a statistical point of view), and ranking and selection (comparison with alternative systems)." [Wainer, 2009]

2.7.6 STEP 6: PRESENT THE RESULTS

Simulation outputs are analyzed in order to understand the system behavior. These outputs are used to obtain responses about the behavior of the original system. "At this stage, visualization tools can be used to help with the process. The goal of visualization is to provide a deeper understanding of the real systems being investigated and to help in exploring the large set of numerical data produced by the simulation.” [Wainer, 2009]

CHAPTER 3

LITER ATURE REVIEW

Simulation modeling is used in many fields, such as supply chain management, transportation, logistics, manufacturing, reengineering processes, maintenance, optimization, risk management, layout design, project management, and etc.

In this chapter, the literature reviews of supply chain management, manufacturing management, and risk management is presented.

3.1 SUPPLY CAHIN

The objective of supply chain management is to meet customer demand for guaranteed delivery of high quality and low cost with minimal lead time.

Some of inefficiencies in the business can be found from suppliers or in the business processes themselves. So simulation according to Chang et al. can helps companies to understand the overall supply chain processes and characteristics to be able to capture system dynamics, to model unexpected events in certain areas and understand the impact of these events on the supply chain as well as being able to dramatically minimize the risk of change in planning process. [Chang et al., 2002]

And also Chang et al, in order to analyze the supply chain, simulator should use operating performance prior to the implementation of the system, perform what-if analysis to lead better planning decisions, and compare of various operational alternatives without interrupting the real system.[Chang et al., 2002]

Hellström et al. used simulation in analyzing a case study to model both operational (material handling) and tactical (order process, inventory management) supply chain scenarios. The response from the model was that the material handling procedures became faster and more accurate, resulting in less utilization of resources. While in tactical planning, simulation had the ability to tell how the retail supply chain performed and behaved when different ordering rules were used. [Hellström et al., 2002]

X. Qi developed an integrated making decision model for a supply chain system where a manufacturer faces a price-sensitive demand and multiple capacitated suppliers. “The goal is to maximize total profit by determining an optimal selling price and at the same time acquiring enough supplying capacity.”[Qi, 2007]

Thierry et al. focus on the role of modeling and simulation in studying various issues in supply chain management based on time horizon decisions [Thierry et al., 2010] as shown in Table (2.1).

Saxena et al. presented a simulation model to analyze the effect of different ordering policies and different set of parameters for different nodes of supply chain on a cost and time performance. It was founded just-in time (JIT) strategy and the echelon removal strategy was observed to be the most effective in smoothing demand variations."[Saxena et al., 2010]

As shown in pervious reviews, this thesis asserts some points such as the simulation is powerful tool in supply chain planning before performing the planned scenarios or decisions at all levels (strategic, tactical or operational level) in the real system to avoid or minimize the risk. Also, simulation is analyzing tool of how supply chain dynamically works either internal business process or external variables that affect or are affected through the supply chain. In addition, some of the previous reviews have deal with stochastic product demand as in this thesis.

Table (3.1): Supply chain planning issues

Time horizon	Supply chain planning issues
Long range (strategic)	• Number and location of suppliers • Production facilities • Distribution centers • Warehouses and customers. • etc.
Medium and short range decisions (tactical and operational)	• material management • inventory management • planning processes • forecasting processes • etc.

On the other hand, the previous reviews have not deal with strategic decisions such as number of distribution centers that are required to improve supply chain performance although [Thierry et al., 2010] focused on the role of simulation modeling based on time horizon, and [Saxena et al., 2010] deled with some strategies (JIT).Also, they deled with one product, while this thesis deals with multi-products sharing with interrelated raw materials which are determined by bill of materials (BOM) for each product.

3.2 INVENTORY MANAGMNET

Inventory management is an important tool to mitigate the risks arising due to Supply failures. Cannella et al. conclude that an increment of production capacity does not necessarily improve customer service without demand amplification. Risk in this case is due to satisfying at a higher cost an over-estimated market demand. [Cannella et al., 2008]

Samvedi et al. developed a simulation model to study which inventory method will be the best for such situations and the impact of periodic inventory parameters values on supply disruption situations. Moreover, the research led to that the cost of the players in the chain increases with increasing maximum inventory level and decreases with increasing review period.[Samvedi et al., 2011]

Alizadeh et al. developed an inventory simulation model to reduce total inventory cost when demand and lead time are stochastic variables. In addition, they used optimization to determine the optimal or near optimal lead time to minimize the inventory total cost. [Alizadeh et al., 2011]

Akcay et al. studied estimation of inventory targets when demand process is auto-correlated and only a limited amount of historical data is available. A developed simulation model was used to expect the cost due to demand parameter uncertainty, and to obtain the value of the bias parameter to reduce the impact of parameter uncertainty in inventory-target estimation. [Akcay et al., 2012]

As shown in pervious reviews, simulation models were developed to study impact of increment of production capacity, periodic inventory parameters, inventory targets, or to minimize total inventory cost when demand and lead time are stochastic. Indeed, simulation can be used to model real inventory system where demand and lead time are stochastic, need to determine optimal inventory target level, optimal reorder point and optimal order quantity for fixed-ordered-quantity system, optimal reviewing time for fixed-time-reviewing system, optimal inventory capacity, and so on.

3.3 MANUFACTURING MANAGMENT

- PRODCUTIION PLANNING AND SCHEDULING

Vasudevan et al. presented the integration use of process simulation, production scheduling, and material handling. Several suggested improvements were simulated and analyzed. These improvements increase productivity by 47% and annual revenue $1,800,000. [Vasudevan et al., 2008].

Wu et al. introduced an integrated dynamic simulation model for multi-workstation production systems. The model is used to analyze the fundamental properties and dynamic behavior of multi-workstation production systems. As a result; “the low variation of the lead time at each workstation indicated simulation was able to predict lead times based on real production data. The predicted lead time can be used to plan production in common static capacity planning systems used in industry, such as MRP.” [Wu et al., 2008]

Sun et al. developed a multi-item MRP (Material Requirements Planning) simulation model to study the effects of factors such as forecast errors, process variability, and levels of updating frequency on the performance of MRP system in terms of average inventory and fill rate under different operating conditions.[Sun et al., 2009]

Hübl et al. introduced a simulation model for analyzing production systems. The model included stochastic behavior for customer performance, processing times, set up times and purchasing lead time.

The model combines three hierarchical levels; the highest level: MPS (Master Production Schedule) which calculates the aggregated production program. The midterm level: two PPC (Production Planning and Control) methods MRPII and Conwip (Constant Work in process).and lowest level, different dispatching rules. The interactions between the levels were tested and manufacturing system was analyzed [Hübl et al, 2011]

In my point view planning and scheduling simulation models -as shown in previous literature reviews- are useful when dealing with planning input variables such as stochastic customer behavior, stochastic market demand, net requirement quantities, delivery time, resources, etc. in addition, planning and scheduling scenarios are simulated to find the best scenario. These models were built to study of real systems and their performance measures such as resources utilization, fill rate, lead time, etc. on the other hand, planning and scheduling models are effected when multiple products share raw materials determined by bill of material for each product. These interrelated variables will be undertaken in this work.

- BOTTELNECKS DETECTION AND ELIMINATION

Sengupta et al. present a method to identify and rank the bottlenecks in a manufacturing system by using simulation techniques. The proposed method was based on analyzing inter-departure time from different machines, the duration of machine being active without interruption, and utilization of machines. It was founded that bottle necks were detected where the machine with the highest utilization, and the machine with the longest average up-stream queue length. [S. Sengupta et al, 2008].

Moreover, Pawlewski et al. presented simulation model to describe the elements of the production system in the relationships between them and to analyze when resources were required and when were available in the same time frame. [Pawlewski et al., 2010]

This thesis is based on the previous reviews. So that bottlenecks can be detected by measure performance variables such as duration production line being active (or more detailed machines in the production line) without interruption, utilization either daily production utilization (real production time to available production time) or annual utilization (number of production periods to available annual production periods).

- MAINTENACE MANAGMENT

Ali et al. presented simulation optimization model to minimize maintenance investment and system downtimes. The model was based on optimization selection for maintenance polices optimization system design, and optimization maintenance scheduling schemes in order to evaluate these variables on the overall system performance.[Ali et al., 2008]

Altuger et al. developed maintenance simulation to analyze production line performance and equipment utilization. The model assessed different preventive maintenance scheduling techniques to select the best. Maintenance scheduling techniques included: Global Maintenance Order (GMO), Reliability-Based Maintenance Order (RMO) and Value-Based Maintenance Order (VMO). [Altuger et al., 2009]

Breakdowns in general can be defined as causes make the production line or machine stop. Therefore breakdown can include scheduled maintenance, unscheduled maintenance, parts shortage, and reproduction.

➢ SETUP TIME REDUCTION

Kämpf et al. explores the optimal sequencing and lot size problem for a stochastic production and inventory system with multiple items. The system consists of a single-stage-multiple-product type manufacturing unit that has to meet a random demand for N items. Simulation model was developed to find optimal sequencing and lot size parameter values that maximize expected profit per time unit. [Kämpf et al., 2006]

Grewal et al. investigate the benefits of setup time reduction and lot size optimization as well as reorder point optimization as decision variables. Discreet event simulation model was developed to study the effect of cited decision variables on performance variables such as total inventory and customer service levels. It was found that setup time reduction alone reduces the total system inventory required to meet a specific customer fill rate, and the optimal lot sizes decrease significantly with reduced setups. In addition, lot sizes are found to be slightly smaller at increased service level targets. [Grewal et al., 2009]

Setup time reduction affects the performance measures, total inventory, and customer fill rate positively. Setup times can be reduced also by adopting some production management polices as will be shown in the thesis.

- LEAN MUNIFACTURING

“Lean is the set of ‘tools’ that assist in the identification and steady elimination of waste (muda), the improvement of quality, and production time and cost reduction.”[Wilson, 2010] The wastes include over production, transportation, unnecessary inventory, inappropriate process, activity resulting from rejected product, unnecessary motion, knowledge disconnections, and unused creativity.

Heilala et al. proposed an integrated simulation tool to maximize production efficiency and balance environmental constraints already in the system design phase. They used simulation to identify production waste (e.g. waiting, work in process, inventories, and transportations), Value Stream Mapping (VSM) and other process modeling methods. Then they developed scenarios to eliminate these wastes. [Heilala et al., 2008]

Brown et al. presented a simulation model to study “the ability to identify cost reduction opportunities through improving operational efficiencies provides companies with the ability to reduce costs while maintaining service levels”.[Brown et al., 2009]

Gregg et al. presented an approach for modeling manufacturing process flows. Simulation incorporates a work flow schedule to model cycle time and resource usage, accounting for task sequencing, task duration variability, resource requirements (labor, tooling, position, etc.), maximum capacity, and contention. “The approach has been used successfully within

Boeing to support analysis and cycle time reduction of aircraft and spacecraft production flows and resource requirements analysis including labor and equipment."[Gregg et al., 2011]

Mahfouz et al. developed simulation based optimization model to evaluate the lean implementation in SME (Small to Medium Enterprise) packaging manufacturer. Four lean factors have been defined; demand management, preventive maintenance, labor capacity, and production flow, and examined against three response functions, cycle time, WIP (Work in Process) and staff utilization.

"The model has contributed significantly to develop a better understanding of the system dynamics (i.e. impact on overall performance) through the factor analysis phase."[Mahfouz et al., 2011]

In my point view; simulation means simulating the real system, studying system behavior, detecting manufacturing wastes, developing scenarios to eliminate the wastes, and analyzing system performance.

3.4 RISK MANAGEMENT

"Risk can be defined as the probability of occurrence of an event that would have a negative effect on a goal." [Vose, 2000]

Lesnevski et al. presented a procedure for generating a fixed-width confidence interval for a coherent risk measure. Coherent risk measures based on generalized scenarios were viewed as estimating the maximum expected value from among a collection of simulated “systems”. The procedure improved upon previous methods by being reliably efficient for simulation of generalized scenarios and portfolios with heterogeneous characteristics. [Lesnevski et al., 2006]

Chen et al. presented simulation model to evaluate product prices and to estimate the risk measures of portfolio. [Chen et al., 2007]

Better et al. explored applications of simulation optimization involving risk and uncertainty due to simulation optimization capabilities, quality of solutions, interpretability, and practicality. They demonstrated advantages of using a Simulation Optimization approach to tackle risky decisions by show casing the methodology on two popular applications from the areas of finance and business process design. [Better et al., 2008]

Hennet et al. analyze the risks incurred by supply chains-both externally and internally- which present several alternatives to evaluate the risks of disruption of a supply chain and bankruptcy of one or several of its member enterprises that discuss the integration of risk management within classical supply chain management approaches. [Hennet et al., 2009]

In point view; there are some risk issues as shown in the previous reviews. Simulation can measure risk by analyzing the model behavior, suggesting scenario to reduce or eliminate the risk, and evaluating the total performance. These theses will highlight internal and external risks in manufacturing, Inventory, and supply chain systems.

CHAPTER 4

CASE STUDY

4.1. SINOKROT FOOD COMPANY

Sinokrot Food Company is based in Baytonia industrial zone in Ramallah and Al-Bireh governance –West Bank. It produces more than 60 products through 8 modern production lines according to international quality and health standards. Some of these products are Ali Baba, Ali Baba- Gifts, Jericho Wafer, Sinokrot Wafer, Sababa Nougat, Marsh, Zaki, Toffee Nut, Rollo, Rolls Royce, Noody Loose, Noody 48 pieces, Marie Biscuit, Family Cookies 300 gm, Family Cookies 600 gm, Jammy, Noody tubes,. It has a local market share of about 30% and exports its products to Jordan, Saudi Arabia, USA and England. It is the first Palestinian company that obtained the ISO 2000 certificate in the year 1996. It is also the first Palestinian and Arab food company that was able to develop and produce fortified food products so as to participate in solving the malnutrition dilemma among children. It distributes its products to more than 4000 outlets in the local market. Among the notable business partners are the World Food Program (WFP), American Near East Refugee Aid (ANERA) and the Islamic Bank for Development.

4.2 SINOKROT SYSTEM

4.2.1 PRODUCTION

Production system in SFCo includes 8 production lines to produce 60final products. Production rates, daily produced quantity, production lines breakdown times and frequencies are stochastic variables. The following sections describe in more details of production system.

- **PRODUCTS**

Sinokrot Food Company (SFCo.) produces more than 60 products, 98% of them are semi-daily produced, while others are produced rarely or when are demanded. Semi-daily produced products are 20 products, and they are denoted in simulation system by PR; as abbreviation of ***pr***oducts.

- **PRODUCTS GROUPING**

SFCo owns 8 production lines. Each production line produces alike products called “products groups”, i.e. “production line 1” produces “products group 1” ,”production line 2” produces “products group 2” and so on, as an exception of this rule, “ production line 1” produces “products group 2” if the line is not busy.

“products group 1” includes “product 1” and “product 2”, while “products group 2” includes “product 3”, product 4”, product 5”, and “product 5”. Table (A.1) in Appendix A shows these products groups. These products groups are obtained by interviewing the production manager.

- **PRODCUTIO PERIODS**

The production system of SFCo includes 2 production periods; the first begins in 7:30 to 16:00 (production time is 8.5 hours), while the second begins 16:00 to 23:30 (production time is 7.5 hours) as obtained from daily production reports.

- **PRODUCTION RATES**

Production rate can be expressed by produced quantities per production period. In our case, production line rate of each product varies refers to considered reasons related to human power, quality of raw material, reproduction, breakdowns and unscheduled maintenance. In addition, the production rate is a stochastic variable by which the value changes according to product and production period.

In our case, production rate is defined as in term of actual time consumed (second) to produce 1unit (1carton case, or 1 kg for "product 11"). Data of production rate is obtained from daily production reports for 12 months, calculating net production time (after removing breakdowns time), and calculating production rate by dividing net production time by produced quantity as shown in EQ.1. The calculated production rates were compared with production rates obtained by sit watching and monitoring (samples). The result of comparing assured that homogeneity of both sources of data, besides to discussing them with production manager.

$$Prodcution\ Rate = \frac{production\ period\ (second) - breakdowns\ (second)}{produced\ quantity\ (unit\ or\ case)}$$	**EQ.1**

The production rates of all products were analyzed by 'StatFit' software. 'StatFit' fittings of all production rates for the two production periods showed the best statistical distribution that fitting them according to rank criteria. Fitting results are summarized in Table(A.2) in Appendix A. while Figure B.1 in Appendix B exhibits 'StatFit' fitting report of production rate of "product 1" for the first production period as a sample of production rates fittings. Some of production reports included "product 9", 'product 10" and "product 18" have merged produced quantities in the two production periods. Therefore, it was assumed the production rates of these products were the same.

- **GENERAL BREAKDOWNS**

There are many real causes of production line breakdown such as:

i. Unscheduled maintenance (emergency maintenance)
ii. Reworking due to bad quality
iii. Unready production lines

There are two stochastic variables of breakdowns; breakdown period (how much time it consumes) and frequency (how many days that breakdown occurs). Breakdowns data are collected and analyzed as same as cited production rates, and summarized for all production lines in Table (A.3) in Appendix A.

- **PRODUCTION MANAGEMENT**

Production management is based on:

i. Checking maximum inventory shortage of a product among products in the same product group. Product inventory shortage is

$$\begin{aligned} product\ inventory shortage \\ &= target level inventory \\ &+ booked sales of the product \\ &- product sales inventory level \end{aligned} \qquad \textbf{EQ.2}$$

ii. Checking availability of raw material used to produce the expected quantities.

iii. To utilize setup time there was no change product through production periods. The change occurs only at beginning of them.

4.2.2 RAW MATERIALS INVENTORY MANAGEMENT

SFCo consumes many raw materials to produce more than 60 products. SFCo purchases these materials from local suppliers and or international suppliers. Also, it assures the quality when receipts them. Number of raw materials is more than 100 but they can be grouped in 11 groups, namely RM1, RM2… and RM11.

- **RAW MATERIALS INVENTORY MANAGEMENT**

Raw material inventory management is periodic order; some of raw materials are ordered every 26 working days (month), and some of them are ordered every 20 working days. There was no accurate historical of ordered quantities because some of raw materials were sold to other manufacturers. Therefore, the ordered quantities and reorder points were assumed to be correct according to production manager experience. Table (A.4) in Appendix A exhibits the raw material order frequency, ordered quantities and reorder point.

- **RAW MATERIALS RISK**

Some factors affect the raw material ordered quantities and reviewing times such as international or local suppliers, purchasing lead time, fluctuate draw material prices, and Israeli occupation polices.

- **BILL OF MATERIALS**

Table (A.5) in Appendix A exhibits product structure of components (raw materials) according to laboratory supervisor. Bill of material is expressed by weight to produce one case of product.

4.2.3 DISTRIBUTION CENTERS AND PRODUCT DEMAND

Distribution centers are very important components of the supply chain. Sinokrot Food Company (SFCo) provides Palestinian market with its products through 5 distribution centers distributed in West Bank. Distribution centers provide the company with required products (customers' orders), and receipt the finished products to deliver them to the customers.

The distribution centers are denoted in simulation system by DC; as abbreviation of ***D***istribution ***C***enter.

- **TOTAL DAILY PRODUCT DEMAND**

Total daily product demand for any product is sum of distribution centers demands as shown in EQ.3. Daily demands of any product were obtained from historical reports (for 12 months). all of these daily demands were grouped for each month and analyzed by using 'StatFit' software to fit them with best statistical distribution as shown in Table (A.6) in Appendix A. Figure B.1 in Appendix B exhibits 'StatFit' fitting report of total daily "product 6" demand as an example.

$TotalDailyProductDemand(case) = \sum_{1}^{5} Distribution\ Center\ Prodcut\ Demand$	**EQ.3**

➢ DAILY DISTRIBUTION CENTER PRODUCT DEMAND

Annual total product demand is sum of annual distribution centers demands for any product. Share percentage of distribution center product demand can be calculated by dividing annual distribution center product demand by annual total product demand as shown in EQ.4.Therefore daily distribution center product demand is calculated as multiplying share percentage of distribution center product demand by total daily product demand as shown in EQ.5.The results were shown in Table (7) in Appendix A.

$\text{Share percentage of distribution center product demand } (case) = \frac{\text{annual distribution center product demand}}{\text{annual total product demand}}$	**EQ.4**
$\text{Daily distribution center product demand}(case) = \text{share percentage of distribution center product demand} \times \text{total daily product demand}$	**EQ.5**

4.2.4 SALES INVENTORY MANAGEMENT

When finished products are packaged and palletized, they are transported to sales inventory. Inventory worker arrange deliverable pallets according to sales orders, and arrange the rest of produced product in well-conditioned environment to avoid food spoilage. Inventory supervisor refreshes inventory level when he receipts or back finished product up to transporters.

- **SALES INVENTORY CAPACITY**

Sales inventory consists of 3 vertical layers to utilize the sales inventory space; sales inventory is capable to store 200 pallets of products. Sales department determined target level by their experience for each product so that to avoid product shortage to fulfill distribution center demand. Table (A.8) in appendix A exhibits product target level.

- **SALES INVENTORY MANAGEMENT**

The main principle in food inventory is FIFO (first in, first out) because it keeps material or product in good quality and safety.

Inventory monitoring principle is based on product inventory level, safety stock level, the product demand, and booked order demand. To determine which product is most required among the product group, it have to be the higher production priority which can be defined as the difference between product sales inventory target in addition to booked sales and product sales inventory level.

Sales inventory input is presented by produced quantity of a product, while sales inventory output is presented by product sold quantity. Following equation EQ.6 presents product sales inventory level in a certain time period (i).

$SalesInventory\ level(i) = SalesInventory(i-1) + ProducedQuantity(i) - SoledQuantity\ (i)$	**EQ.6**

4.2.5 SALES, PALLETIZING AND TRANSPORTATION

The last operations that SFCo performs before deliveries the final products are palletizing the required products and arranging them in such manner according to transporter capacity i.e. 10-12 pallets.

- **SALES AND PALLETIZING**

To prepare ordered quantity of products, they must be palletized. Ordered quantities can be rounded to quarter of pallet. Table (A.9) in Appendix A exhibits number of cases per pallet.

- **TRANSPORTATION**

SFC owns 5 transporters to deliver the products to the 5 distribution centers; each transporter is capable to deliver 10-12 pallets per charge. The transportation time depend on the distance between the sales inventory and distribution center, and Israeli occupation obstacles.

- **TRANSPORTATION RISK**

Israeli occupation policies affect transportation time; the policies are reflective of security and general policy in Israel. So, transportation time is dependent factor varies from time to time.

4.2.6 GENERAL CONCEPTUAL MODEL

Conceptual model is a represent of the actual system or real life system under study. The general conceptual model of Sinokrot system is shown in Figure (4.1).

4.3. PROBLEM DIFINITION AND OBJECTIVES

Analytical making decision process is very hard one when dealing with stochastic input variables and complex interrelated variables. To overcome this problem, simulation techniques are used in making decision at all levels; strategic, operational, and tactical level.

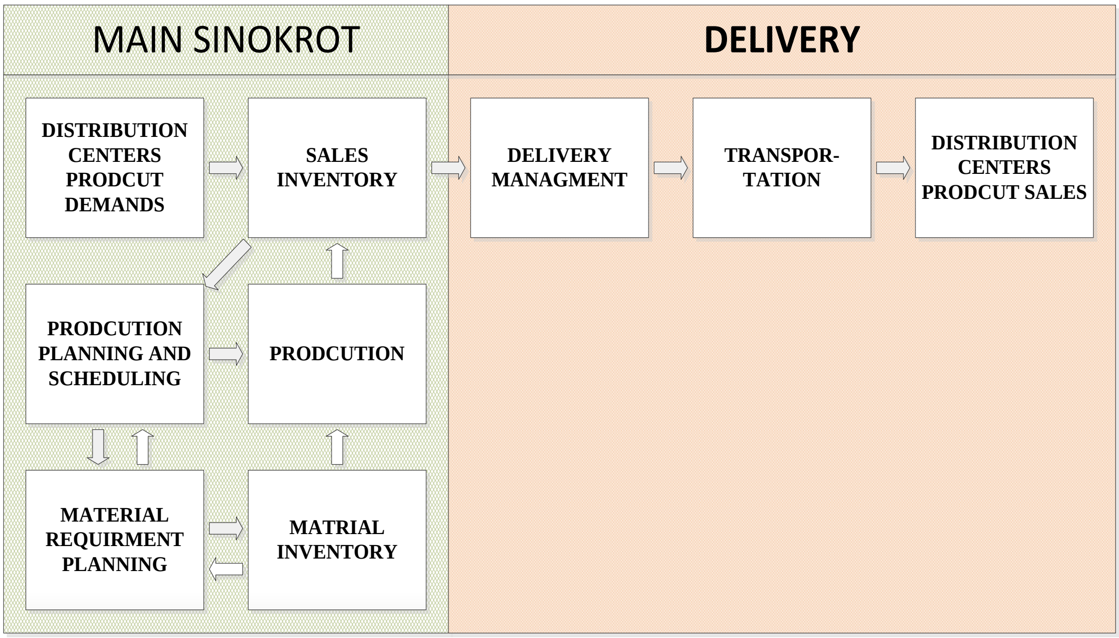


Figure (4.1): General Sinokrot conceptual model

Simulation modeling of: supply chain, manufacturing system, and risk management is a cornerstone of simulation applications for many years. Recently, there has been an increasing interest in excellence in evaluating the real system proposed scenarios or decisions and optimization system parameters.

According to the case study, there are many objectives in simulating the real life system in order to achieve the organization objectives:

1. Develop real model (ad-hoc model), to evaluate current parameters and performance indicators of supply chain, manufacturing system, and risk management.

2. Develop simulation models to evaluate decisions or scenarios in order to achieve organization objectives at all levels; strategic, operational, and tactical levels.
3. Develop optimization simulation model to design or re-design inventory management parameters to minimize inventory costs, minimize stored quantity according to lean manufacturing philosophy, and maintain stock-out percentage less than a specific point.

4.4 SIMULATION MODEL AND DESCRIPTION

Before describing the simulation model, some ARENA terms are required to be understood as well as the abbreviations that used in this thesis (especially in the following equations) as shown in Table (4.1).

Simulation model is composed of two separated simulation models; the first is "Main Sinokrot simulation" model, while the second is "Delivery simulation" model. The output of main Sinokrot simulation model is the input data of the delivery simulation model by using MS Excel sheet named “Main Sinokrot simulation” to overcome problems and constraints of student version of ARENA Software such as limited number of modules and variables.

Main Sinokrot simulation model is composed of creation entities creation module in addition to 3 branches or stations named; “product demand and sales”, “production planning management and production”, “and raw material management". Creation entities modules create entities and assign their sequence or future stations or branches that will enter. Number of daily created entities in simulation model is 131 entities which are named orders assigned as in Table (4.2).

Table (4.1): Used ARENA terms and abbreviations

Term	Meaning	Used Abbreviation
Attribute	store information for each entity common characteristic of all entities , but with a specific value than differ from one entity to another values are tied to a specific entities	[att.]
Expression	Predefined or set values such as constants	[exp.](argument 1, argument 2)
Variables (global)	Store some real-valued quantity that can be reassigned during the simulation run. They can be vector or matrix as dimensional tables of individual values.(one- or two-dimensional arrays)	(argument 1)[1dVar.] for one-dimensional array (argument 1, argument 2) [2dVar.] for two-dimensional array

In the beginning, entities attributes for each entity in simulation model are assigned including EPD (entities per day), creation day, creation month, entity sequence. Figure (4.2) illustrates process flowchart of entities creation and assigning attributes, while Figures C.1 and C.3 in Appendix C illustrate the ARENA software modules that used to create the entities.

Table (4.2): Simulation entities and orders sequence

Entities	orders
1-20	Distribution center 1 products demand orders
21-40	Distribution center 2 products demand orders
41-60	Distribution center 3 products demand orders
61-80	Distribution center 4 products demand orders
81-100	Distribution center 5 products demand orders
101-120	Production orders
121-131	Raw material orders

Distribution center demand varies according to creation day and creation month for each distribution center of each product. For each order, Distribution center demand attribute (DC DEMAND) is assigned as in EQ.7 which is based in EQ.5, then 2 dimensions variable DCs DEMAND (PR,DC) and total demand of the 5 distribution centers DCs DEMAND (PR,6) is assigned directly as in equations EQ.8 and EQ.9 which based on EQ.3.

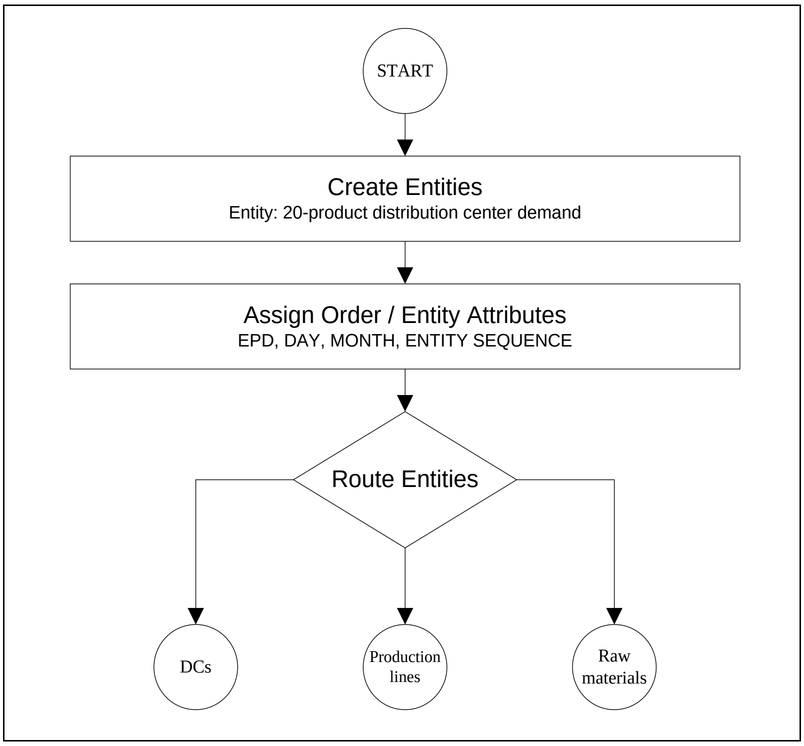


Figure (4.2): Create entities and orders (main Sinokrot model)

$DCDEMAND\ Q\ [att.] = DC\ DEMAND\ PER\ (PR, DC)[exp.] \times TOTAL\ DC\ DEMAND\ (PR, MONTH)[exp.]$	**EQ.7**
$TDCs\ DEMAND\ (PR, DC)\ [2dVar.] = DCDEMAND\ Q\ [att.]$	**EQ.8**
$TDCs\ DEMAND\ (PR, 6)[2dVar.] = \sum_{DC=1}^{5} DCs\ DEMAND\ (PR, DC)\ [2dVar.]$	**EQ.9**

In general, the simulation model checks out if the daily total demand of a specific product can be fulfilled or not. In case the demand is greater than the stored product sales inventory, the orders are assigned booked sales, otherwise assigned distribution centers demand as shown in sub-model distribution center demand in Figure (4.3).The simulation system launches values either of booked sales or distribution center demands as MS EXCEL sheets. Then the booked sales orders stay in simulation system until fulfilled, while distribution center demand go forward next process “sub-model sales inventory”.

When booked sales order is fulfilled, reassign booked sales modules assigns it as distribution center demand, update the sales inventory according to EQ.8 and EQ.9, as well as converting distribution center demand to palletized distribution center sales as shown in sub-model sales inventory in Figure (4.3).

$DSALES\ INENTOORY\ (PR)[1dVar.] = SALESINVENTORY\ (PR)[1dVar.] - DC\ DEMAND\ Q[att.]$	**EQ.10**
$Cs\ DEMAND\ (PR,6)[2dVar.] = DCs\ DEMAND\ (PR,6)\ [2dVar.] - DCDEMAND\ Q\ [att.]$	**EQ.11**

The simulation system creates daily 20 production order and assigns their production attributes such as product, production line, and total booked sales.

The created production orders enter submodel production management. The simulation model holdes them, assignes the priority according to maximum product sales inventory shortage, and releases them when all orders are heldi.e when number of held orders becomes 20 orders, as shown in Figure (4.4)

Then many “decide” modules are used to check if the production lines availability for production periods 1 and 2.If the production line is available, the production ordres book the available production lines while the other production orders in same products group leave the system according to unavailable production lines.

In a special case when the production line 1 is available (not busy) in period 1 or period 2, and when ther are sales inventory shortage of products group 2 more than group 1, the production orders of this group are assigned as products group 1 and they are managed to be produced in according to maximum sales inventory shortage, otherwise they leave the simulation system.

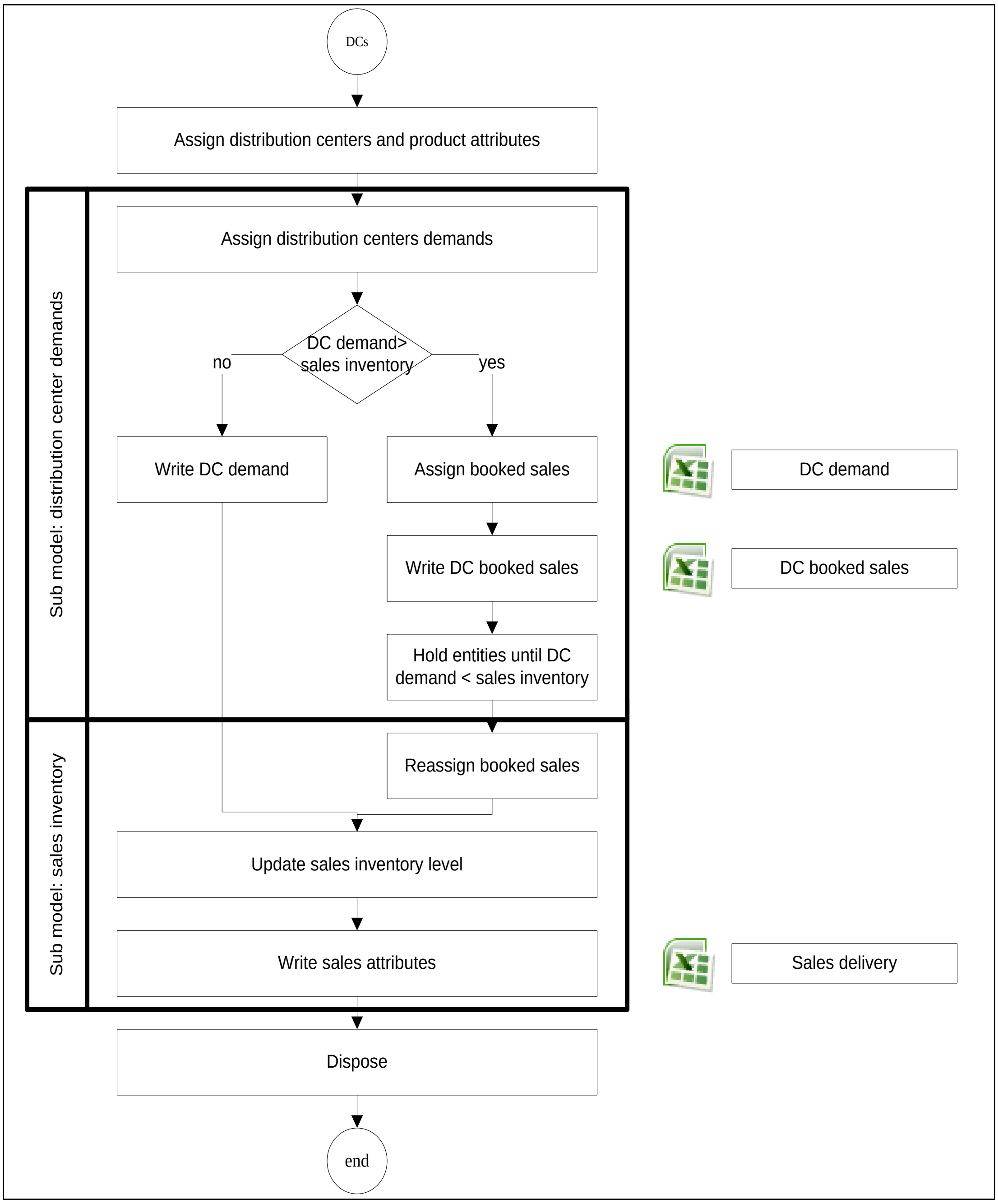


Figure (4.3): Distribution center demand and sales

Expected production quantity for each managed production order is assigned as in EQ.12.

For production period 1 $EXPECTED\ PRD\ (PR,1)[2dVar.] = \frac{8.5\ (hr) \times\ 3600(sec/hr)}{PRODUCTIVITY\ [exp.](PR,1)}$	**EQ.12**
For production period 2 $EXPECTED\ PRD\ (PR,2)[2dVar.] = \frac{7.5\ (hr) \times\ 3600(sec/hr)}{PRODUCTIVITY\ [exp.](PR,2)}$	

Production orders enter sub-submodel named raw material inventory planning to assign expected consumable raw material. The sub-submodel checks the availability of them. If the raw material is not available, the production fails and leaves the system after assigning lost producable quantities.Then another production order bookes the available line.

Product sales invnetory shortage is the core player; the simulation model check if the expected product quantity will fullfill the shortage.In case the expected product quantity is enough and assigned consumable raw materials are available, the production order will be assgned to be produced in the first production period. so, the production line will be free for the second production period and another production order can be assigned to be produced in the second production period.

If the expected product quantitiy of the the first product will not fullfill the shortage, the correspondent production line will be booked to produce the production order in both production periods (the first and second production periodes).

The fullfilled production orders enter sub model named production after assigning for each production order attributes such as expected production quantitiy, consumable raw material, production period, as shown in Figure (4.4),and Appendix C illustrates more ARENA software modules details.

Production submodel represents actual production environoment. The production breakdowns for many causes are assigned to be considered in produced quantities. Sub-submodel breakdown assignes production breakdown frequency and breakdown time. The brakdown containes quality causes, maintenance causes (planned and emergency mantainance), and due to shortage in labors.

Prduction submodel assignes produced quantity according to EQ.13 which based on EQ.1.

For production period 1 $PRODUCED\ Q\ (PR,1)[2dVar.] = \frac{8.5\ (hr) \times\ 3600(sec/hr) - BREAKDOWN\ TIME[exp.]}{PRODUCTIVITY\ [exp.](PR,1)}$	**EQ.13**
For production period 2 $RODUCED\ Q\ (PR,2)[2dVar.] = \frac{7.5\ (hr) \times\ 3600(sec/hr) - BREAKDOWN\ TIME[exp.]}{PRODUCTIVITY\ [exp.](PR,2)}$	

Production orders enter sub-submodel named raw material inventory planning to assign expected consumable raw material. The sub-submodel checks the availability of them. If the raw material is not available, the production order fails and leaves the system after assign lost produced quantities.Then another production order does not book the available line and the lost production quantitiy is described as cost.

Although production orders leave the system but their attributes and variables are transmitted and expressed to the second model by using Excel sheets. The Attributes include day creation, product, deliverable product pallets, distination distribution center, and delivery time (day). Number of product delliverable pallets is calculated as in EQ.14.

$TDeliverable\ Palets\ (PR, DC)[2dVar.] = \frac{Total\ DC\ Demand\ [att.]}{paletizing\ [exp.](PR)}$	**EQ.14**

The last type of created orders in this simulation model is raw material orders, which enter raw materiall station. Raw material management modules check if the order frequency (periodic raw material order) and assgne there ordered quantities, as shown in Figure (4.5), and Appendix C illustrates more ARENA software modules details.

As soon as the raw material ordered quantities are assigned, the simulation update raw material inventory level as in EQ.15.

$TRAW\ MATERIAL\ INVENTORY\ (RM)[1dVar.] = RAW\ MATERIAL\ INVENTORY\ (RM)[1dVar.] + \ ORDER\ Q[att]$	**EQ.15**

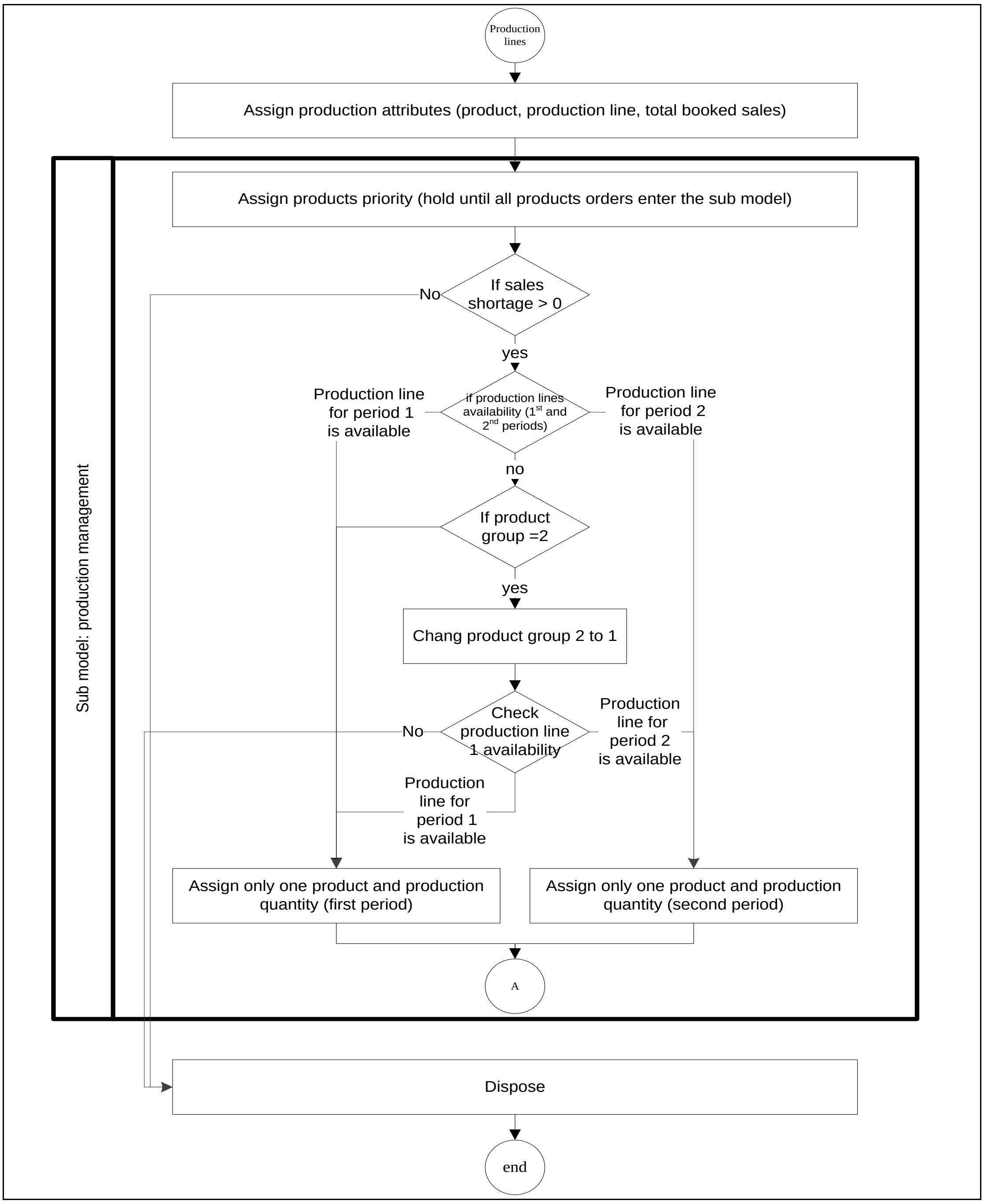
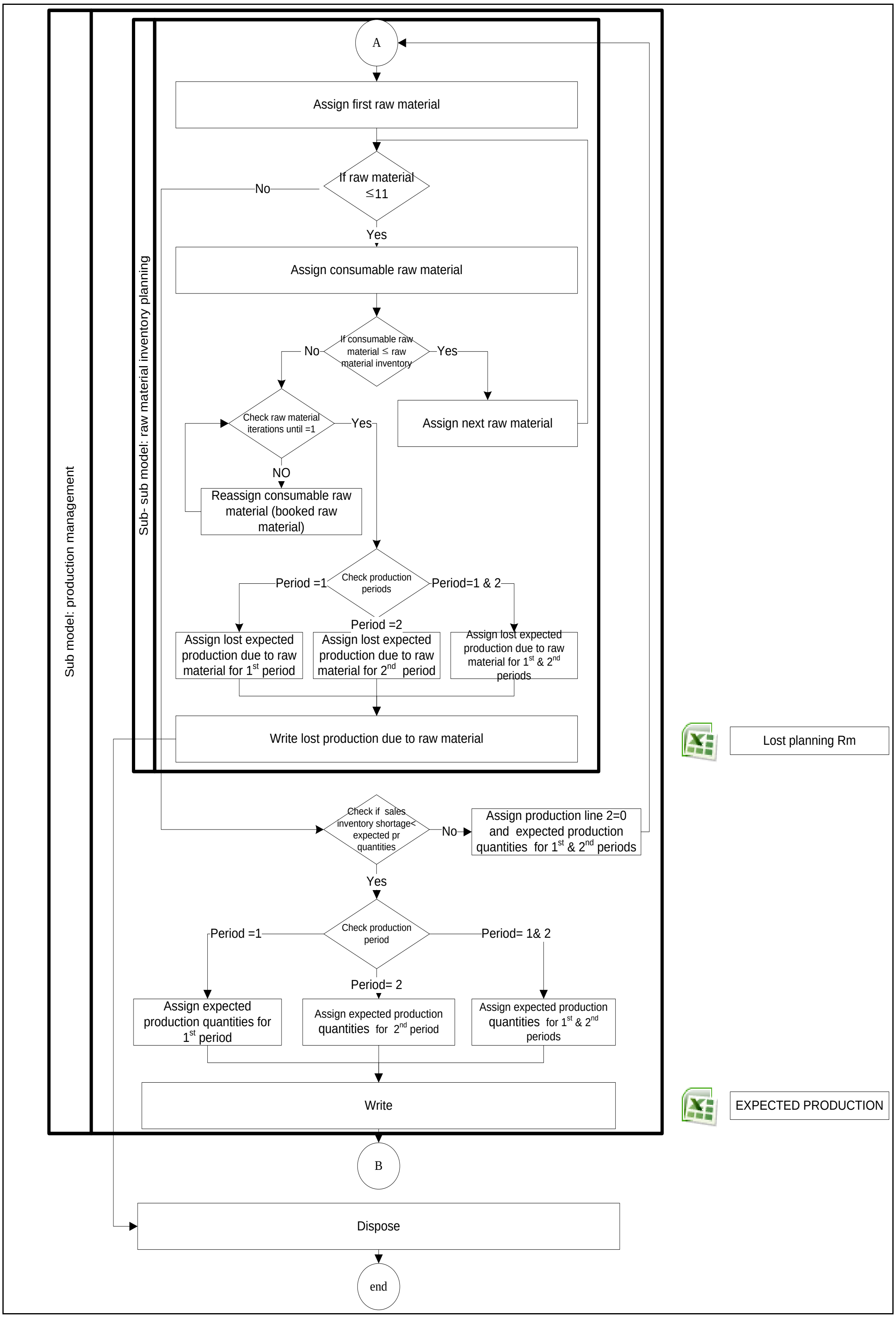
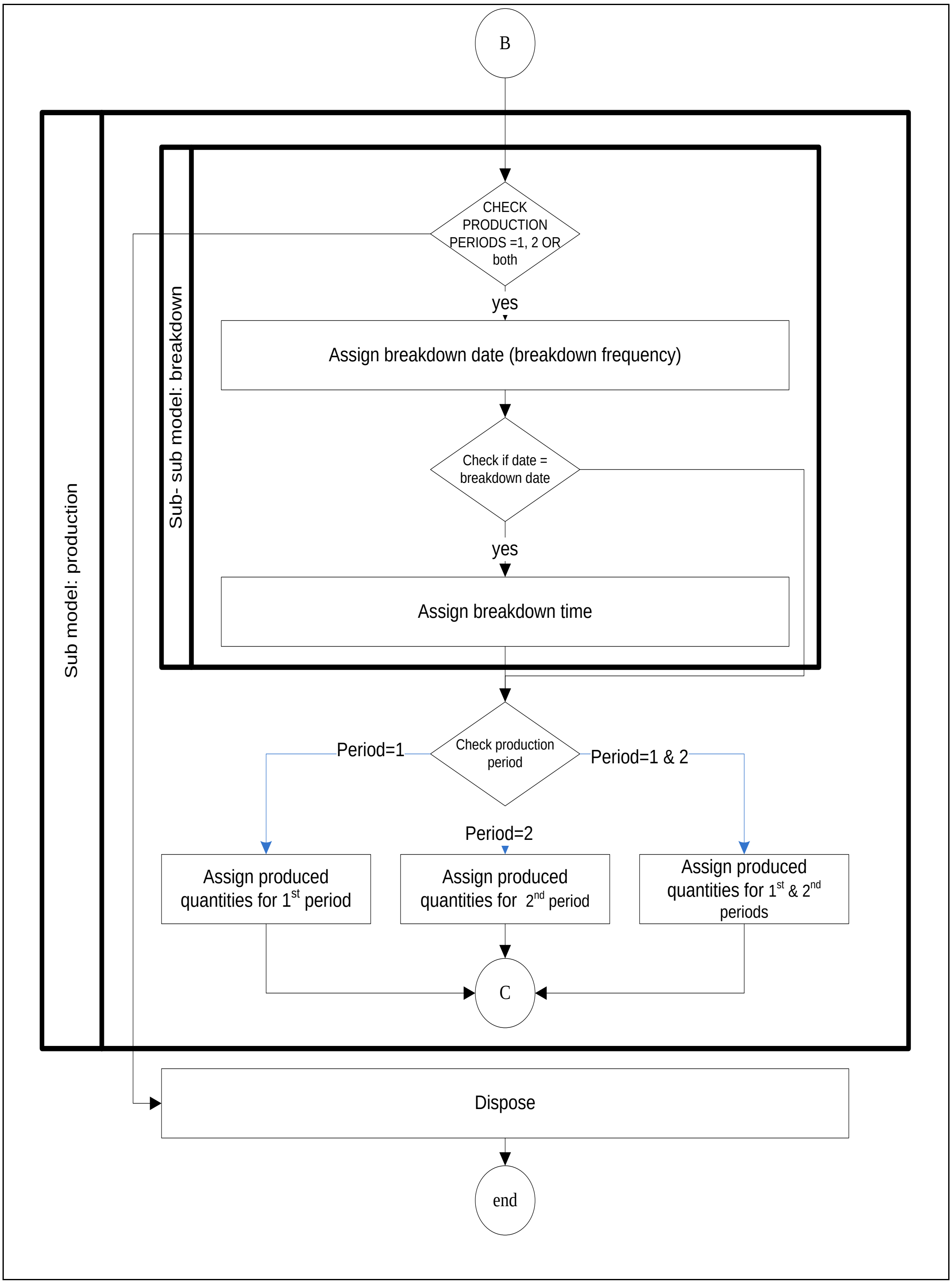


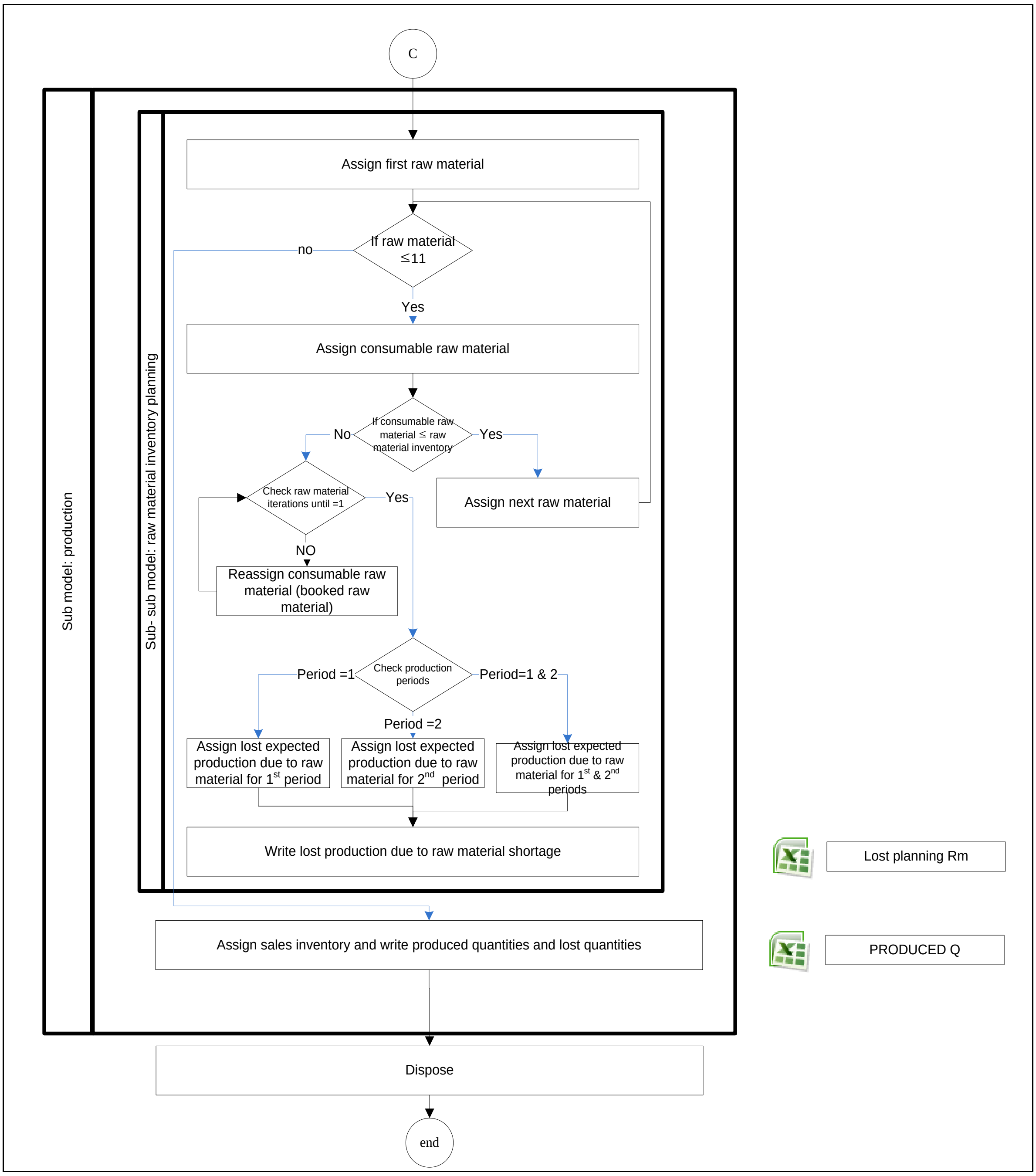
Figure (4.4): Sub-Model: Production Management (Continue)



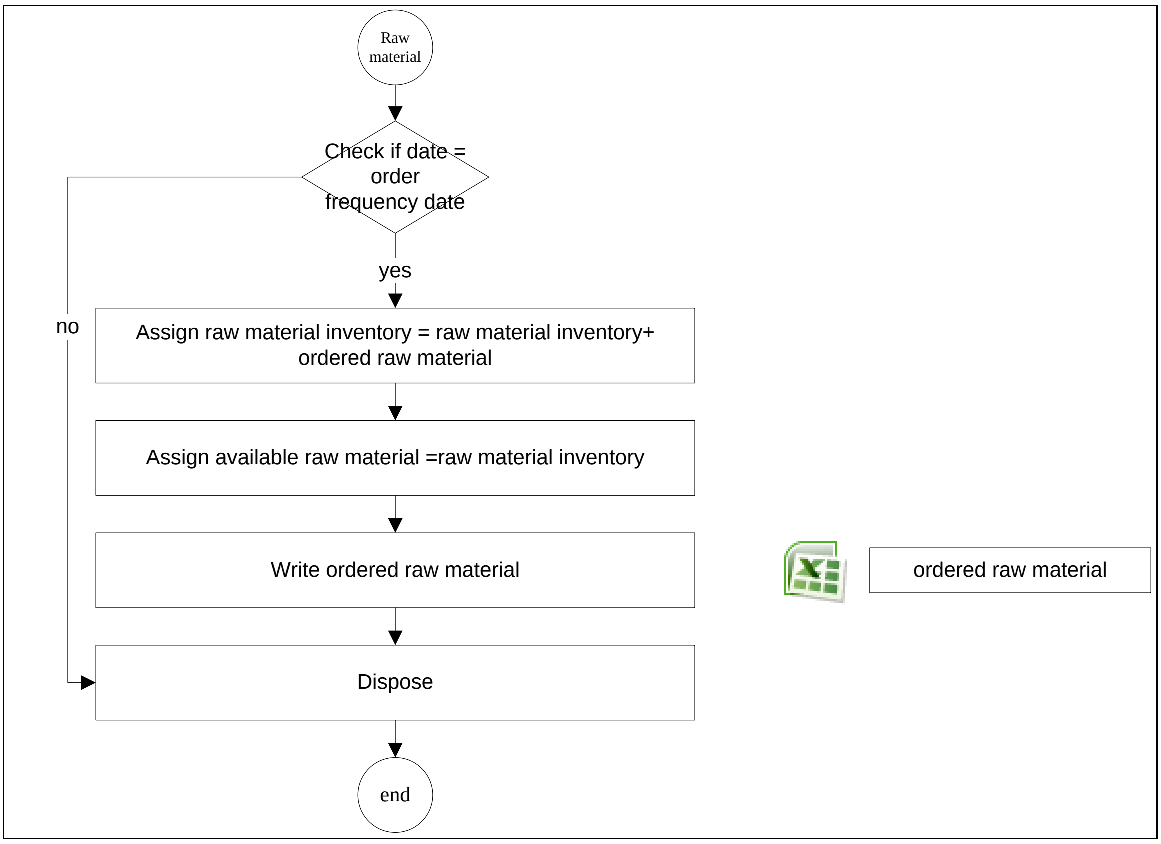
Figure(4.4): Sub-Model: Production Management (Continue)



Figure(4.4): Sub-Model: Production Management



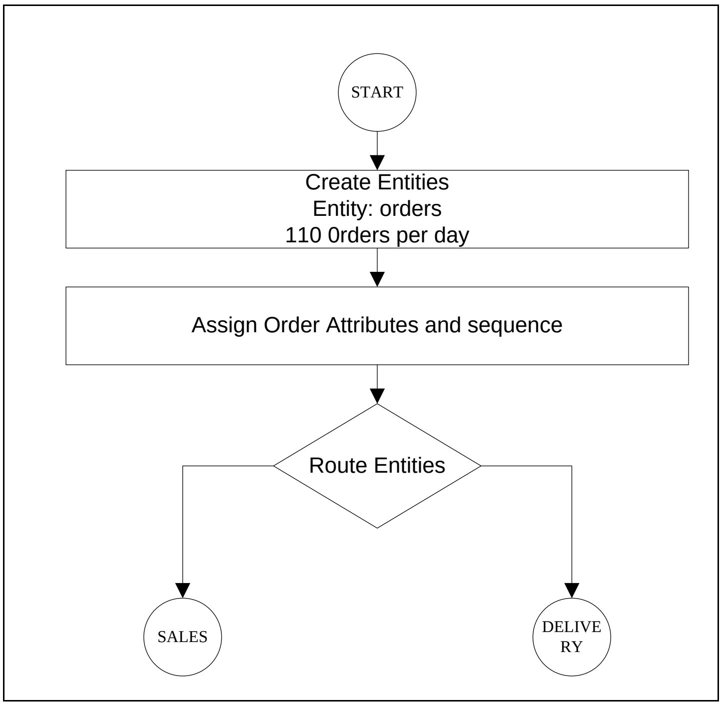
Figure(4.5): Raw material orders (Continue)



Figure(4.5): Raw Material order

All output data are expressed to "Sinokrot Sales Delivery simulation" by MS EXCEL sheets named "Main Sinkort Model" as input data to "Sinokrot Sales Delivery simulation" model.

"Sinokrot Sales Delivery simulation" is composed of 2 branches named; delivery management and distribution management. Each of them creates orders named delivery orders and distribution orders, as shown in Figure (4.6), Appendix C shows more details.



Figure(4.6): Create entities and orders (Sinokrot Sales Delivery simulation)

When delivery orders are created (100 entity per working day), they assign required attributes such as day, month, distribution center, and deliverable pallets. The orders are grouped until deliverable pallet exceeds half pallet for each product that will be delivered. After that, products delivery orders are grouped until total deliverable pallets exceeds 10 pallets and not more than 12 pallets. Next, the simulation model assigns charge ready for distribution. Otherwise, when product delivery pallets is less than half pallet, they booked until exceeds half pallet. As shown in Figure (4.7).

Distribution orders are created to represent charges, i.e. number of distribution orders is same as number of charges as output of delivery management. The distributions orders wait until transporters are available, then they are transported to specified distribution center and recording waiting and transportation time, as shown in Figure (4.8).

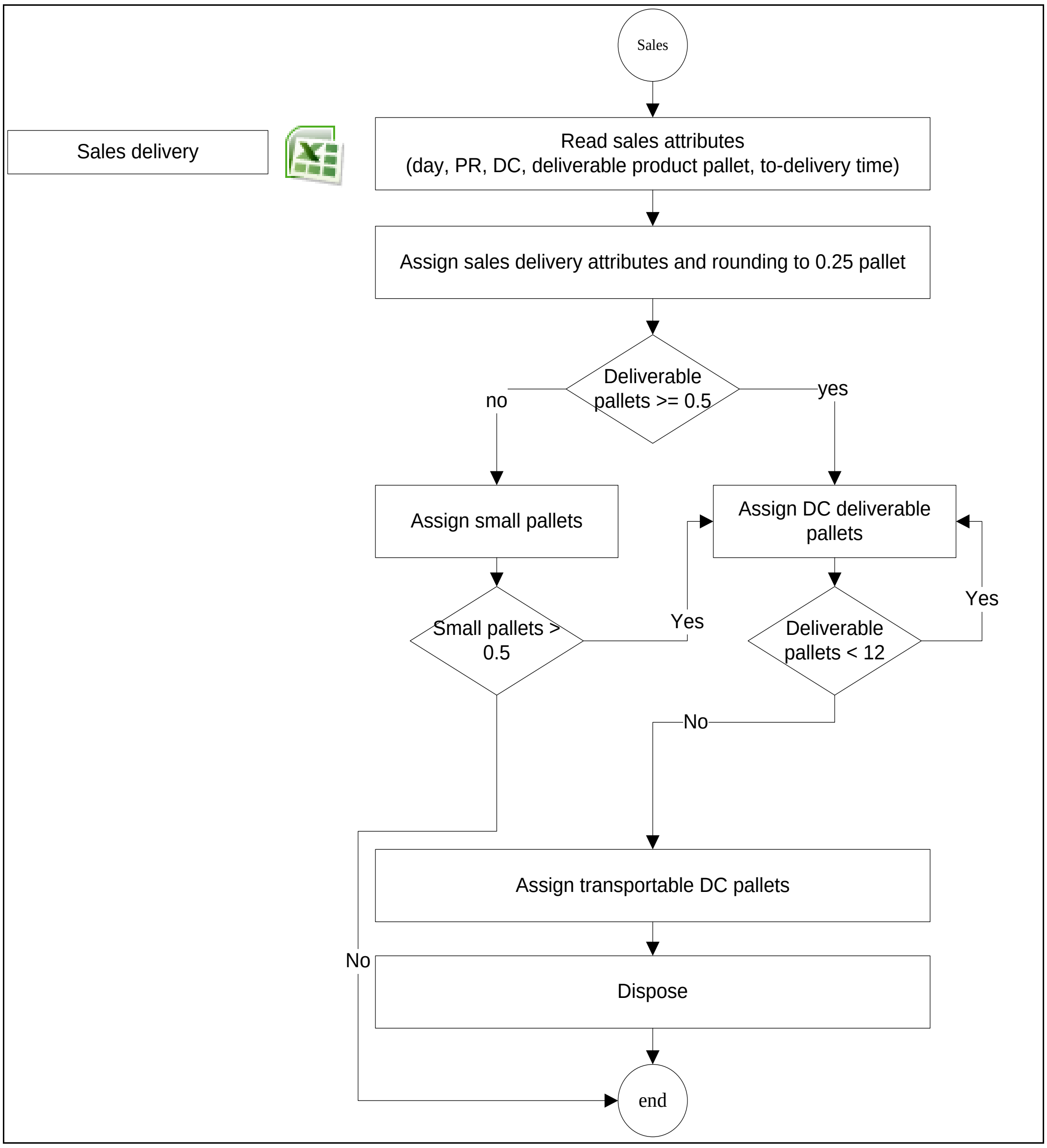


Figure (4.7): Delivery management

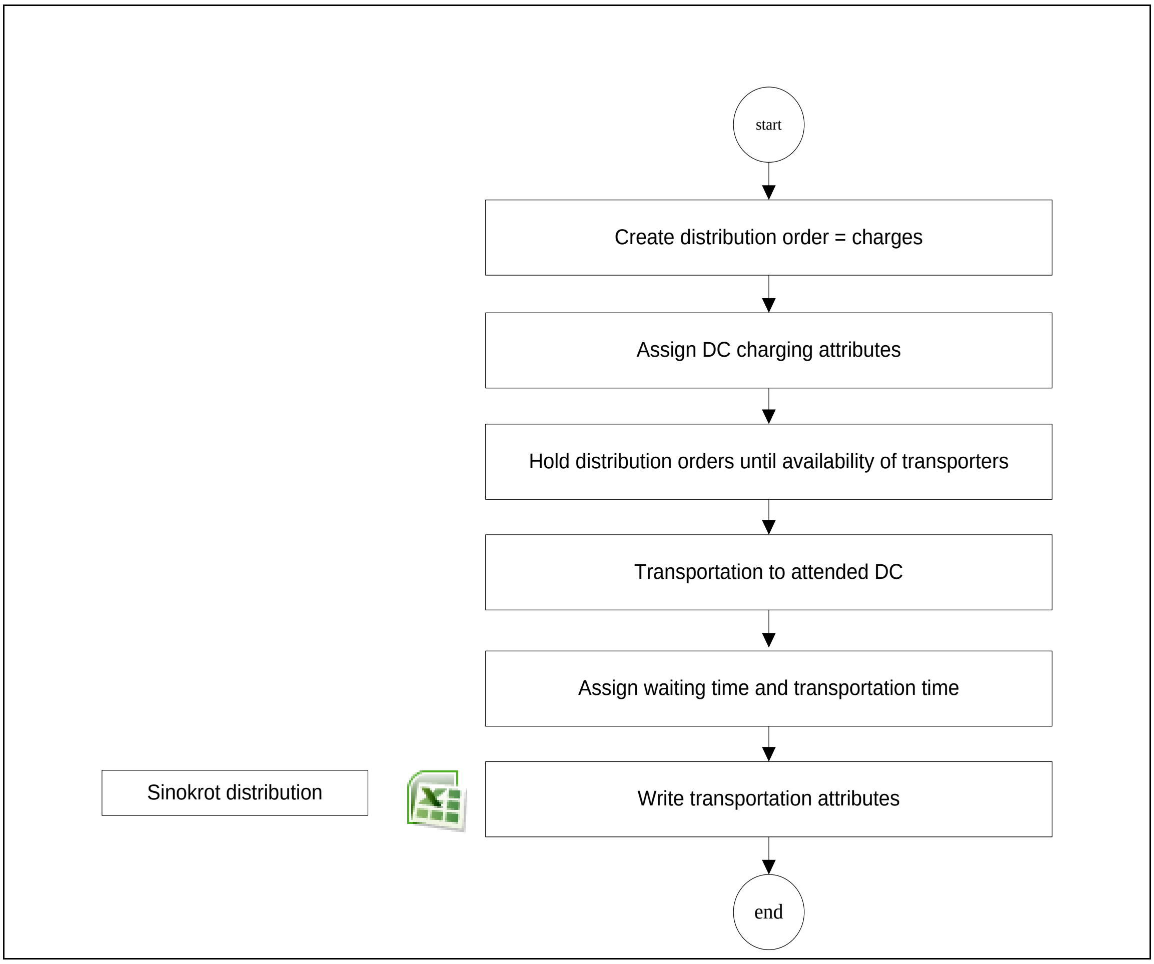


Figure (4.8): Distribution management

4.5. MODEL VERIFICATION

Verification is the process of insuring that the model operates as intended. This phase generally consists of debugging. The following techniques are used to perform debugging according to [Law and Kelton, 2000]:

4.5.1 DIVIDE AND CONQURE APPROACH

It is breaking the larger detailed system model into a smaller, simpler, or perhaps higher-level model. Therefore, any errors in syntax or variable naming can be more easily addressed to enhance the details or expansion of the model.

SINOKROT simulation model is divided to two main models; SINOKROT main model and SINOKROT delivery model related to each other by MS EXCEL sheet to transfer data as shown in the following Figure (4.9).

4.5.2 ANIMATION

- Different entity pictures

Entities pictures are not only used to show entities type but also the status in the system as shown in Table (4.3).Some examples are shown in Figure (4.10).To illustrate this concept, pictures of production entities are blue pages to represent production orders for period 1, green pages to rep-resent production orders for period 2, and red pages to represent failed production orders..

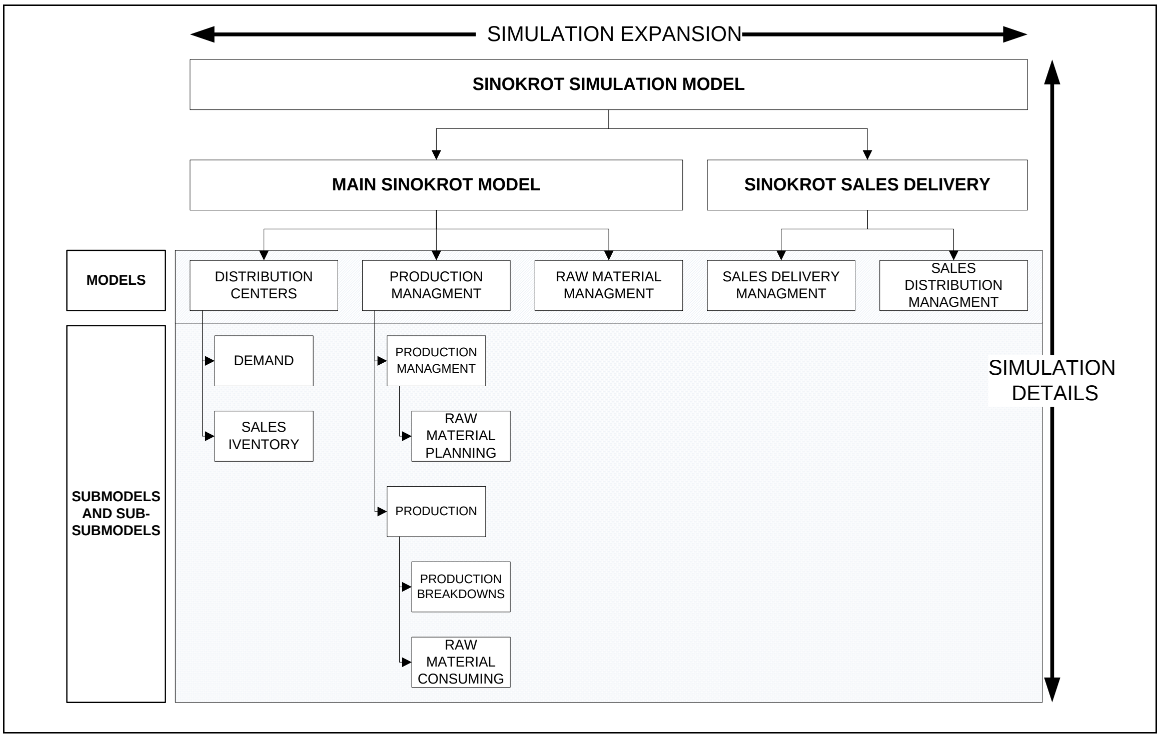


Figure (4.9): Simulation model structure for verification

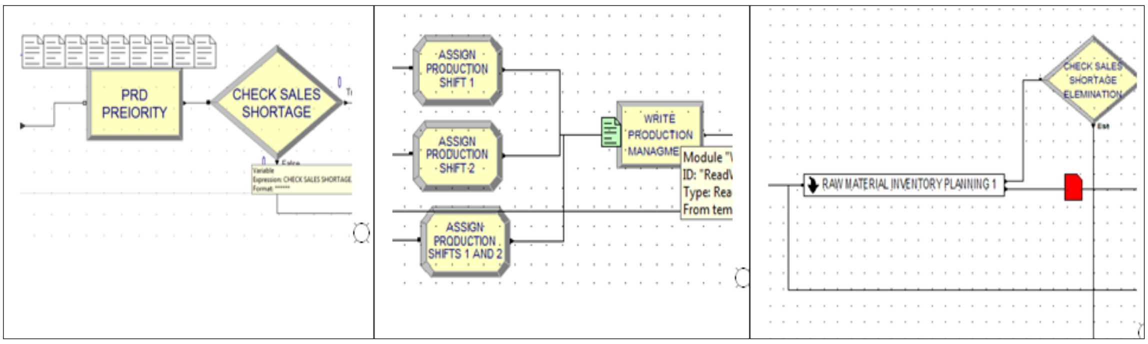


Figure (4.10): Simulation entity type and picture for verification

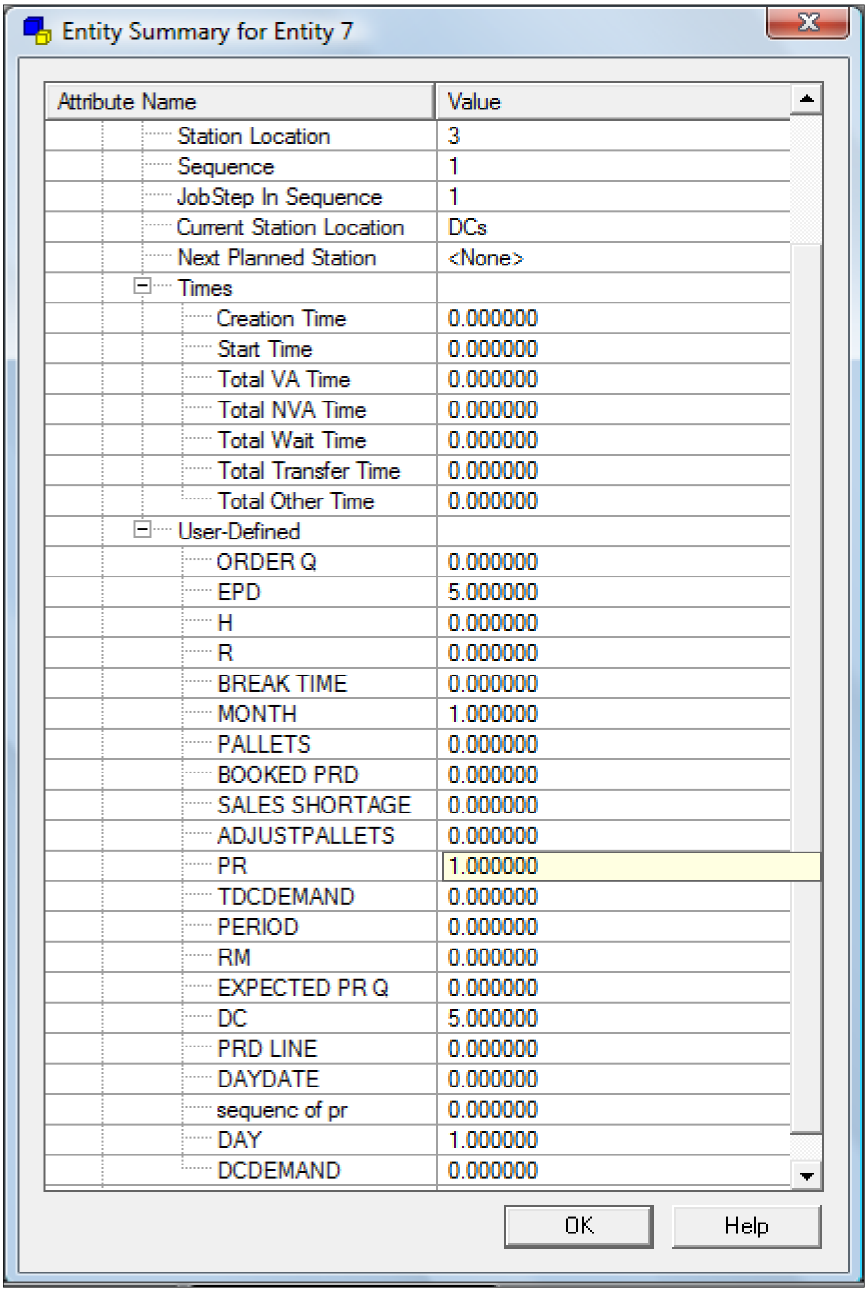
Table (4.3): Simulation entity type and picture

Model	Entity type	Entity status	Picture
SINOKROT MAIN MODEL	Demand and sales entities	Sales demand order	Yellow ball
		Sales order	Green ball
		Booked sales order	Red ball
	Production entities	Plan production order	Envelope
		Production order for period 1	Blue page
		Production order for period 2	Green page
		Production order for both period	Yellow page
		Failed production order	Red page
	Raw material entities	Raw material	Empty box
		Ordered raw material	Package
SINOKROT DELIVERY MODEL	Delivery order	Delivery order	Blue page
		Pallets more than 0.5	Yellow page
		Delivered pallets	Empty box
	Distribution order	Distribution order	Report
		Transportation order	Truck

- Following or tracking the entities through the system, as shown in Figure (4.11)

1. Using variable displays in the simulator screens, as shown in Figure (4.12)
2. Stepping through the program
3. Writing data to external files, such as MS Excel sheets "Sinokrot main model".
4. Using error and debugs manger in ARENA Software, as shown in Figure (4.13)

The final result of using previous verification techniques is that Sinokort models of the case study are verified.



Entity Summary for Entity 7

Attribute Name	Value
Station Location	3
Sequence	1
JobStep In Sequence	1
Current Station Location	DCs
Next Planned Station	<None>
Times	
Creation Time	0.000000
Start Time	0.000000
Total VA Time	0.000000
Total NVA Time	0.000000
Total Wait Time	0.000000
Total Transfer Time	0.000000
Total Other Time	0.000000
User-Defined	
ORDER Q	0.000000
EPD	5.000000
H	0.000000
R	0.000000
BREAK TIME	0.000000
MONTH	1.000000
PALLETS	0.000000
BOOKED PRD	0.000000
SALES SHORTAGE	0.000000
ADJUSTPALLETS	0.000000
PR	1.000000
TDCDEMAND	0.000000
PERIOD	0.000000
RM	0.000000
EXPECTED PR Q	0.000000
DC	5.000000
PRD LINE	0.000000
DAYDATE	0.000000
sequenc of pr	0.000000
DAY	1.000000
DCDEMAND	0.000000

OK Help

Figure (4.11): Following the entities for verification

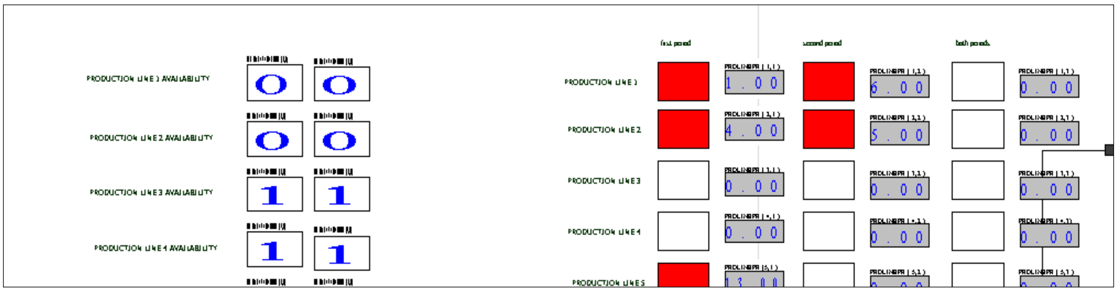


Figure (4.12): Using variable displays for verification

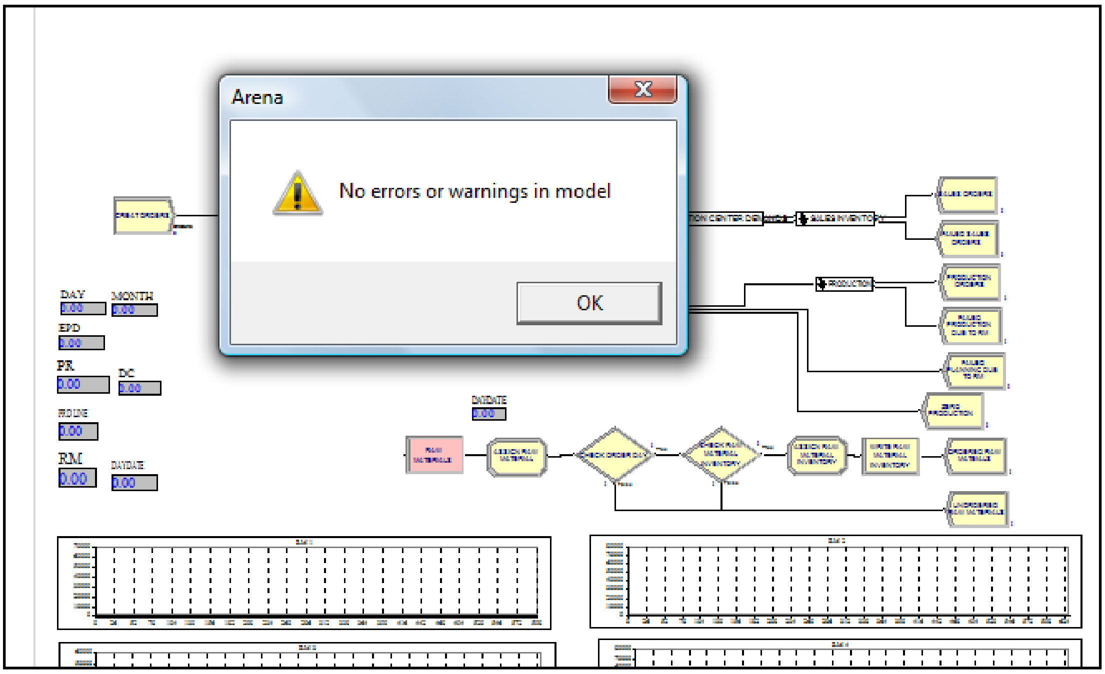


Figure (4.13): Check the simulation model for verification

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4.6 MODEL VALIDATION

There are two major types of validation according to [LAW and Kelton,2000]:

- “Face validity means that the model, at least on the surface, represents reality, i.e. face validity is review the simulation results for reasonableness, if the results are consistent with how the enterprise perceives the system should operate, then the simulation model is said to have face validity.

- Statistical validity involves a quantitative comparison between the output performance of the actual system and the model Sinokrot simulation models are reviewed to assure face validation (reviewing simulation results) by researcher and Sinokrot Staff. On the other hand, statistical validity is conducted in the following manner according to [Chung et al., 2004], and Figure (14.4) shows this manner.

1. Analyzing statistically the real data and data that generated by simulation model which named simulation data.
2. Check normality of real and simulation data by chi-square test, Kolmogorov-Smirnov, or Anderson-Darling, with confidence interval 95% in our case study ($\alpha = 0.05$).
3. If both of them are normal distribution i.e. hypothesis test result is to not reject the null hypothesis(as illustrated in General Concept of Input Data Fitting in Appendix B), then natural pairing test must be conducted, otherwise i.e. one of them is not normal distributed, non-parametric test must be conducted.
4. T-student test is used to accept or reject the null hypothesis that both of real data and simulation data are paired naturally. If result is not to reject the null hypothesis, the simulation system is valid; otherwise,

if the result is to reject the null hypothesis, F-test must be conducted to check if they have the same variances.

5. If both variances of both data are equal, then independent T-test must be conducted, otherwise i.e. variances are not equal, Smith–Satterthwaite test must be conducted.
6. If independent T-test shows no rejection of the null hypothesis, so the simulation system is valid, otherwise the simulation model must be developed and revalidated.
7. According to step 2, if one of them is not normal distributed, non-parametric test should be conducted such as U test or rank sum test. So if the result is to accept the null hypothesis, the simulation is valid, and otherwise the simulation model must be developed and revalidated.
8. According to step 5, if Smith–Satterthwaite test accept the null hypothesis, simulation model is valid, otherwise, it must be developed and revalidated.

To check the validity of Sinokrot simulation models, the real data and simulation data are compared according the pervious procedure. Some of these comparisons summaries are shown in Table (4.4) and Appendix D shows the details.

It is concluded that Sinokrot simulation models are valid to the reality.

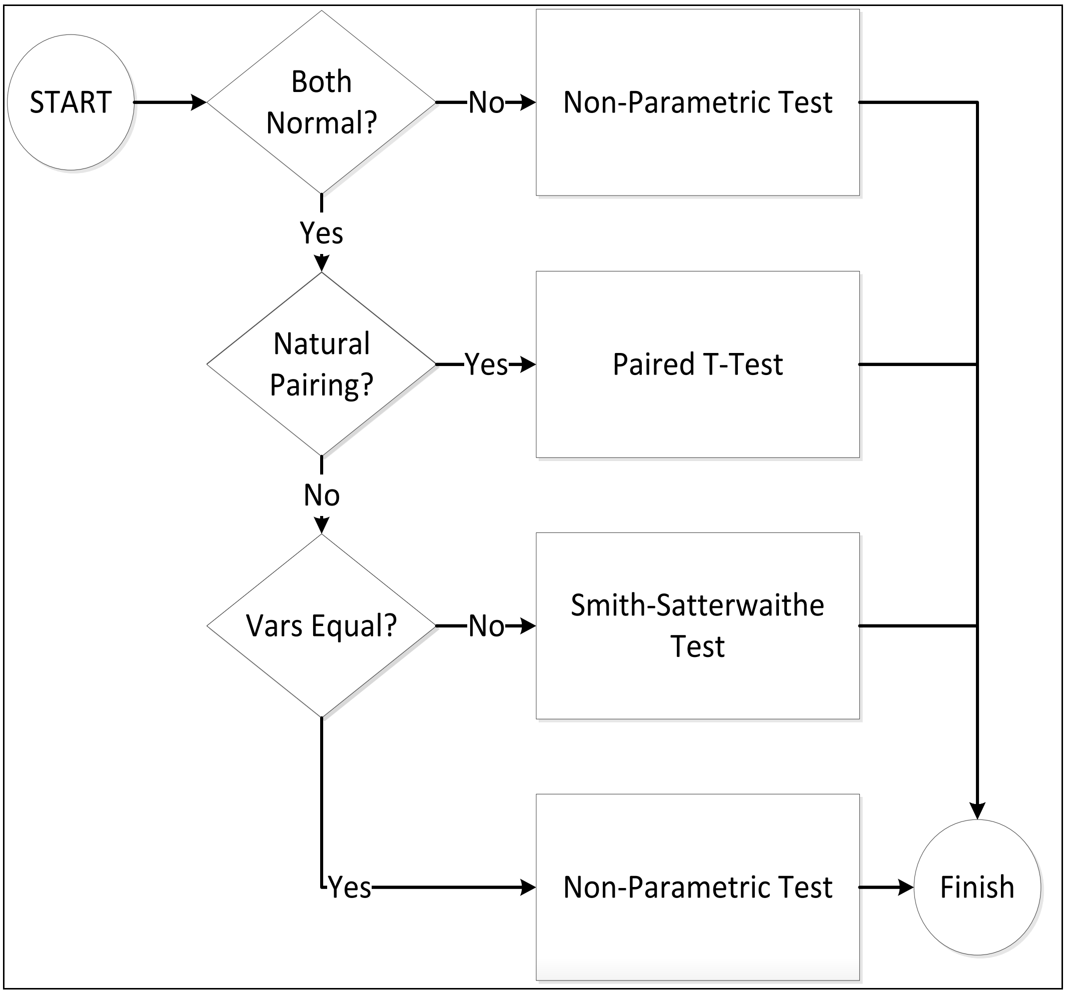

Figure (4.14): Simulation model validation procedure [Chung, 2004]

Table (4.4): Simulation model validation summary (continue)

	Pairs	Normal (chi-squired test)	Non-parametric test (rank sum test)	Natural pairing (paired T test)	Variances are equal? (F test)	independency (Independent T test)	Smith-Satterwaith test	validation
Demand validation summary								
1	rdemand1 & mdemand1	yes	----	yes	------	-----	-----	yes
2	rdemand5 & mdemand5	yes	----	yes	------	-----	-----	yes
3	rdemand10 & mdemand10	yes	----	yes	------	-----	-----	yes
4	rdemand15 & mdenand15	yes	----	yes	------	-----	-----	yes
5	rdemand17 & mdemand17	no	yes	----	------	-----	----	yes
Production rate validation summary								
1	rprivity1p1& sprivity1p1	no	yes	-----	----	----	----	yes
2	rprivity1p2 & sprivity1p2	yes	----	yes	----	----	----	yes
3	Rprivity5p1& sprivity5p1	yes	----	yes	----	----	----	yes
4	Rprivity5p2 & sprivity5p2	no	yes	-----	----	----	----	yes
5	rprivity15p1& sprivity15p1	no	yes	-----	----	----	----	yes
6	rprivity15p2 & sprivity15p2	no	yes	-----	----	----	----	yes
7	rprivity17p1& sprivity17p1	yes	----	yes	----	----	----	yes
8	rprivity17p2 & sprivity17p2	yes	----	yes	----	----	----	yes
produced quantities validation summery								
1	rprod1p1 - sprod1p1	yes	----	yes	------	-----	-----	yes
2	rprod5p2 - sprod5p2	yes	----	yes	------	-----	-----	yes
3	rprod15p1 - sprod15p1	yes	----	yes	------	-----	-----	yes
4	rprod17p1 - sprod17p1	no	yes	------	------	-----	-----	yes

Table keys	
rdemand1: real “product 1” demand	mdemand1: simulation “product 1” demand
rprivity1p2: real production rate of “product 1” for production period 2	sprivity1p2:simulation production rate of “product 1” for production period 2
rprod1p1: real produced quantities of “product 1” for production period 1	sprod1p1: simulation produced quantities of “product 1” for production period 1

4.7 REPLICATION EXPERIMENTALDESIGN

“The input distributions of simulation models are usually probabilistic in nature. This input variability naturally results in some variation in the output measures of performance. Because the output measures have some variation, it is inappropriate for the simulation practitioner to recommend any given course of action based on the results from a single simulation run or replication. To reduce the chance of making a wrong recommendation, it is necessary to run a number of simulation replications and then make the recommendations based on all of the available data”. [Chung, 2004]

“A good design of simulation replications allows the analyst to obtain the most statistical information from simulation runs for the least computational cost. In particular, we seek to minimize the number of replications and their length, and still obtain reliable statistics”. [Altiok et al., 2007]

In our case, to obtain the minimum replications of Sinokrot simulation model that assure reliable output statistics, simulation model variables such as product sales are statistically studied and analyzed. “Product sales” as a function of “number of replications” is shown in Figure (4.15) which shows 12 replications as the minimum replication number.

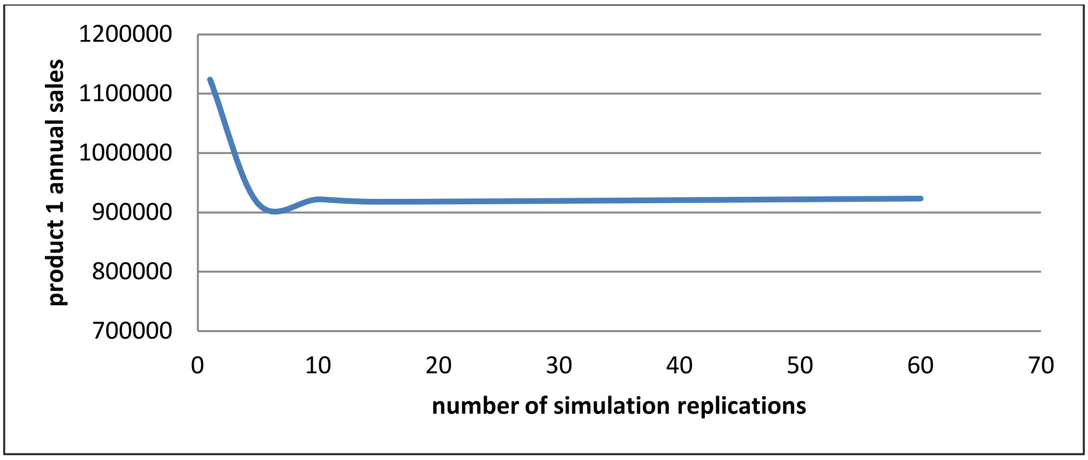

Figure (4.15): Statistical steady state sales versus number of simulation replications

4.8 SCENARIOS DEVELOPMENT AND ANALYSIS

According to Dijk and Sluis," Simulation is standard used and known for evaluation purposes of process performance. Its application for optimization purposes, however, seems to be limited mainly to a comparison of scenarios or parameterized search methods". [Dijk and Sluis, 2008]

4.8.1 SCENARIO 1: 15% MARKET DEMAND INCREASE

- **OBJECTIVES**

Study the effect of increasing in market demands upon the following factors or variables:

1. Actual product sales
2. Product sales to product demand percentage
3. Daily sales inventory average
4. Produced quantities of products
5. Daily production lines utilization

6. Annual production line utilization

The last two performance variables can be defined as shown in EQ.16 and EQ.17. Where actual utilized production time during one period is net production times after subtracting breakdowns times, and production time is 8.5 hours for the first production period and 7.5 for the second production period. While number of utilized production periods is annual sumو first and second production periods are actually used. Number of available production period is 624 production period per year (multiplying of 2 production periods per day, 26 day per month, and 12 month per year).

$\text{Daily production line utilization} = \frac{\text{actual utilized production time during one period}}{\text{production period}}$	**EQ.16**
$\text{Annual production line utilization} = \frac{\text{number of utilized production periods}}{\text{number of prodction period per yaer}}$	**EQ.17**

- **SCENARIO 1 RESULTS ANALYSIS AND RECOMANDATIONS**

Sinokrot simulation model is used to study the cited variables when market demands of products increase by 15%. Those variables are compared with ad hoc (as is) SFCo system. The comparison results are shown in Tables 4.4 and 4.5. While statistical experiment design are used to compare population means such as T-test and F-test to compare statistically between to populations, the results are not to reject null hypothesis (no differences between the two populations) as shown in table (E.1) in appendix E.

Table (4.5) and Table (4.6) show the following points:

1. Sales to demand percentages are about 100% for both ad hoc and scenario 1.
2. In general, annual produced quantities are the same in both systems. To fulfill the 15% demand increase, Sales inventory level average and inventory level at the end of year in scenario 1 are less than those in ad hoc system.
3. Annual production line utilization percentages are the same for both ad hoc and scenario 1to produce the same annual produced quantities. It can be concluded that SFCo can fulfill the market demand increase by 15 %.

Annual production lines results show weak annual utilization of production lines. It is recommended to increase market demands of the products; marketing campaigns must be increased in order to increase sales and annual production line utilization.

Table (4.5): Scenario1 comparisons (15% demand increase), (continue)

Ad hoc (As is) system										
PRODCUTS	1	2	3	4	5	6	7	8	9	10
Annual demand	1,396,993	9,889	124,535	213,019	87,219	122,756	15,548	13,348	6,699	9,959
Sales to demand %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	68,482	4,114	4,759	5,498	1,991	4,800	485	1,808	874	522
Sales inventory at end of year	75,283	2,468	4,668	5,512	1,871	4,322	522	3,066	333	880
Annual produced quantity	1,446,958	10,535	119,950	217,086	79,053	109,008	11,833	11,703	5,589	7,752
PRODCUTS	11	12	13	14	15	16	17	18	19	20
Annual demand	14,004	24,613	28,567	7,108	51,069	12,008	17,657	18,258	7,699	5,016
Sales to demand %	100%	100%	100%	100%	100%	98%	98%	100%	100%	99%
Daily average of sales inventory	569	1,604	1,444	450	3,628	1,550	2,047	1,476	836	952
Sales inventory at end of year	240	885	1,756	308	3,619	1,462	1,734	2,231	522	2,299
Annual produced quantity	10,787	21,080	22,868	5,684	49,501	11,638	15,874	16,955	6,315	6,666
Scenario 1 results										
PRODCUTS	1	2	3	4	5	6	7	8	9	10
Annual demand	1,607,928	11,391	143,074	242,609	100,854	141,171	17,897	15,418	7,716	11,423
Sales to demand %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	53,765	7,134	4,692	17,740	2,301	4,832	525	1,929	740	533
Sales inventory at end of year	56,152	16,342	2,686	37,323	2,474	5,104	484	1,391	1,286	452
Annual produced quantity	1,453,239	16,844	113,827	236,302	78,119	107,612	11,833	11,703	5,589	7,752
PRODCUTS	11	12	13	14	15	16	17	18	19	20
Annual demand	16,193	28,294	32,887	8,175	58,734	13,837	20,454	20,988	8,931	5,132
Sales to demand %	100%	100%	100%	100%	100%	98%	98%	100%	99%	100%
Daily average of sales inventory	644	1,562	1,449	440	3,580	1,725	2,105	1,516	875	709
Sales inventory at end of year	300	1,896	1,210	525	3,572	2,556	2,531	966	730	2,552
Annual produced quantity	10,787	21,080	22,868	5,684	49,501	11,638	15,874	16,955	6,315	5,921

Table (4.6): Production line utilization

DAILY PRODCUTION LINE UTILIZATION								
PRODUCTION LINES	1	2	3	4	5	6	7	8
Ad hoc (As is) system	98.5%	99.2%	99.3%	98.3%	99.9%	99.9%	100.0%	100.0%
Scenario 1 results	98.6%	99.1%	99.2%	98.3%	99.9%	99.9%	100.0%	100.0%
ANNAUAL UTILIZATION OF PRODCUTION LINES								
PRODUCTION LINES	1	2	3	4	5	6	7	8
Ad hoc (As is) system	48.6%	82.2%	10.6%	3.5%	8.7%	18.6%	4.6%	3.0%
Scenario 1 results	48.6%	82.4%	10.6%	3.5%	8.6%	18.6%	4.6%	3.0%

4.8.2 SCENARIO 2: DEVELOPMENT OF SALES INVENTORY TARGET LEVEL

- **OBJECTIVES**

Study the effect of reduction of sales inventory target on sales inventory average.

- **SCENARIO 2 RESULTS ANALYSIS AND RECOMANDATIONS**

Production priority in Sinokrot simulation model is based on the difference of product sales inventory target level and current product sales inventory level. This deference is called product sales inventory shortage as shown in EQ.2.

Scenario 2 based on the following questions, can sales inventory average be reduced according to lean manufacturing philosophy? How can it be done, and what are sales inventory target levels required in condition of maintaining sales to demand percentages?

Sinokrot simulation model is used to determine minimum sales inventory during the year and to determine scenario 2 sales targets as shown in EQ.18.

$\text{Sales target level (scenario 2)} = \text{Sales target level (Ad hoc)} - \text{Minimum sales inventory (Ad hoc)}$	**EQ.18**

❖ SCENARIO 2 RESULTS ANALYSIS AND RECOMANDATIONS

After running "scenario 2: simulation model", the results are exhibited in Table (4.7) and Table (4.8), and the following points can be concluded:

1. Reduction of sales target levels do not effect on the sales to demand percentages and annual produced quantities.
2. Reduction of sales target levels lead to 83% sales inventory average reduction, and- as a results- lead to reduction of inventory holding cost.
3. Reduction decreases sales inventory at the end of year.

According to previous point, it is recommended to adopt the reduction of sales targets.

Table (4.7): Scenario 2 comparison (Development of sales inventory target level), continue

Ad hoc (As is) system										
Products	1	2	3	4	5	6	7	8	9	10
Annual demand	1,396,993	9,889	124,535	213,019	87,219	122,756	15,548	13,348	6,699	9,959
Sales to demand %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	68,482	4,114	4,759	5,498	1,991	4,800	485	1,808	874	522
Sales inventory target	75,000	400	3,000	1,250	1,900	4,200	300	300	200	200
Minimum sales inventory	14,609	84	1,871	13	287	2,410	1	0	40	69
Sales inventory at end of year	75,283	8,468	4,668	5,512	1,871	4,322	522	3,066	333	880
Annual produced quantity	1,453,239	16,844	113,827	236,302	78,119	106,286	11,833	11,703	5,589	7,752
Products	11	12	13	14	15	16	17	18	19	20
Annual demand	14,004	24,613	28,567	7,108	51,069	12,008	17,657	18,258	7,699	5,016
Sales to demand %	100%	100%	100%	100%	100%	98%	98%	100%	100%	99%
Daily average of sales inventory	569	1,604	1,444	450	3,628	1,550	2,047	1,476	836	952
Sales inventory target	250	700	1,200	300	3,500	400	600	700	450	450
Minimum sales inventory	103	142	136	4	1,201	1	8	0	6	2
Sales inventory at end of year	240	885	1,756	308	3,619	1,462	1,734	2,231	522	2,299
Annual produced quantity	10,787	21,080	22,868	5,684	49,501	11,638	15,874	16,955	6,315	5,921
SCENARIO 2										
Products	1	2	3	4	5	6	7	8	9	10
Annual demand	1,396,993	9,889	124,535	213,019	87,219	122,756	15,548	13,348	6,699	9,959
Sales to demand %	100%	100%	100%	98%	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	57,176	1,793	3,062	3,542	1,735	2,429	432	1,348	610	449
Sales inventory target	60,391	316	1,129	1,237	1,613	1,790	299	300	160	131
Minimum sales inventory	14,609	82	686	0	287	1,367	44	64	57	77
Sales inventory at end of year	57,144	502	2,298	7,489	1,721	1,955	444	1,684	1,499	418
Annual produced quantity	1,436,716	11,095	112,126	224,429	77,855	106,913	11,926	16,884	5,704	7,646

Table (4.7): Scenario 2 comparison (Development of sales inventory target level)

SCENARIO 2										
Products	11	12	13	14	15	16	17	18	19	20
Annual demand	14,004	24,613	28,567	7,108	51,069	12,008	17,657	18,258	7,699	5,016
Sales to demand %	100%	100%	100%	100%	100%	98%	98%	100%	99%	100%
Daily average of sales inventory	365	1,948	1,337	441	2,456	1,547	1,843	1,473	1,027	866
Sales inventory target	147	558	1,064	296	2,299	399	592	700	444	448
Minimum sales inventory	94	213	136	4	1,266	2	9	611	109	2
Sales inventory at end of year	573	1,513	1,417	557	2,248	1,275	1,513	935	1,191	2,670
Annual produced quantity	10,693	19,922	22,528	5,719	48,542	10,295	15,929	16,429	6,177	5,944

Table (4.8): Sales inventory average reduction

Products	1	2	3	4	5	6	7	8	9	10
Sales inventory average reduction	83%	44%	64%	64%	87%	51%	89%	75%	70%	86%
Products	11	12	13	14	15	16	17	18	19	20
Sales inventory average reduction	64%	121%	93%	98%	68%	100%	90%	100%	123%	91%

4.8.3 SCENARIO 3: ALLOCTING PRODCUTION LINE 1 FOR PRODUCT GROUP 1 ONLY

- **OBJECTIVES**

Study the effect of allocating production line 1 for product group 1 only upon the following variables:

- Product sales to demand percentage
- Annual produced quantities
- Annual production line utilization

- **SCENARIO 3 RESULTS ANALYSIS AND RECOMANDATIONS**

Production line 1 is shared between product groups 1 and 2, while production line 2 is allocated only for producing product group 2. In this scenario, production line 1 is allocated to produce product group 1 only. To study the effects of this scenario, Sinokrot simulation model is used after deletion simulation modules that used to allow product group 2 enters the production line 1 in production management sub-model.

After running “scenario 3 simulation model”, the results are exhibited in Table (4.9) and Table (4.10), and the following points can be concluded:

Allocating “production line 1” to produce “product group 1” only does not effect on sales to demand percentages. SFCo owns good potentials to provide the market with same required products quantities.

Approximately, there are no differences between ad hoc system and Scenario 3 in annual produced quantities.

Annual production line utilization reveals that SFCo does not require extra production line.

It is recommended to increase market demands of the products, marketing campaigns must be increased and so sales and annual production line utilization will be increased.

Table (4.9): Scenario 3 comparison

Ad hoc (As is) system						
PRODCUTS	1	2	3	4	5	6
Annual demand	1,396,993	9,889	124,535	213,019	87,219	122,756
Sales to demand %	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	68,482	4,114	4,759	5,498	1,991	4,800
Sales inventory at end of year	75,283	2,468	4,668	5,512	1,871	4,322
Annual produced quantity	1,446,958	10,535	119,950	217,086	79,053	109,008
SCENARIO 3						
PRODCUTS	1	2	3	4	5	6
Annual demand	1,396,993	9,889	124,535	213,019	87,219	122,756
Sales to demand %	100%	100%	100%	100%	100%	100%
Daily average of sales inventory	67,456	4,070	4,443	4,296	1,789	4,360
Sales inventory at end of year	68,833	2,450	3,627	5,380	1,670	4,176
Annual produced quantity	1,438,106	10,535	112,904	217,369	78,944	106,972

Table (4.10): Annual production line utilization

ANNAUAL UTILIZATION OF PRODCUTION LINES		
Production line	1	2
Ad hoc (As is) system	48.60%	82.20%
SCENARIO 3	39.90%	88.62%

4.8.4 SCENARIO 4: RAW MATERIAL INVENTORY MANGMENT BASED ON FIXED-ORDERED QUANTITY

❖ **OBJECTIVES**

Developing raw material inventory system based on simulation procedure to:

1. Minimize average daily inventory level
2. Minimize inventory stock out to fulfill the production demand.
3. Determine optimum order quantity and optimum reorder point for each raw material.
4. Analyze inventory attributes according to Lean manufacturing philosophy, where Lean manufacturing is a management philosophy focused on eliminating waste, reducing inventory, and increasing profitability.

Ad hoc raw material inventory attributes, and performance variables are shown in Table (4.11), note that costs are expressed by cost unit for confidential purposes.

D. Blanchard mentions some principles that companies should follow to build and manage lean systems as the following:

- Measure any improvements in subsystem performance by weighing their impact on the whole system.

- Maintain inventories in an undifferentiated (unfinished) form for as long as it is economically feasible to do so.
- Buffer variation in demand with capacity, not inventory.
- Use forecasts to plan and pull to execute.
- Make decisions that promote a growth strategy and focus on improving throughput.
- Reduce variation in the system, which will allow the supply chain to generate higher throughput with lower inventory and lower operating expense.

❖ **SCENARIO 4 MODEL**

There are many models that inventory management based on, but the main models that widely used are fixed-ordered quantity model which will be discussed here and fixed-time period model will be discussed in the scenario 5. These models will be studied and analyzed by using simulation techniques to achieve the objectives.

Total annual cost is sum of holding cost, annual demand, and ordering cost. It can be calculated by EQ.19. Optimum order quantity can be calculated by EQ.20 where is first derivative of EQ.19, and Figure (4.16) illustrates optimum order quantity that minimize the total cost, while Figure (4.17) shows the inventory position.

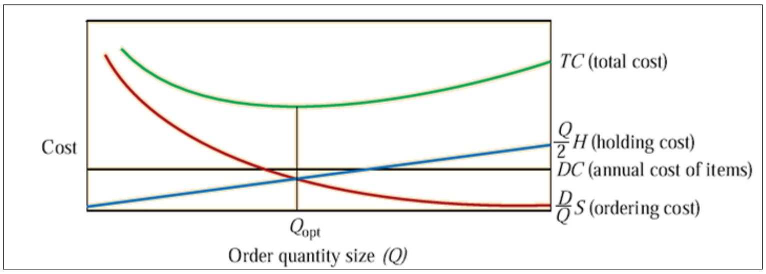

Figure (4.16): Annual Product cost, based on size of order [Jacob and Chase, 2008]

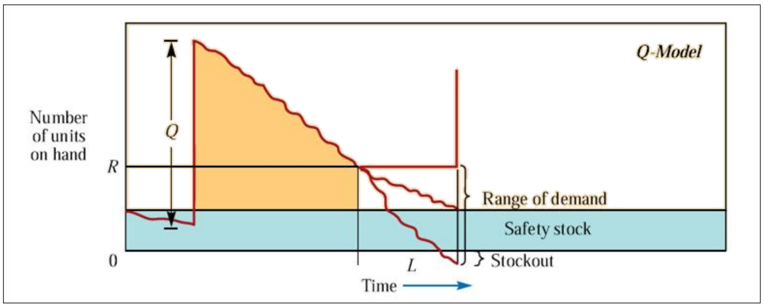

Figure (4.17): Inventory position and lead time [Jacob and Chase, 2008]

Total Annual Cost = Annual purchase Cost + Annual Ordering Cost + Annaula Holding Cost $TC = DC + \frac{D}{Q}S + \frac{Q}{2}H$	EQ.19
$Qopt. = \sqrt{\frac{2DS}{H}}$	EQ.20
$R = \bar{d}L + Z\sigma L$	EQ.21
Safety stock $= Z\sigma L$	EQ.22

Where:

- TC: Total annual cost
- C: cost per unit
- S: cost of placing an order
- L: lead time
- $\bar{d}$:average daily demand
- R: Reorder point
- D: demand (annual)
- Q: quantity to be ordered
- H: annual holding and storage cost per unit
- Z: number of standard deviations for a specified service probability
- σ_L: standard deviation of usage during lead time

EQ.21 is applicable to determine re-order point when lead time is deterministic and safety stock is considered according to standard deviation of usage material during lead time. In reality, lead time is rarely deterministic; however, it depends on dynamic variables such as logistics, transportation, and administration arrangements. So there is more probability of occurrence of risky stock out which leads to production failures and increases costs and loses.

Table (4.11): Ad hoc raw material inventory system, continue

Raw material	1	2	3	4	5	6
Annual Demand (Kg)	799,509	521,615	297,669	627,633	3,861	27,105
Inventory Level Average (Kg)	45,705	38,746	30,128	54,849	1,163	2,236
Order Quantity (Kg)	45,000	49,000	32,000	62,000	1,000	2,600
Theoretical Optimum Order Quantity (Kg)	14,094	9,195	6,201	11,064	80	478
Number of Orders	24	12	12	12	12	12
Time between Orders (day)	13	26	26	26	26	26
Re-order Point (Kg)	43,562	23,700	15,456	33,024	362	848
Theoretical re-order point (Kg)	14,094	9,195	6,201	11,064	80	478
Stock-out probability	1.6%	4.4%	3.5%	2.6%	1.3%	1.1%
purchasing cost (per Kg)	4	4	3	5	15	11
Ordering Cost (per Order)	100	100	100	130	15	15
Holding Cost (per Kg)	0.60	0.60	0.60	0.60	1.00	0.80
purchasing cost (cost unit)	2,798,280	2,086,460	863,241	3,138,165	57,914	292,735
Ordering Cost (cost unit)	2,400	1,200	1,200	1,560	180	180
Holding Cost (cost unit)	27,423	23,248	18,077	32,910	1,163	1,789
Inventory Total Cost (cost unit)	2,828,103	2,110,908	882,518	3,172,634	59,257	294,704

Table (4.11): Ad hoc raw material inventory system

Raw material	7	8	9	10	11	Sum
Annual Demand (Kg)	46,088	236,163	15,816	908	25,994	
Inventory Level Average (Kg)	5,986	20,156	4,630	35	4,930	
Order Quantity (Kg)	5,800	23,500	3,900	200	4,300	
Theoretical Optimum Order Quantity (Kg)	812	4,920	279	25	458	
Number of Orders	12	12	12	3	12	
Time between Orders (day)	26	26	26	100	26	
Re-order Point (Kg)	2,668	22,391	1,072	81	2,281	
Theoretical re-order point (Kg)	812	4,920	279	25	458	
Stock-out probability	4.5%	2.2%	4.3%	19.4%	5.3%	
purchasing cost (per Kg)	9	14	15	20	21	
Ordering Cost (per Order)	38	100	60	10	40	
Holding Cost (per Kg)	0.90	0.60	0.60	2.50	1.00	
purchasing cost (cost unit)	396,359	3,235,430	234,073	18,166	545,864	
Ordering Cost (cost unit)	456	1,200	720	31	480	13,666,687
Holding Cost (cost unit)	5,388	12,094	2,778	86	4,930	9,607
Inventory Total Cost (cost unit)	402,203	3,248,724	237,571	18,284	551,274	129,885

The following procedure is proposed to overcome the cited problem:

1. Run main Sinokrot simulation model, and collect the output file (excel sheet named main Sinokrot simulation model) to obtained daily demand of each raw material and total annual demand (D).
2. Determine the optimum order quantity theoretically by using equation EQ.20.
3. Determine the mean of lead time statistical distribution, then consider it as deterministic lead time then calculate Reorder point with safety stock equals to zero.
4. Calculate theoretical Reorder point.
5. Build simulation model as shown conceptually in Figure (4.18) which named scenario 4: fixed Q-based raw material inventory system, and shown modularly in figure (E.1) in appendix E.
6. Tabulate values of multiplications of the optimum order quantity (Q_{opt}) and Reorder point for each raw material.
7. Run scenario 4 simulation models by using optimum order quantities and reorder point as well as recording the results such as raw material inventory, stock out percentage, and number of orders.
8. Calculate annual holding cost by using EQ.19 but take in consideration that annual holding cost can theoretically calculated by multiplying half of order quantity unit by holding cost per year. This case is special case when stock out equals zero but practically it is

supposed to use raw material inventory level average instead of half order quantity.

9. Calculate purchasing cost by multiplying cost per unit, order quantity and number of orders.
10. Calculate ordering cost by multiplying cost per order by number of orders.
11. Excel sheet is used to calculate the above costs and total annual inventory costs are automatically calculated.
12. Re-run Scenario 4 simulation model by using multiplications of order point and Reorder point values, and go through steps 7 to 12.
13. After complete the required table, sort Q values and Re-order point values where inventory stock-out percentage greater than 0.
14. Actual optimum order quantity and optimum Re-order point where the total costs are minimal as shown in Table (E.2) in appendix E.

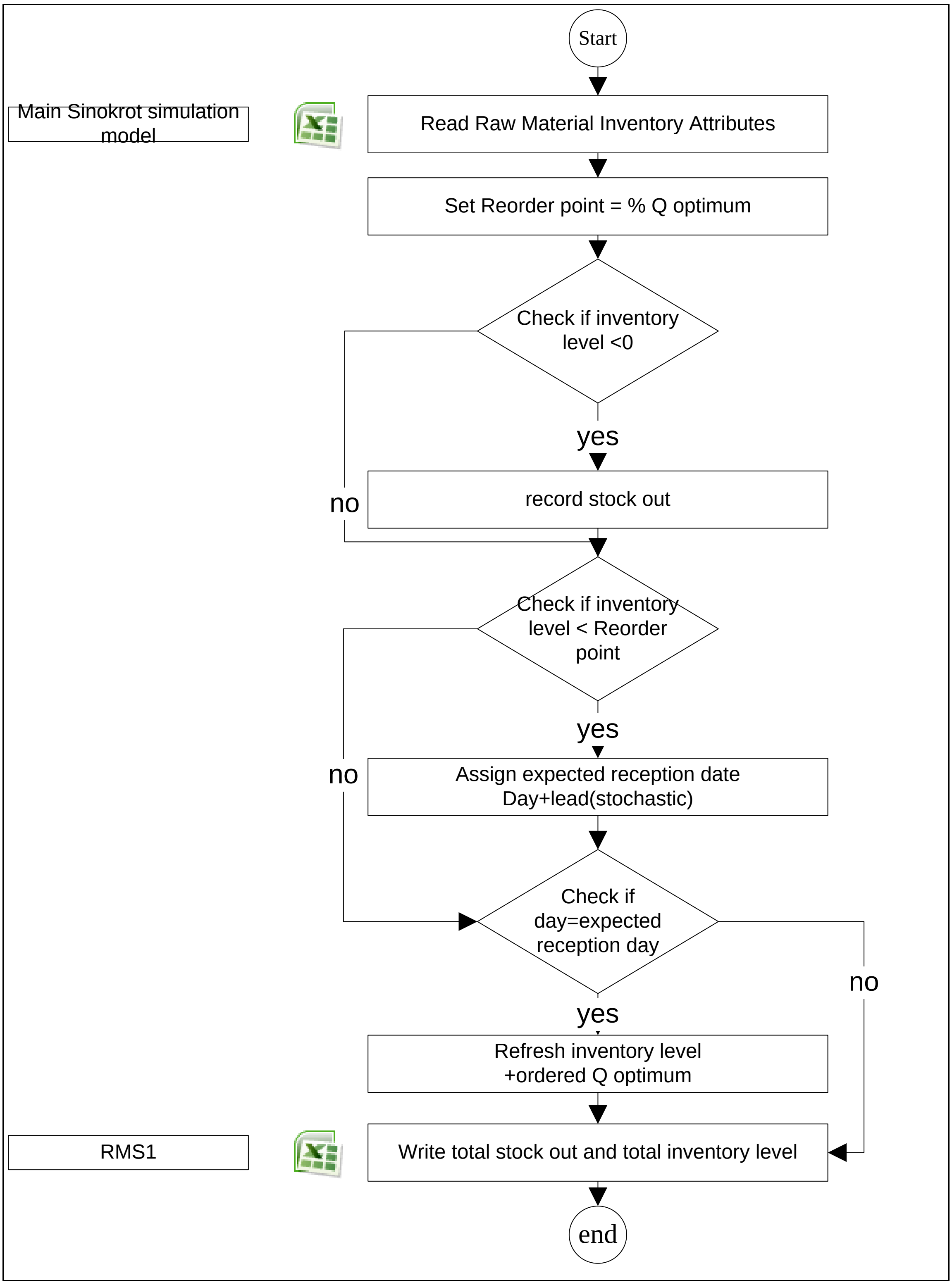

Figure (4.18): Raw material simulation modelin case of demand and lead time are stochastic (fixed order quantity)

Table (4.12): Scenario 4 (Q-based inventory system, continue

Raw material	1	2	3	4	5	6
Annual Demand (Kg)	652,068	421,354	242,371	324,455	2,206	24,197
Inventory Level Average (Kg)	151,787	50,443	40,590	162,938	1,316	1,905
Order Quantity (Kg)	130,414	105,338	80,790	324,455	2,206	4,033
Theoretical Optimum Order Quantity (Kg)	5	4	3	1	1	6
Number of Orders	64	80	107	320	320	53
Time between Orders (day)	105,704	9,195	6,201	11,064	80	478
Re-order Point (Kg)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Theoretical re-order point (Kg)	4	4	3	5	15	11
Stock-out probability	100	100	100	130	15	15
purchasing cost (per Kg)	0.60	0.60	0.60	0.60	1.00	0.80
Ordering Cost (per Order)	2,282,238	1,685,416	702,876	1,622,275	33,090	261,328
Holding Cost (per Kg)	500	400	300	130	15	90
purchasing cost (cost unit)	91,072	30,266	24,354	97,763	1,316	1,524
Ordering Cost (cost unit)	2,373,810	1,716,082	727,530	1,720,168	34,421	262,942
Holding Cost (cost unit)	652,068	421,354	242,371	324,455	2,206	24,197
Inventory Total Cost (cost unit)	151,787	50,443	40,590	162,938	1,316	1,905

Table (4.12): Scenario 4 (Q-based inventory system)

Raw material	7	8	9	10	11	Sum
Annual Demand (Kg)	31,241	212,637	13,444	572	21,631	
Inventory Level Average (Kg)	8,069	10,405	2,319	469	3,449	
Order Quantity (Kg)	15,620	23,626	4,481	572	5,408	
Theoretical Optimum Order Quantity (Kg)	2	9	3	1	4	
Number of Orders	160	36	107	320	80	
Time between Orders (day)	812	4,920	279	186	1,375	
Re-order Point (Kg)	0.0%	0.0%	0.0%	0.0%	0.0%	
Theoretical re-order point (Kg)	9	14	15	20	21	
Stock-out probability	38	100	60	10	40	
purchasing cost (per Kg)	0.90	0.60	0.60	2.50	1.00	
Ordering Cost (per Order)	268,673	2,913,127	198,971	11,440	454,251	
Holding Cost (per Kg)	76	900	180	10	160	
purchasing cost (cost unit)	7,262	6,243	1,391	1,173	3,449	10,433,684
Ordering Cost (cost unit)	276,011	2,920,270	200,543	12,623	457,860	2,761
Holding Cost (cost unit)	31,241	212,637	13,444	572	21,631	265,813
Inventory Total Cost (cost unit)	8,069	10,405	2,319	469	3,449	10,702,258

Table (4.13): Compared costs of scenario 4 with ad hoc system

Raw material	1	2	3	4	5	6
Purchasing cost (cost unit)	82%	81%	81%	52%	57%	89%
Ordering Cost (cost unit)	21%	33%	25%	8%	8%	50%
Holding Cost (cost unit)	332%	130%	135%	297%	113%	85%
Inventory Total Cost (cost unit)	84%	81%	82%	54%	58%	89%
Raw material	7	8	9	10	11	Sum
Purchasing cost (cost unit)	68%	90%	85%	63%	83%	76%
Ordering Cost (cost unit)	17%	75%	25%	32%	33%	29%
Holding Cost (cost unit)	135%	52%	50%	1358%	70%	205%
Inventory Total Cost (cost unit)	69%	90%	84%	69%	83%	78%

❖ SCENARIO 4 RESULTS AND RECOMANDATIONS

Results of executing raw material simulation procedure such as optimum order quantity, optimum reorder point, daily average inventory, and total inventory are shown in Table (4.12). Comparisons between main Sinokrot simulation model and scenario 4 are conducted as shown in Table (4.13).

Statistical experiments are used to compare between main Sinokrot simulation model and scenario 4 (Q-based raw material inventory). Daily inventory level results which are optioned from both simulation models present two different populations. Independent T test and F test are used to conduct the null hypothesis assure that there are significant differences between both populations means as shown in table (E.3) in appendix E. and also Figure (4.19) represents this differences.

Table (4.13) exhibits significant differences in annual purchasing cost and total annual inventory cost between the models; these differences refer to many factors such as following:

1. Optimum Order quantity in scenario 4 is 360% more than ad hoc system but consider that stock out percentages are 0% in scenario 4, This factor leads to increase sales inventory average, and –as a results- 205% increasing of holding cost.
2. Although of increasing in optimum order quantities, number of orders in scenario 4 is less than in ad hoc system i.e. 29% ordering cost to ad hoc system, an –as a result- the annual purchased

quantities is less than ad hoc system i.e. 76% purchasing costs to ad hoc system.

3. Total annual inventory costs in scenario 4 are 78% of ad hoc system. So it is recommended to adopt scenario 4.

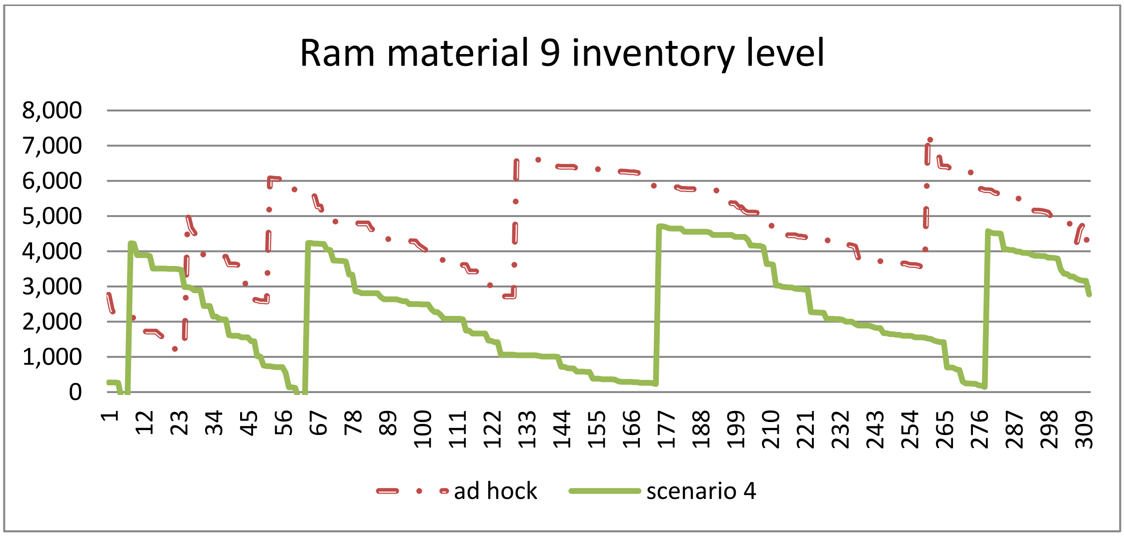

Figure (4. 19): Raw Material 4 Inventory for main Sinokrot and scenario 4 models (raw material 9)

4.8.5 SCENARIO 5: RAW MATERIAL INVENTORY MANGMENT BASED ON FIXED-TIME PERIOD MODEL

- **OBJECTIVES**

Developing raw material inventory system based on simulation procedure in order to:

1. Minimize average daily inventory level.
2. Minimize inventory stock out to fulfill the production demand.
3. Determine optimum time between orders for each raw material.
4. Analyze inventory attributes according to Lean manufacturing philosophy.

- **SCENARIO 5 MODEL**

In fixed–time period system, inventory is counted only at particular times, such as every week or every month. Also, generated order quantities vary from period to period depending on the usage rates. Safety stock must protect against stock outs during the review period itself as well as during the lead time from order placement to order receipt.

Time between inventory reviews and putting orders (T) is determined by inventory manger experience or routine visits of vendors taking in account the ordered quantities have to fulfill raw material demands including time between reviews and lead time as in EQ. 23.

Order quantity = over the vulnerable period + safety stock – quantity on hand (plus on order if any) $Q = \overline{d}(T + L) + Z\sigma(T + L) - I - Q \text{ on hand}$	EQ.23

As cited in scenario 4, lead time is rarely deterministic, so there is more probability of occurrence of risky stock out which leads to production failures, increases costs and loses. Safety stock is also stochastic when lead time is stochastic. If T is shorter than optimum T, the inventory level will be high, but if T is longer, then stock out occurs.

To determine optimum T that minimize stock out and simultaneously minimize inventory level, simulation techniques are used to overcome these problems. Figure (4.20) illustrates proposed simulation procedure and the results are shown in Table (E.4) in appendix E.

Raw material simulation model is developed to simulate the same conditions of ad hoc simulation model according to fixed-time period inventory management as shown in Figure (4.21). The detailed raw material simulation model is shown in Figure (E.2) in appendix (E).

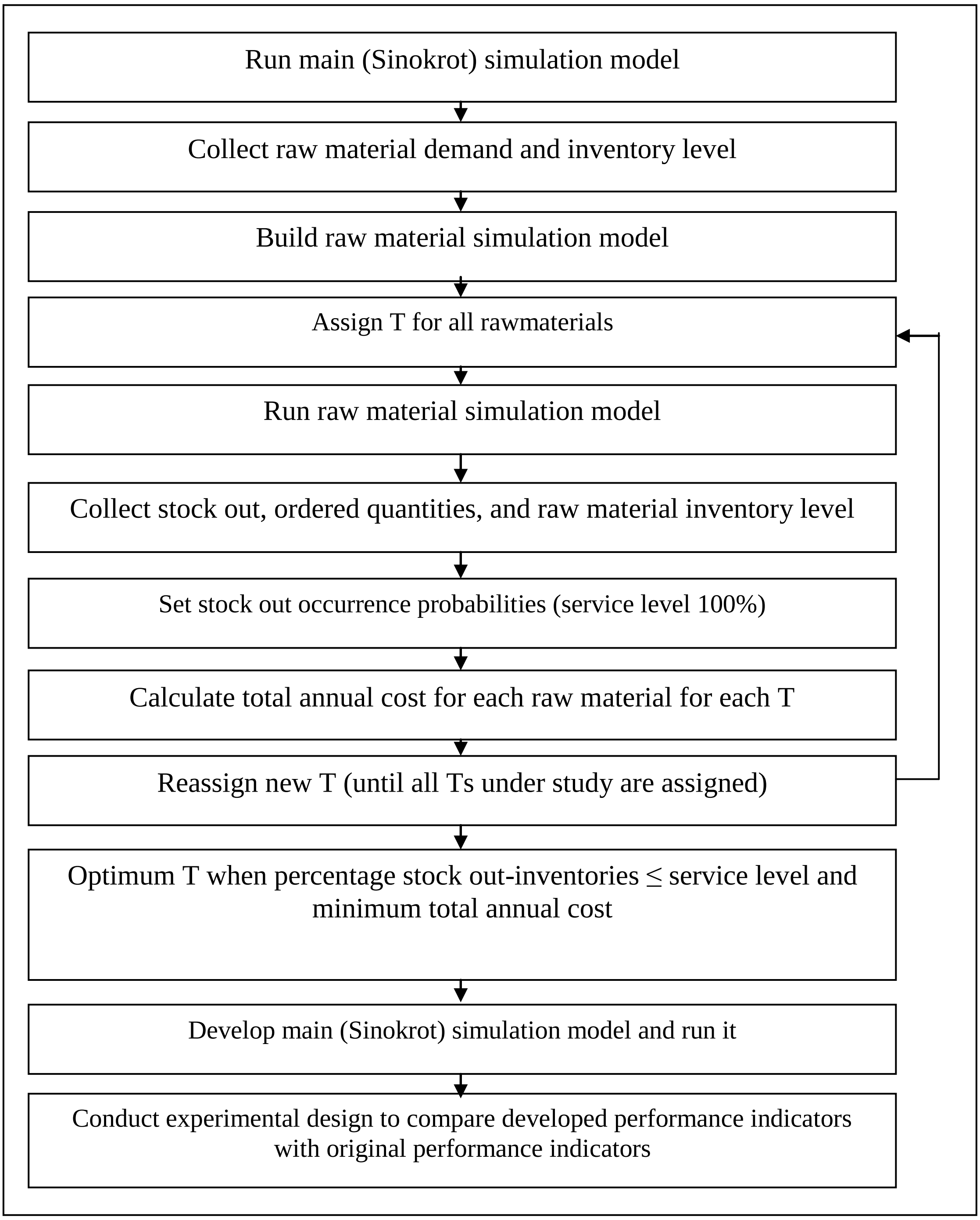

Figure (4.20): Proposed simulation model of fixed time based raw material inventory

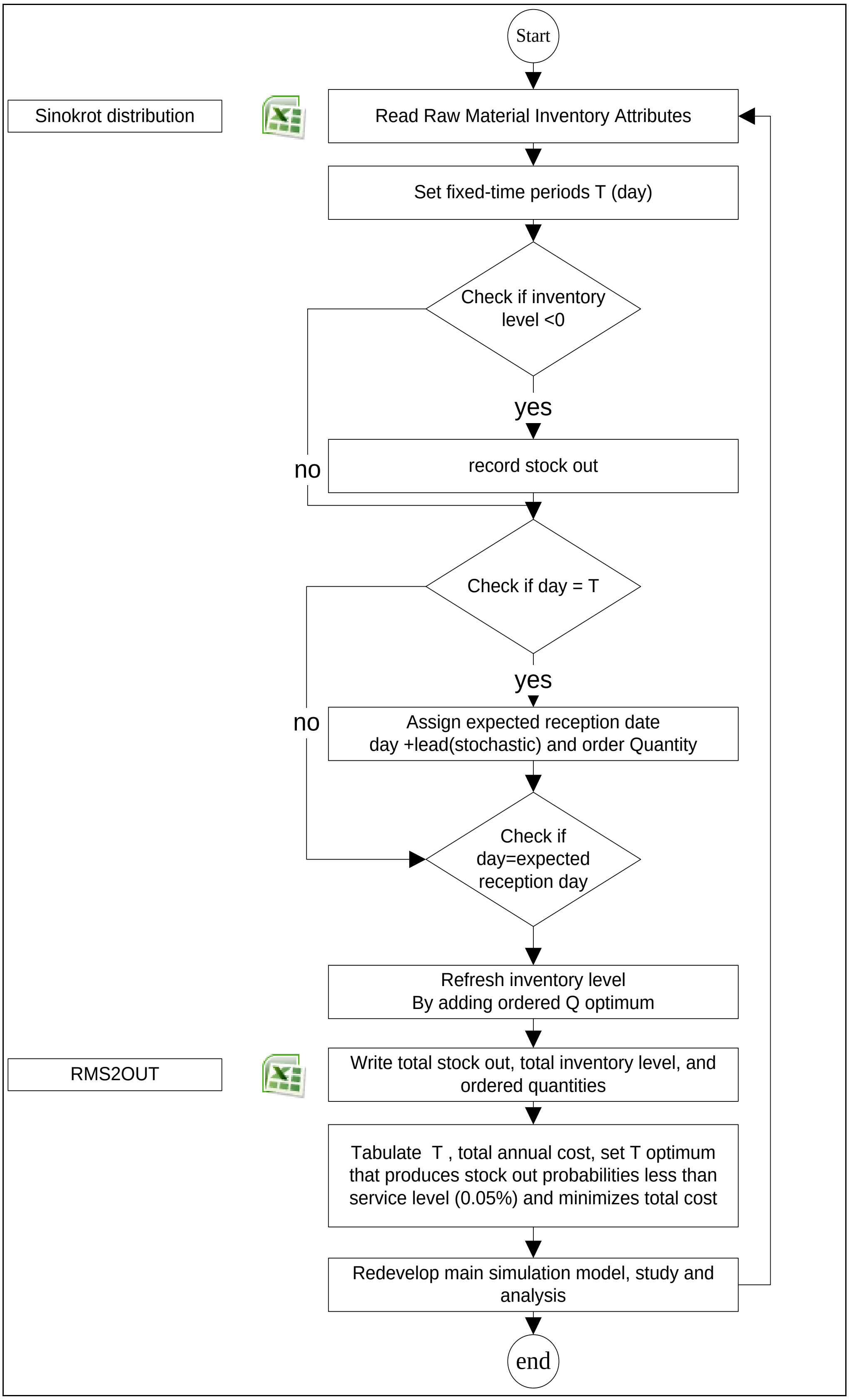

Figure (4.21): Raw material simulation modelin case of stochastic demand andstochastic lead time

Results of executing raw material simulation procedure such as order quantity, optimum fixed-time period, daily average inventory, and total inventory are shown in Table (4.14), while Table (4.15) exhibits comparative results between ad hoc system and scenario 5(fixed-period-based raw material inventory). Figure (4.22) presents inventory level of “raw material 9” as an example in both models.

Moreover, Statistical experiments are used to compare between ad hoc model and scenario 5. Daily inventory level results are optioned from both simulation models present two different populations, T-test and F-test are conducted as shown in table (E.5) in appendix E. it is assumed as a null hypothesis there are mean differences between populations, where the results assure that differences according to 95% confidence interval.

General results of Scenario 5 (T-based inventory system) exhibit the following points:

1. Average of order quantities in this system is about 30% of order quantities in the ad hoc system which leads to 67% reduction in annual purchased quantities.
2. Ordering cost in scenario 5 is 117% when compared with ordering cost in the ad hoc system due to number of orders in scenario 5.
3. When 67% reduction in annual purchased quantities occurs, the holding cost is reduced to 81% due to reduction in average of raw

materials. This point clarifies how this system achieves lean manufacturing objectives in reducing of inventories.

4. In general, total annual inventory cost drops to 67% of total annual costs in the ad hoc system.

For the previous points, it is recommended that to adopt simulation modeling of T-based inventory system, un-required stored quantities, and total inventory costs must be reduced.

Table (4.14): Scenario 5 (T-based inventory system), continue

Scenario 5						
Raw material	**1**	**2**	**3**	**4**	**5**	**6**
Annual Demand (Kg)	577,368	318,711	195,808	416,892	3,984	10,812
Inventory Level Average (Kg)	36,943	19,452	27,541	38,602	1,991	946
Order Quantity Average (Kg)	24,057	13,857	24,476	29,778	332	901
Number of Orders	24	23	8	14	12	12
Optimum Time between Orders (day)	9	8	24	14	19	10
Stock-out probability	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Purchasing cost (per Kg)	4	4	3	5	15	11
Ordering Cost (per Order)	100	100	100	130	15	15
Holding Cost (per Kg)	0.60	0.60	0.60	0.60	1.00	0.80
purchasing cost (cost unit)	2,020,750	1,274,810	567,846	2,084,485	59,847	116,811
Ordering Cost (cost unit)	2,400	2,300	800	1,820	180	180
Holding Cost (cost unit)	22,166	11,671	16,524	23,161	1,991	757
Inventory Total Cost (cost unit)	2,045,316	1,288,781	585,170	2,109,466	62,018	117,748

Table (4.14): Scenario 5 (T-based inventory system), continue

Scenario 5						
Raw material	7	8	9	10	11	Sum
Annual Demand (Kg)	28,920	164,580	9,310	21	18,550	
Inventory Level Average (Kg)	4,539	31,330	3,478	535	3,236	
Order Quantity Average (Kg)	1,446	12,660	665	3	1,325	
Number of Orders	20	13	14	7	14	
Optimum Time between Orders (day)	9	14	11	25	14	
Stock-out probability	0.0%	0.0%	0.0%	0.0%	0.0%	
purchasing cost (per Kg)	9	14	15	20	21	
Ordering Cost (per Order)	38	100	60	10	40	
Holding Cost (per Kg)	0.90	0.60	0.60	2.50	1.00	
purchasing cost (cost unit)	248,723	2,254,776	137,851	421	389,511	9,155,831
Ordering Cost (cost unit)	760	1,300	840	70	560	11,210
Holding Cost (cost unit)	4,085	18,798	2,087	1,339	3,236	105,815
Inventory Total Cost (cost unit)	253,568	2,274,874	140,778	1,830	393,307	9,272,856

Table (4.15): Compared total inventory costs (scenario 5) with Ad hoc system

Raw material	1	2	3	4	5	6
Purchasing cost (cost unit)	72%	61%	66%	66%	103%	40%
Ordering Cost (cost unit)	100%	192%	67%	117%	100%	100%
Holding Cost (cost unit)	81%	50%	91%	70%	171%	42%
Inventory Total Cost (cost unit)	72%	61%	66%	66%	105%	40%
Order quantity (Kg)	53%	28%	76%	48%	33%	35%
Number of orders	185%	88%	31%	54%	46%	46%
Raw material	7	8	9	10	11	Sum
Purchasing cost (cost unit)	63%	70%	59%	2%	71%	67%
Ordering Cost (cost unit)	167%	108%	117%	224%	117%	117%
Number of orders	77%	50%	54%	7%	54%	77%
Holding Cost (cost unit)	76%	155%	75%	1551%	66%	81%
Inventory Total Cost (cost unit)	63%	70%	59%	10%	71%	67%
Order quantity (Kg)	25%	54%	17%	2%	31%	

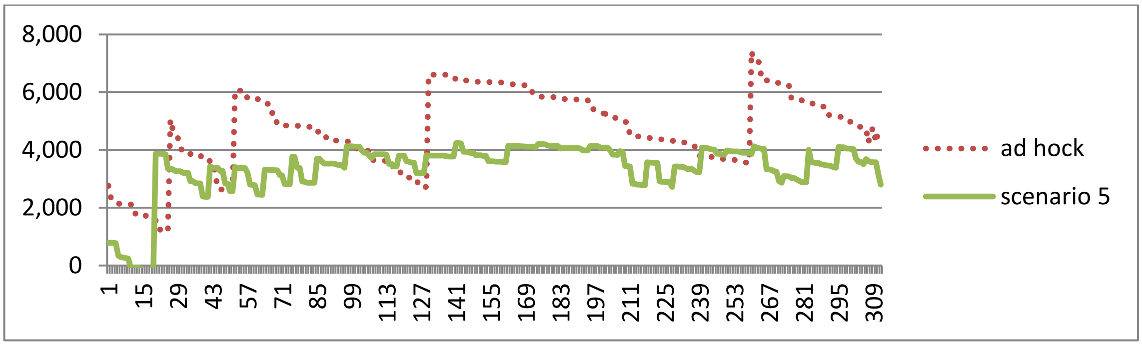

Figure (4. 22): Raw Material 4 Inventory for main Sinokrot and scenario 5 model

CHAPTER 5

THESIS CONCLUSION

5.1 THESIS RESULTS AND CONCLUSIONS

In this thesis, it is provided an overview of the main concepts that are related to the simulation studies of supply chain management systems, manufacturing system, and risk management. Simulation has the ability to tell how a supply chain or a manufacturing system performs behave over time when different rules and policies are applied. This point agrees with conclusions at [Chang et al., 2002], [Thierry et al., 2010] and [Hennet et al., 2009].

Simulation is used to study stochastic natures of demand, and lead time, effect of finite production capacity over the performance of supply chain as conducted in simulation scenarios. Like similar conclusions are conducted in [Thierry et al., 2010] and [Cannella et al., 2008].

Simulation is a very efficient way of analyzing what – if scenarios and can be used for improving the performance of manufacturing system i.e. management and processes. The models were tested for many different parameters. It would be beneficial to run a real life model on simulator designed for those conditions before actual collaboration and decision variable is put into practice.

Simulation models of a supply chain have been built to facilitate the use of simulation in designing, evaluating, and optimizing supply chains. Some Simulation models are discussed in this thesis. The first application is to show behavior of supply chain, manufacturing, and risk attributes when the market demand of products increases where the market demand is stochastic variable. Also production rates and breakdowns are stochastic, besides of interrelated variables such as consumed raw material (bill of materials), and production lines readiness for production. Many performance variables are considered in making decision such as sales to demand percentage, produced quantities, daily production line utilization, and annual production line utilization.

Simulation modeling detects behavior of the studied system and shows performance variables so that enable mangers to take decisions at all levels; for example, strategic decisions as focus marketing campaigns to increase products sales. Also, there are operational decisions such as redesign inventory target levels of products in order to increase production priorities. And finally, the tactical decisions such as scheduling maintenance (breakdowns reduction) in order to increase daily production line utilization. In addition, the last point agrees with some pervious conclusions which were cited in [Sun et al., 2009] and [Hübl et al, 2011].

Some simulation models are built to optimize inventory management; either optimum order quantity based inventory management, or fixed time reviewing based inventory management. These models are used when the demand and supplier lead time are stochastic with complex interrelated variable such as demand based on bill of materials of all products.

Simulation techniques are used to optimize order quantity and reorder level (point) that minimize total inventory cost, minimize stored quantity average or constrained with inventory capacity and in condition no stock-out quantities. Simulation modeling of this inventory management show reduction of annual cost and stored quantities average in absences of stock out quantities.

On the other hand, simulation modeling of fixed time reviewing based inventory to optimize the fixed time (T) that minimize total inventory cost, reduce stored quantities average with stock-out probability equal to 0 i.e. 100% service level, and also, results show optimum fixed time that full fill the cited parameters.

The last three conclusion points are similar to conclusions in [Alizadeh et al., 2011] and [Alizadeh et al., 2011], but -in addition to stochastic demand- the cited models in this thesis are based on stochastic produced quantities, stochastic breakdowns, and integrated with production planning models.

5.2 CONTRIBUTION TO KNOWLEDG AND PRACTICE

1. Developing integrated simulation system includes supply chain, manufacturing, and risk application where:

- Stochastic market demands of the products varies from month to month, some of them follow trends where others do not, besides to geographical distributed demands according to distribution centers.
- Stochastic production rates depend on nature of products, stochastic breakdowns frequency, stochastic breakdowns times, and production periods.
- Arranging soled products to nearest 0.25 pallets and arranging them in order to maximize soled products according to transporter capacity, in addition to checking available transporter.
- Complex bill of material; where 11 raw materials are used in production of 20 products i.e. used raw materials are interrelated relations and combination of products.
- Manufacturing system includes two models; production planning and production process. Production planning is to check product priority, available production line, expected producible quantity, expected consumed raw material according to each product, and raw material availability. Production process is to produce required product quantities in both production period in consider breakdowns, raw material availability, updates raw material inventory and sales (final products) inventory.
- Raw material inventory based on stochastic lead time and stochastic raw material demands depend to stochastic demands of products.

2. Developing scenarios which are used to evaluate ad hoc system and what if systems in order to improve product sales to product demands, to increase annual production line utilization and to reduce risk sales stock-out probabilities.
3. Developing optimization models in inventories management; fixed order based inventory management and fixed reviewing period based inventory management. These models are developed to determine optimum order quantity and optimum reorder point that minimize daily inventory management which minimize total annual inventory cost with zero stock-out percentage. While the second one is to determine optimum fixed reviewing period T to minimize daily inventory management, minimize total annual inventory cost based with zero stock out percentage. Both models are suitable for food industry.

5.3 THESIS RECOMANDATIONS AND FUTURE WORKS

Besides to recommendations cited in scenarios, there are many future works are recommended, either works based on current Sinokrot simulation model, or works based on modified Sinokrot simulation models as the following points:

Future works based on current simulation model include:

- Studying and analyzing adopting optimum order quantity and reorder point for the sales inventory (finished products) based in the same method mentioned in scenario 4 to minimize risk of stock-out percentages and total annual sales inventory cost.

- Studying and analyzing adopting optimum reviewing time and ordering for the sales inventory (finished products) based in the same method mentioned in scenario 5.
- Studying the manufacturing lead time to minimize sales inventory stock-out percentage and total annual sales inventory costs.
- Analyzing production rates of all production lines by adopting polices to minimize breakdown times such as schedule maintenance and minimize reworks to achieve Lean manufacturing philosophy.

Future works based on modified Sinokrot simulation models include:

- Studying the negative effects of Israeli occupation obstacles in delivering the finished products and/ or receiving raw materials. (It can be based on situations occurred in 2002).
- Studying the effect of fluctuated raw material prices on the whole Sinokrot system.
- Studying optimum geographical distribution of market distribution centers i.e. number and sites, to minimize delivery costs, and maximize Sinokrot market share.
- Studying optimum allocating human resources (number of labors for each production line) that maximize production rate, and minimize the total production costs.

- Adopt optimum manufacturing layout re-design that facilitate production flows and minimize transportation.
- Building a simulation model that facilitate production planning; so that when production manager plan to next week, the excepted produced quantity can be calculated based on the production parameters such number of workers, expected break-downs, and expected consumed raw materials, to facilitate also raw material inventory to put an order or not.

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APPENDICES

APPENDIX A: CONCEPTUAL MODEL

Table (A.1): Production lines and product groups

Production Lines	Product Groups	Products
1	1	Product 1,Product 2
2 (or 1*)	2	Product 3,Product 4, Product 5, Product 6
3	3	Product 7,Product 8, Product 9, Product 10
4	4	Product 11
5	5	Product 12, Product 13
6	6	Product 14, Product 15
7	7	Product 16, Product 17, Product 18
8	8	Product 19,product 20

* If "production line 1" is not busy

Table (A.2): Production Lines rates

Products	Production Line Production rate (Second Per Case)	
	First Production Period	Second Production Period
Product 1	**LOGN(4.5,0.48)	LOGN(4.4,0.62)
Product 2	LOGN(6.3, 5.84)	LOGN(5.5,7.91)
Product 3	LOGN(7.2, 1.83)	LOGN(7.1, 1.4)
Product 4	LOGN(50.0,25.70)	LOGN(48.62, 22.60)
Product 5	LOGN(52.7,20.96)	LOGN(50.8, 4.30)
Product 6	LOGN(23.2, 7.80)	LOGN(21.0, 7.20)
Product 7	LOGN(103.0, 15.59)	LOGN(98.0, 5.44)
Product 8	LOGN(15.8, 3.41)	LOGN(10.0, 9.10)
Product 9	LOGN(70.2, 54.00)	LOGN(70.2, 54.00)
Product 10	LOGN(48.0, 8.98)	LOGN(48.0, 8.98)
Product 11	LOGN(78.5, 38.10)	LOGN(64.7, 19.07)
Product 12	LOGN(28.8, 19.90)	LOGN(22.7, 16.20)
Product 13	LOGN(50.7, 5.30)	LOGN(50.3, 3.60)
Product 14	LOGN(107.5, 26.80)	LOGN(95.4, 9.58)
Product 15	LOGN(62.0, 8.40)	LOGN(59.0,9.00)
Product 16	LOGN(19.7, 2.10)	LOGN(13.7, 1.30)
Product 17	LOGN(24.6, 7.10)	LOGN(27.1, 6.27)
Product 18	LOGN(18.4, 1.50)	LOGN(18.4, 1.50)
Product 19	LOGN(51.0, 18.20)	LOGN(39.3, 16.60)
Product20	LOGN(44.2, 20.00)	LOGN(43.5, 22.30)

** LOGN(mu, sigma): Log Normal distribution

Table (A.3): General Production Line Breakdown

Production Line	**Breakdown Frequency (Working Day)**	**Breakdown Time (Second)**
1	5	LOGN(4105, 713)
2	8	LOGN(4055, 510)
3	9	LOGN(4178, 450)
4	4	LOGN(4334, 409)
5	17	LOGN(910, 500)
6	11	LOGN(654, 330)
7	23	LOGN(1003, 640)
8	20	LOGN(1049,639)

Table (A.4): Raw Material Order Frequency, Ordered Quantities and Reorder Point

Raw Material	**Order frequency (production day)**	**Ordered quantities (Kg)**	**Reorder point (Kg)**
Raw Material 1	13	47000	25000
Raw Material 2	26	49000	35000
Raw Material 3	26	32000	15000
Raw Material 4	26	52000	30000
Raw Material 5	26	1000	700
Raw Material 6	26	2600	1000
Raw Material 7	26	5800	1000
Raw Material 8	26	23500	12000
Raw Material 9	26	3900	2000
Raw Material 10	100	2000	2000
Raw Material 11	26	4300	15000

Table (A.5): Bill of Materials

Product	Raw Materials (Kg)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
1	0.307	0.184	0.120	0.256	0	0.012	0.013	0.102	0	0	0.012	1.008
2	0.167	0.100	0.067	0.139	0	0.007	0.007	0.056	0	0	0.007	0.55
3	0.221	0.133	0.089	0.185	0	0.009	0.009	0.074	0	0	0	0.72
4	1.478	0.887	0.591	1.231	0	0.057	0.061	0.492	0	0	0	4.8
5	0.221	0.133	0.088	0.184	0	0.009	0.009	0.073	0	0	0	0.72
6	0.221	0.133	0.088	0.185	0	0.009	0.009	0.074	0	0	0	0.72
7	0.985	5.398	0	0.981	0	0.032	0	0	0.106	0	0	7.5
8	1.138	3.912	0	1.280	0	0.028	0	0.498	0.142	0	0	7
9	1.138	3.912	0	1.280	0	0.028	0	0.497	0.142	0	0	7
10	1.138	3.912	0	1.280	0	0.028	0	0.498	0.142	0	0	7
11	0.564	0	0.18	0	0	0	0.036	0	0	0	0.42	1.2
12	0.512	0	0.143	0	0	0.006	0.031	0	0	0	0.307	1
13	0.245	0	0.069	0	0	0.003	0.015	0	0	0	0.148	0.48
14	0.197	0.092	0.061	0.135	0.043	0	0.036	0.030	0.003	0	0	0.6
15	1.698	0.796	0.530	1.167	0	0	0.318	0.265	0.027	0	0	4.8
16	0.288	0	0.041	0.049	0	0.003	0.016	0.041	0.263	0	0.016	0.72
17	0.278	0	0.039	0.047	0.023	0.003	0.015	0.039	0.254	0	0.016	0.72
18	0.247	0	0.037	0.045	0.187	0	0.016	0	0.172	0	0.014	0.72
19	0.493	0	0	0.038	0	0	0	0	0.189	0	0	0.72
20	0.44	0	0	0	0	0	0	0	0.144	0.136	0	0.72

Table (A.6): Daily product demand statistical distributions

Product	Daily Product Demand (case)					
	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
1	TRIA(4948,5208,5468)	TRIA(4508,4745,4982)	TRIA(4462, 4697, 4932)	TRIA(4578, 4819, 5060)	TRIA(3745, 3942, 4139)	TRIA(3779, 3978, 4177)
2	UNIF(40,55)	UNIF(35, 39)	TRIA(17, 19, 20)	UNIF(37, 41)	UNIF(31, 35)	UNIF(13,16)
3	TRIA(462,486, 510)	TRIA(517, 544, 571)	TRIA(300, 316, 332)	TRIA(353, 372,510)	TRIA(335, 353, 371)	TRIA(343, 361, 379)
4	TRIA(706, 743, 780)	TRIA(689, 725, 761)	TRIA(726, 764, 802)	TRIA(574, 604, 634)	TRIA(818, 861, 904)	TRIA(647, 681, 715)
5	TRIA(315, 332, 349)	TRIA(278, 293, 308)	TRIA(199, 209, 219)	TRIA(574, 604, 634)	TRIA(234, 246, 258)	TRIA(320, 337, 354)
6	TRIA(372, 390,400)	TRIA(411, 433, 455)	TRIA(390, 411, 432)	TRIA(311, 327, 343)	TRIA(449, 473, 497)	TRIA(486, 512, 538)
7	UNIF(30,40)	UNIF(16, 18)	UNIF(20, 22)	TRIA(25, 30, 37)	UNIF(22, 25)	UNIF(13,16)
8	UNIF(30,50)	UNIF(55, 61)	UNIF(36, 40)	UNIF(28, 30)	UNIF(31, 35)	TRIA(35, 37, 39)
9	UNIF(20,24)	UNIF(28, 30)	UNIF(15, 22)	UNIF(13, 17)	UNIF(18, 21)	UNIF(17, 20)
10	UNIF(7,10)	TRIA(16, 17, 18)	UNIF(10, 14)	UNIF(20, 25)	UNIF(36, 43)	UNIF(20,23)

Table (A.6): Daily product demand statistical distributions (continue)

Product	Daily Product Demand (case)					
	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
11	UNIF(50,70)	TRIA(107, 113, 119)	UNIF(70, 90)	UNIF(67, 75)	UNIF(23, 27)	0
12	UNIF(86,95)	UNIF(68, 76)	UNIF(110, 122)	UNIF(69, 77)	UNIF(110, 122)	TRIA(36, 38, 40)
13	TRIA(758, 798, 838)	TRIA(145, 153, 161)	TRIA(143, 150, 158)	UNIF(68, 77)	UNIF(72, 80)	TRIA(74, 78, 82)
14	UNIF(31, 35)	UNIF(31, 35)	UNIF(33, 37)	TRIA(12, 14, 15)	TRIA(5, 8, 9)	UNIF(5,8)
15	UNIF(131, 145)	TRIA(161, 169, 177)	TRIA(193, 203, 220)	UNIF(100, 115)	UNIF(72, 80)	TRIA(108, 114, 120)
16	UNIF(48, 54)	TRIA(66, 69, 72)	TRIA(87, 94, 99)	TRIA(11, 14, 16)	TRIA(21, 22, 25)	UNIF(0,5)
17	UNIF(127, 141)	TRIA(130, 137, 144)	UNIF(30, 45)	TRIA(65, 74, 76)	TRIA(30, 32, 34)	UNIF(28, 30)
18	0	TRIA(109, 115, 121)	UNIF(170, 190)	0	UNIF(89, 100)	UNIF(35, 39)
19	UNIF(49, 55)	UNIF(65, 71)	TRIA(20, 25, 27)	UNIF(147, 167)	UNIF(240, 266)	UNIF(46, 50)
20	TRIA(14, 15, 16)	UNIF(25, 27)	UNIF(35, 39)	TRIA(46, 50, 55)	UNIF(109, 121)	UNIF(72, 80)

Table (A.6): Daily product demand statistical distributions (continue)

Product	Daily Product Demand (case)					
	Month 7	**Month 8**	**Month 9**	**Month 10**	**Month 11**	**Month 12**
1	TRIA(3663, 3856, 4049)	TRIA(3741, 3938, 4135)	TRIA(3700, 3895, 4090)	TRIA(4206, 4427, 4648)	TRIA(4485, 4721, 4957)	TRIA(5235, 5511, 5787)
2	UNIF(9,13)	TRIA(24, 25, 27)	UNIF(30, 34)	UNIF(35, 42)	UNIF(43, 47)	UNIF(37, 41)
3	TRIA(390, 411, 432)	TRIA(316, 333, 352)	TRIA(516, 543, 570)	TRIA(276, 290, 302)	TRIA(313, 329, 350)	TRIA(390, 411, 432)
4	TRIA(740, 779, 818)	TRIA(550, 586, 615)	TRIA(571, 601, 631)	TRIA(500, 526, 552)	TRIA(648, 682, 716)	TRIA(594, 625, 656)
5	TRIA(185, 195, 205)	TRIA(136, 143, 150)	TRIA(200, 210, 225)	TRIA(175, 184, 193)	TRIA(299, 315, 329)	TRIA(273, 287, 301)
6	TRIA(446, 469, 492)	TRIA(2631, 2769, 2907)	TRIA(371, 390, 410)	TRIA(353, 372, 391)	TRIA(314, 330, 347)	TRIA(383, 403, 423)
7	UNIF(35, 39)	UNIF(52, 58)	UNIF(71, 80)	UNIF(85, 100)	TRIA(112, 118, 124)	UNIF(70, 80)
8	TRIA(44, 46, 48)	TRIA(30, 33, 35)	TRIA(44, 46, 47)	TRIA(59, 62, 65)	UNIF(48, 55)	TRIA(40, 42, 46)
9	UNIF(19, 21)	UNIF(15, 20)	UNIF(20, 23)	UNIF(29, 35)	TRIA(22, 24, 25)	UNIF(19, 23)
10	UNIF(12, 14)	UNIF(23, 27)	UNIF(28, 31)	UNIF(35, 43)	UNIF(68, 78)	UNIF(78, 86)

Table (A.6): Daily product demand statistical distributions (continue)

Product	Daily Product Demand (case)					
	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
11	0	0	UNIF(12, 15)	UNIF(48, 53)	TRIA(48, 50, 54)	UNIF(72, 80)
12	TRIA(38, 40, 42)	TRIA(70, 76, 80)	TRIA(112, 118, 126)	TRIA(76, 80, 84)	UNIF(45, 55)	UNIF(72, 80)
13	TRIA(75, 79, 83)	TRIA(39, 41, 43)	TRIA(52, 55, 58)	TRIA(52, 55, 58)	UNIF(58, 64)	UNIF(76, 84)
14	UNIF(4,7)	UNIF(15,18)	UNIF(20, 24)	UNIF(20, 24)	UNIF(43, 47)	UNIF(30, 37)
15	TRIA(151, 159, 167)	UNIF(106, 118)	UNIF(205, 227)	UNIF(125, 139)	TRIA(242, 253, 269)	TRIA(265, 279, 295)
16	0	UNIF(10, 12)	UNIF(32, 37)	UNIF(28, 35)	UNIF(35, 40)	UNIF(74, 82)
17	UNIF(35, 39)	0	TRIA(15, 17, 18)	TRIA(65, 68, 71)	UNIF(51, 55)	UNIF(35, 39)
18	UNIF(31, 35)	UNIF(23, 36)	UNIF(31, 36)	UNIF(20, 24)	UNIF(73, 89)	UNIF(72, 80)
19	UNIF(0, 3)	0	UNIF(2, 7)	0	0	0
20	UNIF(18, 22)	UNIF(13, 17)	0	UNIF(2, 7)	0	UNIF(5, 8)

TRIA: Triangular Statistical Distribution (minimum value, average, maximum value)
UNIF: Uniform Statistical Distribution (minimum value, maximum value)

Table (A.7): Daily product demand of distribution center percentage

Product	Distribution Center					
	1	2	3	4	5	Total
1	30.0%	30.0%	30.0%	10.0%	0.0%	100%
2	30.0%	30.0%	30.0%	10.0%	0.0%	100%
3	21.1%	15.8%	15.8%	36.8%	10.5%	100%
4	24.0%	24.0%	24.0%	28.0%	0.0%	100%
5	15.4%	0.0%	15.4%	15.4%	53.8%	100%
6	12.5%	25.0%	37.5%	25.0%	0.0%	100%
7	13.3%	6.7%	13.3%	46.7%	20.0%	100%
8	27.3%	27.3%	27.3%	18.1%	0.0%	100%
9	27.3%	27.3%	27.3%	18.1%	0.0%	100%
10	27.3%	18.2%	36.3%	18.2%	0.0%	100%
11	33.3%	11.1%	33.3%	22.3%	0.0%	100%
12	30.0%	20.0%	15.0%	5.0%	30.0%	100%
13	30.0%	20.0%	15.0%	5.0%	30.0%	100%
14	28.0%	28.0%	16.0%	20.0%	8.0%	100%
15	31.6%	26.3%	15.8%	10.5%	15.8%	100%
16	7.1%	14.3%	14.3%	35.7%	28.6%	100%
17	7.1%	14.3%	14.3%	35.7%	28.6%	100%
18	7.1%	14.3%	14.3%	35.7%	28.6%	100%
19	22.2	22.2	33.3	22.3	0	100%
20	22.2	22.2	33.3	22.3	0	100%

Table (A.8): Product Sales Target Level

Products	Product Target Level (case)	Products	Product Target Level (case)
Product 1	75,000	Product 11	250
Product 2	400	Product 12	750
Product 3	3,000	Product 13	1,200
Product 4	12,500	Product 14	300
Product 5	1,900	Product 15	3,500
Product 6	4,200	Product 16	400
Product 7	300	Product 17	600
Product 8	300	Product 18	750
Product 9	200	Product 19	450
Product 10	200	Product20	300

Table (A.9): Number of cases per pallet

Products	Number of cases per pallet	Products	Number of cases per pallet
Product 1	64	Product 11	64
Product 2	64	Product 12	150
Product 3	63	Product 13	60
Product 4	91	Product 14	195
Product 5	64	Product 15	150
Product 6	64	Product 16	120
Product 7	60	Product 17	120
Product 8	60	Product 18	100
Product 9	60	Product 19	100
Product 10	60	Product20	100

APPENDIX B: INPUT DATA FITTING (SAMPLES)

GENERAL CONCEPTOF INPUT DATA FITTING

These tests are based on some sort of comparison between the observed data distribution and a corresponding theoretical distribution. If the difference between the observed data distribution and the corresponding theoretical distribution is small, then it may be stated with some level of certainty that the input data could have come from a set of data with the same parameters as the theoretical distribution.

Example: Kolmogorov–Smirnov

The steps for the Kolmogorov–Smirnov are:

1. Establish null and alternative hypotheses

   Ho: Distribution (parameter 1, parameter 2, …)

   Ha: Not distribution (parameter 1, parameter 2, …)

2. Determine a level of test significance, (such as $\alpha=0.05$, 95% confident).
3. Determine the critical Kolmogorov–Smirnov value from the D table [Chung, 2004]
4. Determine the greatest absolute difference between the two cumulative distributions
5. Compare the difference with the critical Kolmogorov–Smirnov value

Accept or reject the null hypothesis If the maximum absolute difference is less than the critical KS value, then the null hypotheses cannot be rejected. [Chung, 2004]

StatFit keys

Exponential (minimum, beta)

Lognormal (minimum, mu, sigma)

Normal (mean, sigma)

Triangular (minimum, maximum, mode)

Uniform (minimum, maximum)

1- Production line 1 rate (product 1 for first production period) (as sample)

PRODUCTION LINE 1 PERIOD 1 PRODUCT 1

goodness of fit

data points	96
estimates	maximum likelihood estimates
accuracy of fit	3.e-004
level of significance	5.e-002

summary

distribution	Kolmogorov Smirnov	Anderson Darling
Exponential(0., 101)	0.327	13.1
Lognormal(0., 4.5, 0.479)	4.6e-002	0.239
Normal(101, 54.5)	0.129	3.11
Triangular(0., 402, 46.1)	0.329	17.3
Uniform(0., 397)	0.492	43.6

detail

Exponential

minimum =	0. [fixed]	
beta =	100.865	
Kolmogorov-Smirnov		
data points		96
ks stat		0.327
alpha		5.e-002
ad stat(96,5.e-002)		0.137
p-value		0.
result		REJECT
Anderson-Darling		
data points		96
ad stat		13.1
alpha		5.e-002
ad stat(5.e-002)		2.49
p-value		0.
result		REJECT

Lognormal

minimum =	0. [fixed]	
mu =	4.49517	
sigma =	0.479071	
Kolmogorov-Smirnov		
data points		96
ks stat		4.6e-002
alpha		5.e-002
ad stat(96,5.e-002)		0.137

Figure B.1: StatFit software fitting results, (continue)

PRODUCTION LINE 1 PERIOD 1 PRODUCT 1

p-value			0.982
result			DO NOT REJECT
Anderson-Darling			
data points			96
ad stat			0.239
alpha			5.e-002
ad stat(5.e-002)			2.49
p-value			0.976
result			DO NOT REJECT
Normal			
mean	=	100.865	
sigma	=	54.518	
Kolmogorov-Smirnov			
data points			96
ks stat			0.129
alpha			5.e-002
ad stat(96,5.e-002)			0.137
p-value			7.38e-002
result			DO NOT REJECT
Anderson-Darling			
data points			96
ad stat			3.11
alpha			5.e-002
ad stat(5.e-002)			2.49
p-value			2.41e-002
result			REJECT
Triangular			
minimum	=	0. [fixed]	
maximum	=	401.968	
mode	=	46.0588	
Kolmogorov-Smirnov			
data points			96
ks stat			0.329
alpha			5.e-002
ad stat(96,5.e-002)			0.137
p-value			0.
result			REJECT
Anderson-Darling			
data points			96
ad stat			17.3
alpha			5.e-002
ad stat(5.e-002)			2.49
p-value			0.
result			REJECT
Uniform			
minimum	=	0. [fixed]	

Figure B.1: StatFit software fitting results, (continue)

PRODUCTION LINE 1 PERIOD 1 PRODUCT 1

maximum =	396.569	
Kolmogorov-Smirnov		
data points		96
ks stat		0.492
alpha		5.e-002
ad stat(96,5.e-002)		0.137
p-value		0.
result		REJECT
Anderson-Darling		
data points		95
ad stat		43.6
alpha		5.e-002
ad stat(5.e-002)		2.49
p-value		0.
result		REJECT

Figure B.1: StatFit software fitting results2-Product 6 daily demand (month 1)

daily product demand pr6 m1

Auto::Fit of Distributions

distribution	rank	acceptance
Triangular(372, 400, 390)	93.1	do not reject
Lognormal(-825, 7.1, 5.15e-003)	55.4	do not reject
Uniform(375, 398)	48.2	do not reject
Normal(387, 6.24)	41.6	do not reject

Figure B.2: Daily demand StatFit software fitting results, (continue) daily product demand pr6 m1

goodness of fit

data points	23
estimates	maximum likelihood estimates
accuracy of fit	3.e-004
level of significance	5.e-002

summary

distribution	Kolmogorov Smirnov	Anderson Darling
Lognormal(-825, 7.1, 5.15e-003)	0.191	0.573
Normal(387, 6.24)	0.19	0.569
Triangular(372, 400, 390)	0.154	0.427
Uniform(375, 398)	0.169	4.26

detail

Lognormal
minimum = -825.067
mu = 7.10002
sigma = 5.15057e-003
Kolmogorov-Smirnov
data points 23
ks stat 0.191
alpha 5.e-002
ad stat(23,5.e-002) 0.275
p-value 0.329
result DO NOT REJECT
Anderson-Darling
data points 23
ad stat 0.573
alpha 5.e-002
ad stat(5.e-002) 2.49
p-value 0.674
result DO NOT REJECT

Normal
mean = 386.943
sigma = 6.23893
Kolmogorov-Smirnov
data points 23
ks stat 0.19
alpha 5.e-002
ad stat(23,5.e-002) 0.275
p-value 0.334

Figure B.3: Daily demand StatFit software fitting results**,** (continue) daily product demand pr6 m1

result		DO NOT REJECT
Anderson-Darling		
data points		23
ad stat		0.569
alpha		5.e-002
ad stat(5.e-002)		2.49
p-value		0.678
result		DO NOT REJECT
Triangular		
minimum =	371.93	
maximum =	399.951	
mode =	389.796	
Kolmogorov-Smirnov		
data points		23
ks stat		0.154
alpha		5.e-002
ad stat(23,5.e-002)		0.275
p-value		0.594
result		DO NOT REJECT
Anderson-Darling		
data points		23
ad stat		0.427
alpha		5.e-002
ad stat(5.e-002)		2.49
p-value		0.821
result		DO NOT REJECT
Uniform		
minimum =	374.817	
maximum =	398.18	
Kolmogorov-Smirnov		
data points		23
ks stat		0.169
alpha		5.e-002
ad stat(23,5.e-002)		0.275
p-value		0.475
result		DO NOT REJECT
Anderson-Darling		
data points		21
ad stat		4.26
alpha		5.e-002
ad stat(5.e-002)		2.49
p-value		6.51e-003
result		REJECT

Figure B.3: Daily demand StatFit software fitting results

APPENDIX C: SINOKROT SIMULATION MODEL

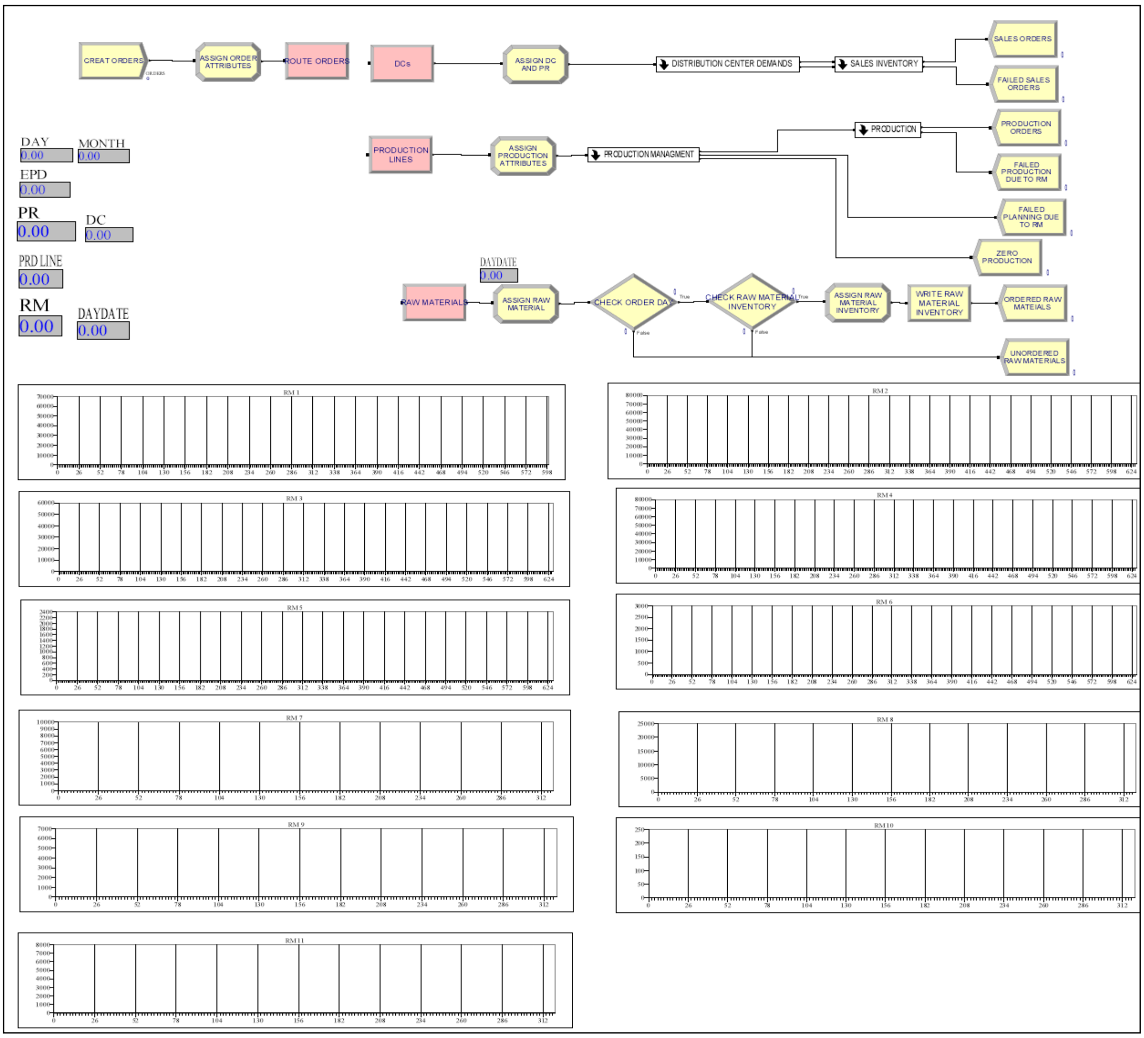

Figure C.1: Main Sinokrot simulation model

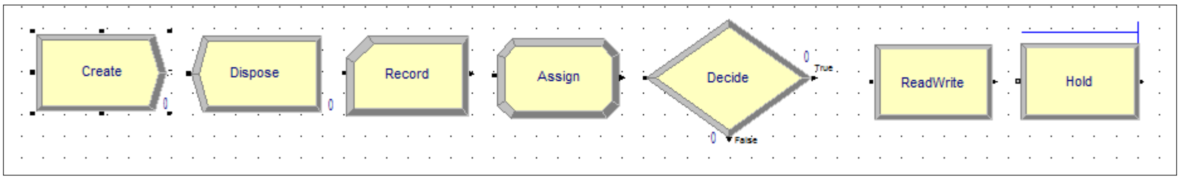

Figure C.2: Simulation modules

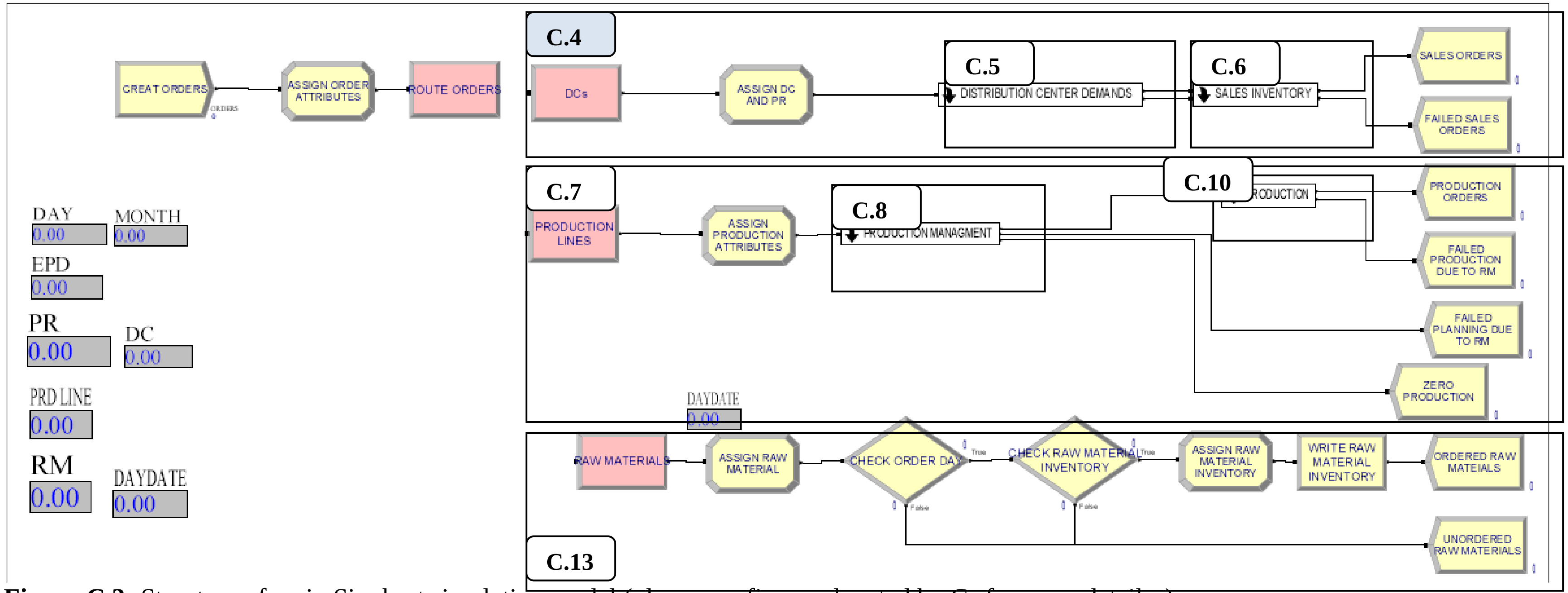

Figure C.3: Structure of main Sinokrot simulation model (please see figures denoted by Cs for more detailes)

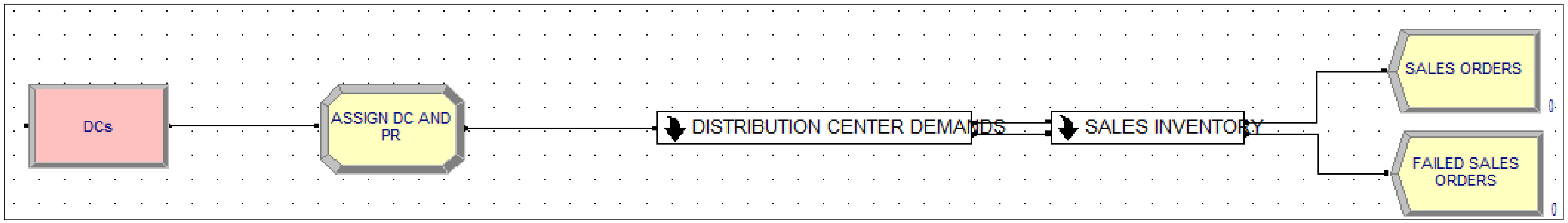

Figure C.4: Distribution centers demand and sales inventory

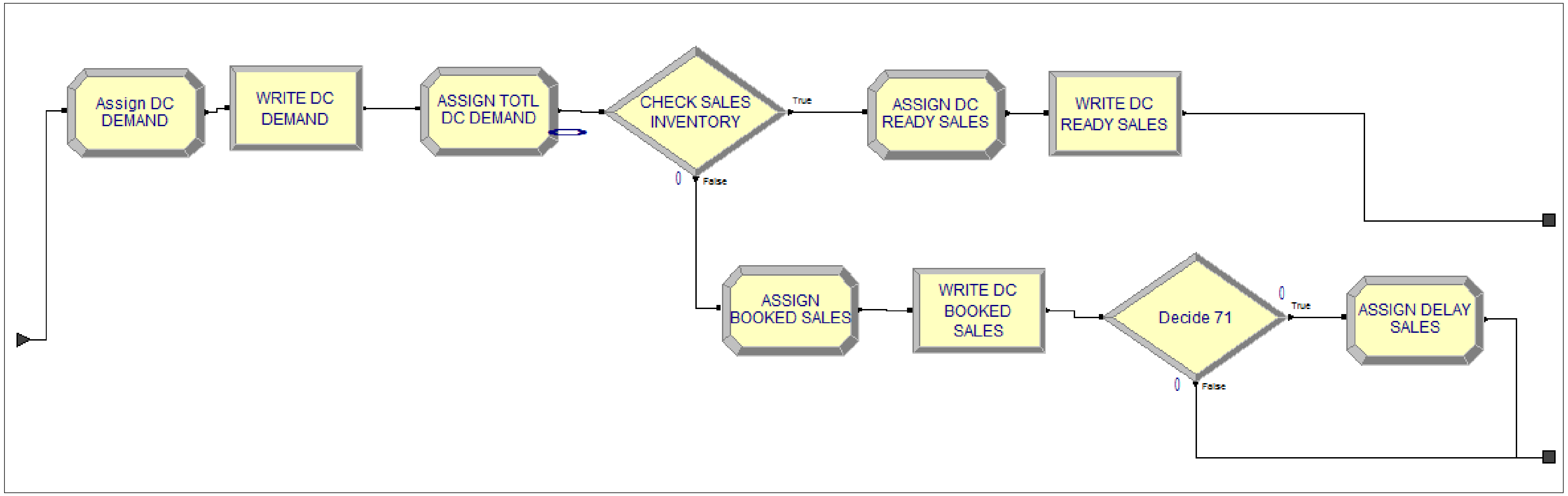

Figure C.5: Distribution centers demand sub-model

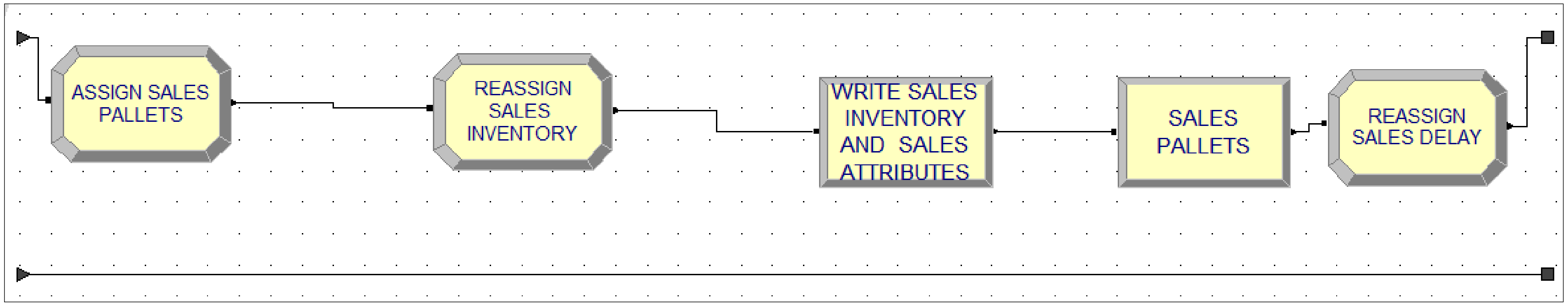

Figure C.6: Sales inventory sub-model

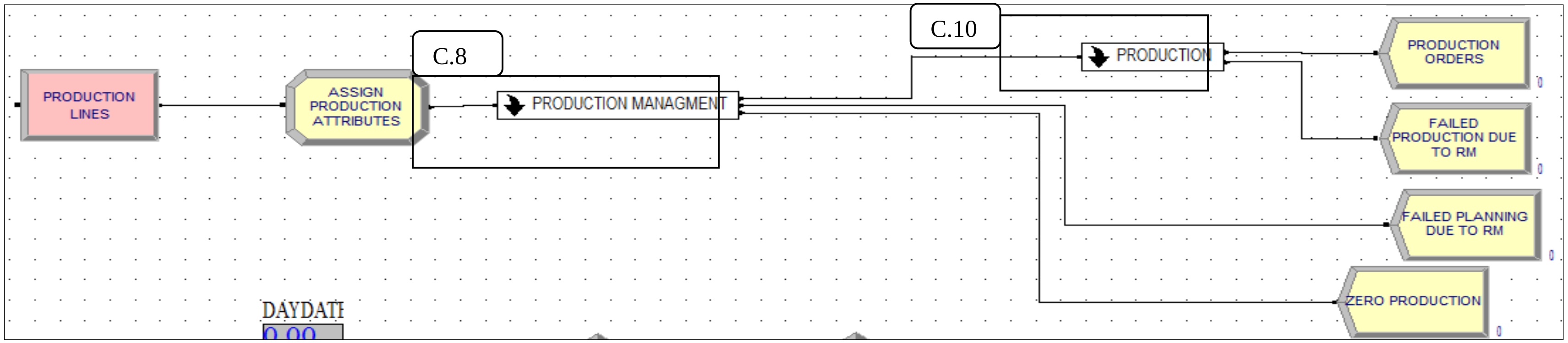

Figure C.7: Production mangment and production

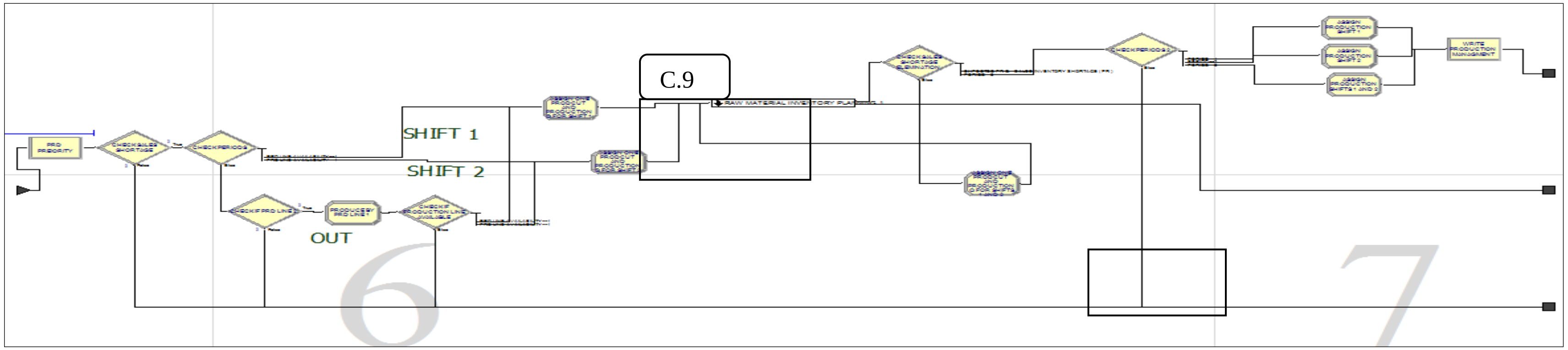

Figure C.8: Production mangment sub-model

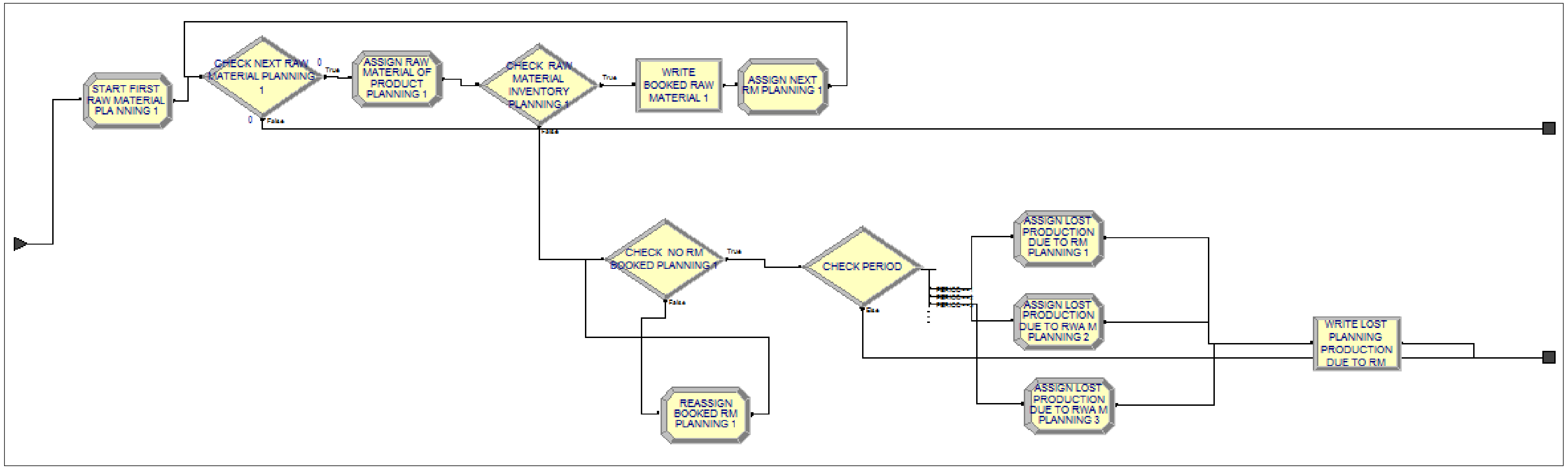

Figure C.9: Raw material requierment planning sub-model

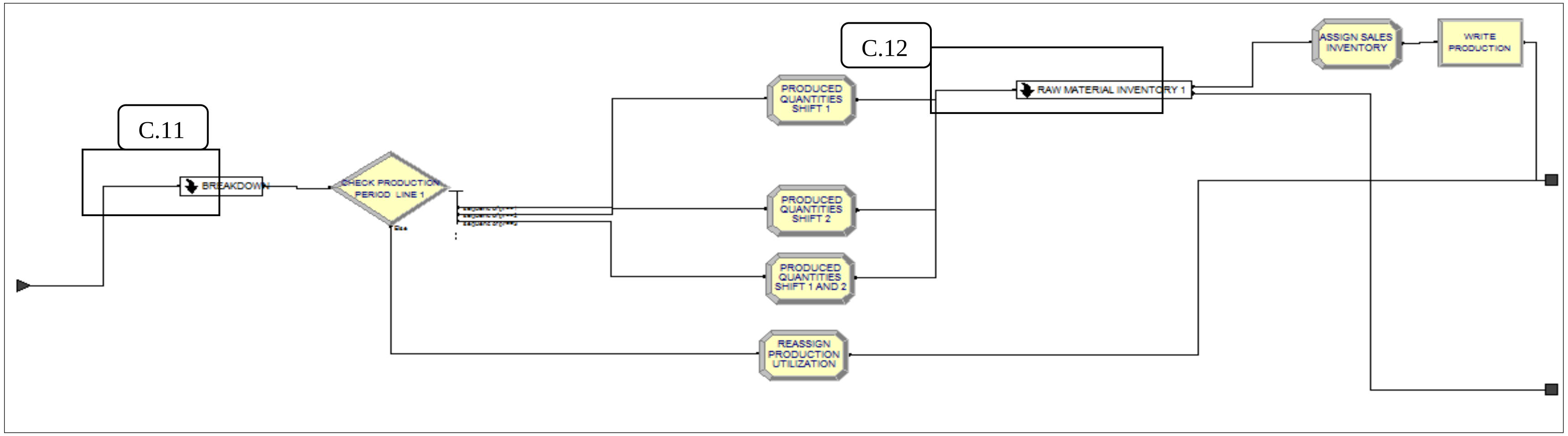

Figure C.10: Production sub-model

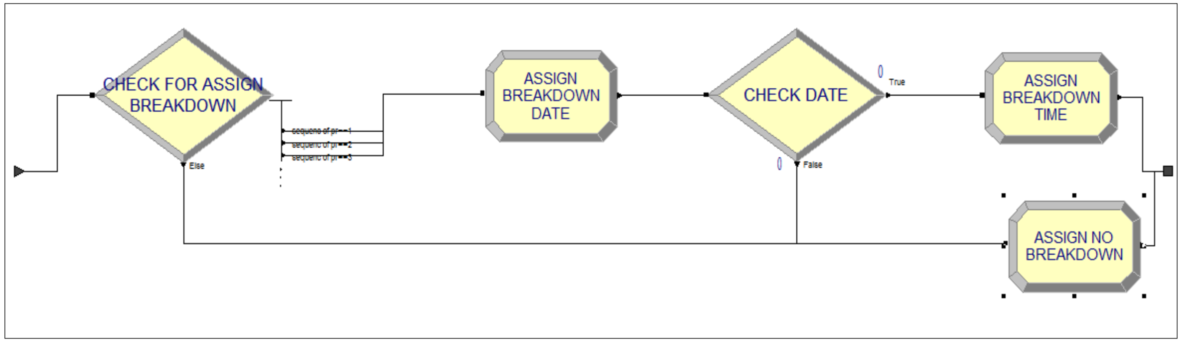

Figure C.11: Break-down sub-model

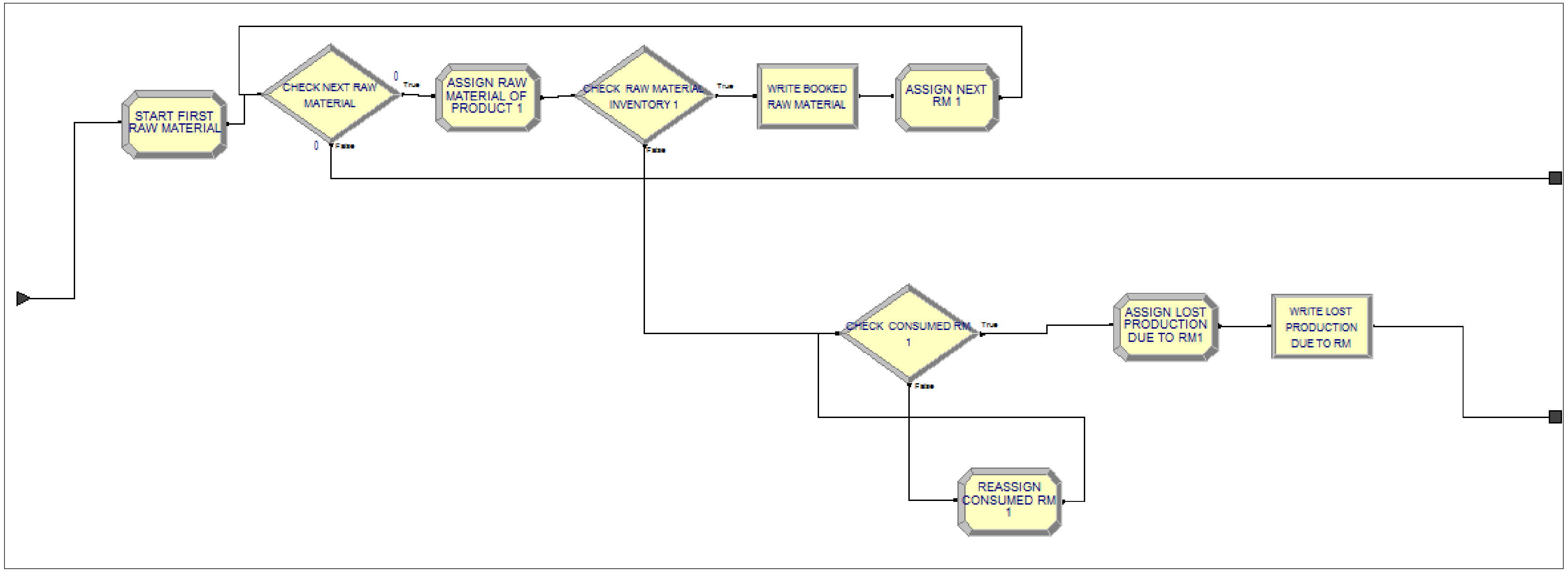

Figure C.12: Raw material inventory sub-model

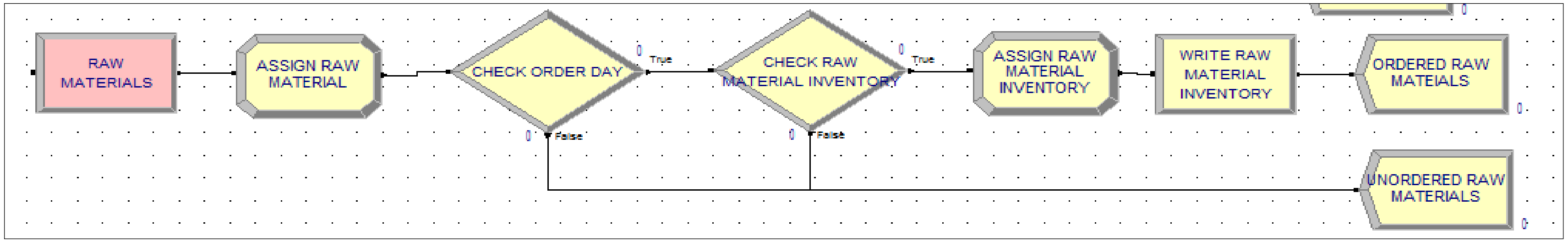

Figure C.13: Raw material orders

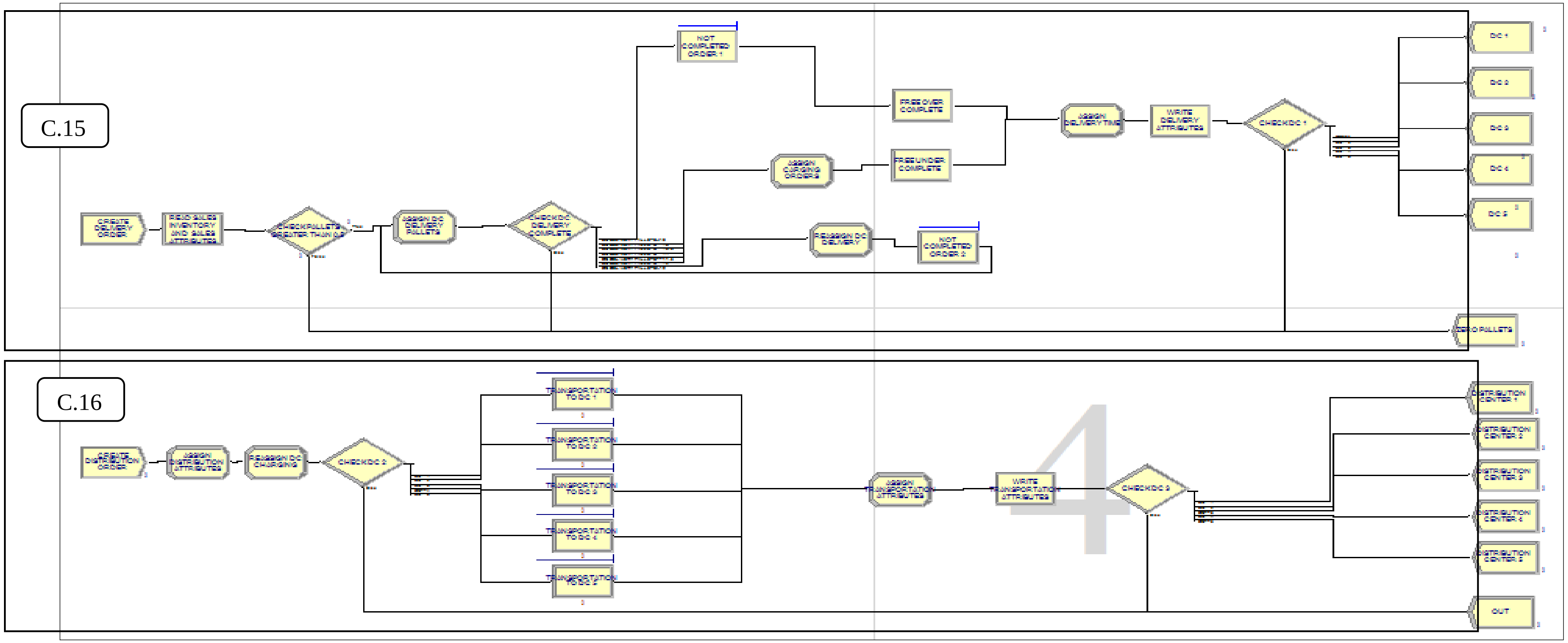

Figure C.14: Structure of Sinokrot sales delivery simulation model (please see figures denoted by Cs for more detailes)

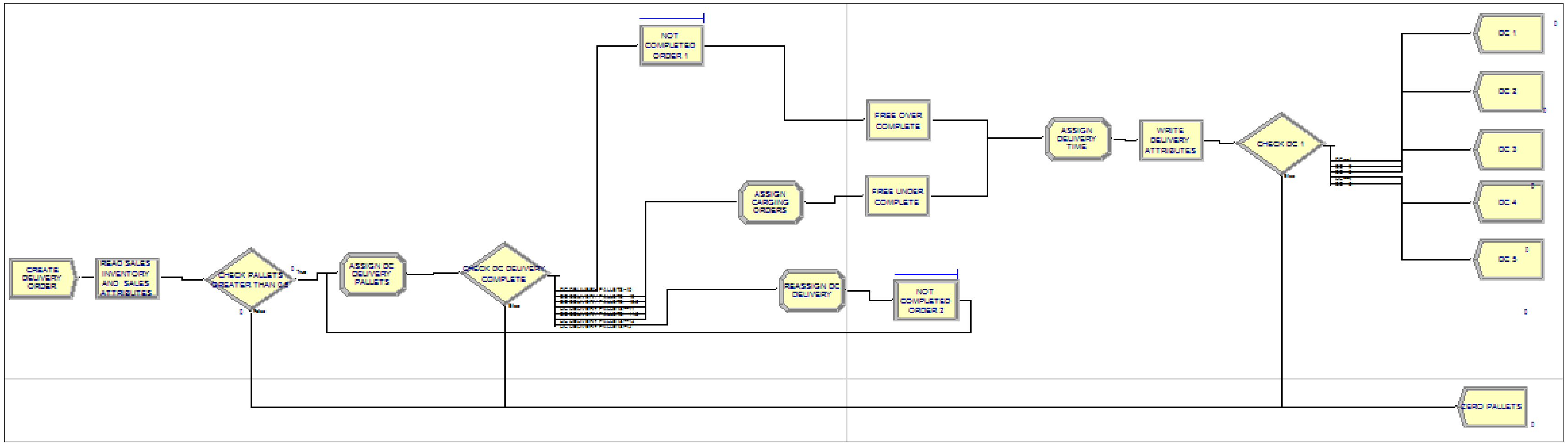

Figure C.15: Delivery orders

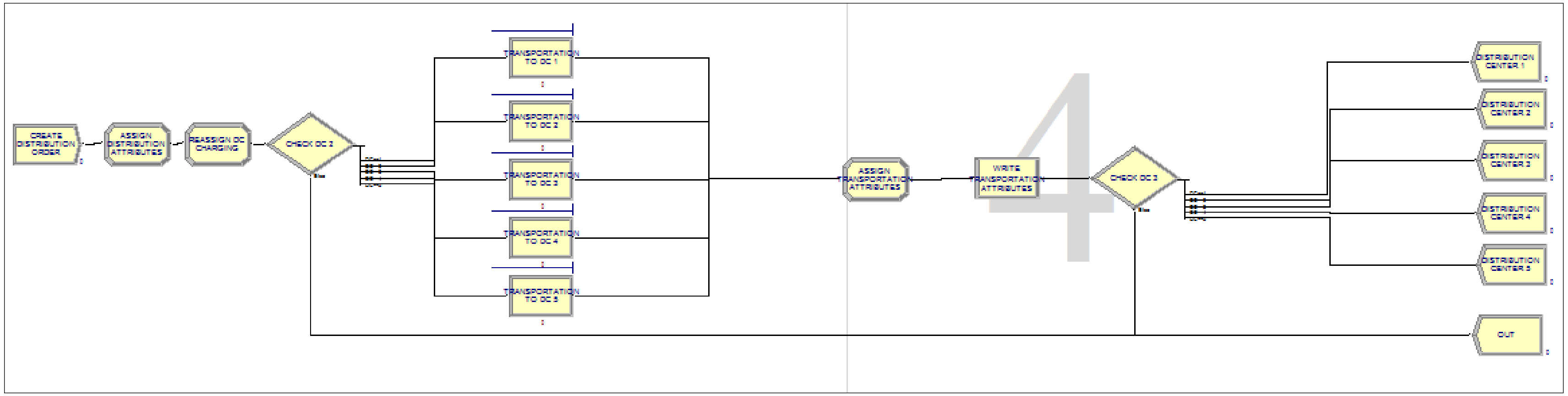

Figure C.16: Distribution orders

APPENDIX D: SIMULATION MODEL VALIDATION

1-DEMAND VALIDATION

Table (D.1): Real demand (semi-month demand of some products)

	Product 1	**Product 5**	**Product 10**	**Product 15**	**Product 17**
Normal	Normal	Normal	Normal	Normal	Normal
mean	57074.7	3185	399.042	2081.54	686.708
sigma	8405.59	849.428	287.709	795.315	526.072
Chi Squared					
total classes	4	4	4	4	4
interval type	equal probable	equal probable	equal probable	equal probable	equal probable
net bins	4	4	4	4	4
chi**2	1.33	1.33	1.67	2.33	8
degrees of freedom	3	3	3	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	7.81	7.81	7.81	7.81	7.81
p-value	0.721	0.721	0.664	0.506	4.60E-02
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	REJECT
Kolmogorov-Smirnov					
data points	24	24	24	24	24
ks stat	0.158	0.118	0.214	0.135	0.261
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.269	0.269	0.269	0.269	0.269
p-value	0.539	0.852	0.19	0.725	6.23E-02
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling					
data points	24	24	24	24	24
ad stat	0.599	0.353	1.73	0.564	1.49
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49	2.49
p-value	0.649	0.894	0.13	0.683	0.178
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.2): Simulation model demand (semi-month demand of some products)

	Product 1	Product 5	Product 10	Product 15	Product 17
Normal	Normal	Normal	Normal	Normal	Normal
mean	58220.4	3635.25	414.792	2125.92	707.958
sigma	6948.88	1498.24	292.944	788.259	531.319
Chi Squared					
total classes	4	4	4	4	4
interval type	equal probable	equal probable	equal probable	equal probable	equal probable
net bins	4	4	4	4	4
chi**2	6.67	5.33	4	4	8
degrees of freedom	3	3	3	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	7.81	7.81	7.81	7.81	7.81
p-value	8.33E-02	0.149	0.261	0.261	4.60E-02
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	REJECT[1]
Kolmogorov-Smirnov					
data points	24	24	24	24	24
ks stat	0.236	0.218	0.209	0.165	0.239
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.269	0.269	0.269	0.269	0.269
p-value	0.117	0.176	0.215	0.484	0.108
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling					
data points	24	24	24	24	24
ad stat	1.19	1.44	1.71	0.714	1.57
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49	2.49
p-value	0.27	0.192	0.134	0.548	0.161
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.3): Paired T-Test (Demand)

Paired Samples Statistics					
Pair		Mean	N	Std. Deviation	Std. Error Mean
1	rdemand1	58220.3750	24	7098.33899	1448.94238
	mdemand1	58225.1667	24	7135.35179	1456.49758
2	rdemand5	3185.0000	24	867.69780	177.11807
	mdemand5	3635.2500	24	1530.46870	312.40562
3	rdemand10	399.0417	24	293.89698	59.99147
	mdemand10	414.7917	24	299.24499	61.08313
4	rdemand15	3603.3750	24	5269.67894	1075.66871
	mdenand15	3679.0833	24	5298.66993	1081.58647

Paired Samples Correlations				
Pairs		N	Correlation	Sig.
1	rdemand1 & mdemand1	24	.691	.000
2	rdemand5 & mdemand5	24	.473	.020
3	rdemand10 & mdemand10	24	.991	.000
4	rdemand15 & mdenand15	24	.987	.000

Paired Samples Test										
Pairs		Paired Differences					t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
					Lower	Upper				
1	rdemand1 - mdemand1	-4.791	5592.451	1141.554	-2366.276	2356.693	-.004	23	.997	yes
2	rdemand5 - mdemand5	-450.250	1356.238	276.84	-1022.939	122.439	-1.62	23	.117	yes
3	rdemand10 - mdemand10	-15.750	41.095	8.3885	-33.1029	1.602	-1.88	23	.073	yes
4	rdemand15 - mdenand15	-75.708	864.740	176.514	-440.856	289.439	-.429	23	.672	yes

Rdemand i: real product i demand, mdemand i: simulation model product i demand

Table (D.4):Non-parametric test (rank sum test) (Demand)

Pairs		U	mean	variance	Z	Z(CI=5%)	H0:data groups are similar
5	rdemand17 - mdemand17	281	288	2352	-1.44	1.96	yes

Table (D.5): Demand validation summery

Pairs		Normal (chi-squired test)	Non-parametric test (rank sum test)	Natural pairing (paired T test)	Variances are equal (F test)	independency (Independent T test)	Smith-Satterwaith test	validation
1	rdemand1 & mdemand1	yes	----	yes	------	-----	-----	yes
2	rdemand5 & mdemand5	yes	----	yes	------	-----	-----	yes
3	rdemand10 & mdemand10	yes	----	yes	------	-----	-----	yes
4	rdemand15 & mdenand15	yes	----	yes	------	-----	-----	yes
5	rdemand17 & mdemand17	no	yes	----	------	-----	----	yes

Demand validation: yes

2-PRODUCTION RATE VALIDATION

Table (D.6): Real Production rate (production rate of some products)(continue)

product	Product 1		Product 5	
period	Period 1	Period 2	Period 1	Period 2
Normal	Normal	Normal	Normal	Normal
mean	5.12605	4.34918	51.5613	41.9132
sigma	1.28914	0.668508	19.6416	16.9344
Chi Squared				
total classes	8	6	4	6
interval type	equal probable	equal probable	equal probable	equal probable
net bins	8	6	4	4
chi**2	21.7	7.24	0.478	9.2
degrees of freedom	7	5	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	14.1	11.1	7.81	7.81
p-value	2.84E-03	0.203	0.924	2.67E-02
result	REJECT	DO NOT REJECT	DO NOT REJECT	REJECT
Kolmogorov-Smirnov				
data points	67	67	23	20
ks stat	0.167	0.113	9.40E-02	0.279
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.163	0.163	0.275	0.294
p-value	4.24E-02	0.333	0.975	7.20E-02
result	REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	67	67	23	20
ad stat	3.48	1.28	0.222	2.47
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	1.56E-02	0.241	0.983	5.15E-02
result	REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.6): Real Production rate (production rate of some products)

product	Product 15		Product 17	
period	Period 1	Period 2	Period 1	Period 2
Normal	Normal	Normal	Normal	Normal
mean	88.0153	74.3043	24.5605	24.4694
sigma	21.0665	12.3169	6.91202	6.82463
Chi Squared				
total classes	5	4	4	4
interval type	equal probable	equal probable	equal probable	equal probable
net bins	5	4	4	4
chi**2	14.6	15.4	2.33	1
degrees of freedom	4	3	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	9.49	7.81	7.81	7.81
p-value	5.70E-03	1.48E-03	0.506	0.801
result	REJECT	REJECT	DO NOT REJECT	DO NOT REJECT
Kolmogorov-Smirnov				
data points	32	28	24	24
ks stat	0.213	0.203	0.171	0.145
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.234	0.25	0.269	0.269
p-value	9.30E-02	0.172	0.434	0.643
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	32	28	24	24
ad stat	2.45	1.39	0.918	0.772
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	5.26E-02	0.204	0.403	0.502
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.6): Simulation Production rate (production rate of some products) (continue)

product	Product 1		Product 5	
period	Period 1	Period 2	Period 1	Period 2
Normal	Normal	Normal	Normal	Normal
mean	4.36555	4.15791	46.7296	50.9529
sigma	0.510217	0.649912	17.9501	4.007
Chi Squared				
total classes	6	6	4	4
interval type	equal probable	equal probable	equal probable	equal probable
net bins	6	6	4	4
chi**2	2.04	0.791	6.74	1.2
degrees of freedom	5	5	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	11.1	11.1	7.81	7.81
p-value	0.843	0.978	8.07E-02	0.753
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Kolmogorov-Smirnov				
data points	67	67	23	20
ks stat	7.36E-02	6.26E-02	0.229	0.127
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.163	0.163	0.275	0.294
p-value	0.835	0.941	0.153	0.863
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	67	67	23	20
ad stat	0.441	0.259	1.3	0.344
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	0.808	0.965	0.232	0.901
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.6): Simulation Production rate (production rate of some products)

product	**Product 15**		**Product 17**	
period	Period 1	Period 2	Period 1	Period 2
Normal	Normal	Normal	Normal	Normal
mean	61.1722	59.2359	21.0882	27.3221
sigma	7.91833	7.43414	7.44759	6.8505
Chi Squared				
total classes	4	4	4	5
interval type	equal probable	equal probable	equal probable	equal probable
net bins	4	4	4	5
chi**2	3.75	1.43	1.67	7.63
degrees of freedom	3	3	3	4
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	7.81	7.81	7.81	9.49
p-value	0.29	0.699	0.644	0.106
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Kolmogorov-Smirnov				
data points	32	28	24	48
ks stat	9.93E-02	0.103	0.132	0.121
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.234	0.25	0.269	0.192
p-value	0.88	0.9	0.747	0.452
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	32	28	24	48
ad stat	0.421	0.281	0.471	0.721
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	0.828	0.952	0.777	0.542
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.7): Paired T-Test (Production rate)

Paired Samples Statistics

pairs		Mean	N	Std. Deviation	Std. Error Mean
2	rprivity1p2	4.3492	67	.67355	.08229
	sprivity1p2	4.1579	67	.65482	.08000
3	rprivity5p1	51.5613	23	20.08308	4.18761
	sprivity5p1	46.7296	23	18.35351	3.82697
7	rprivity17p1	24.5605	24	7.06068	1.44125
	sprivity17p1	21.0882	24	7.60777	1.55293
8	rprivity17p2	27.5929	24	6.79021	1.38604
	sprivity17p2	29.8716	24	7.30181	1.49047

Paired Samples Correlations

pairs		N	Correlation	Sig.
2	rprivity1p2 & sprivity1p2	67	.199	.107
3	rprivity5p1 & sprivity5p1	23	.309	.151
7	rprivity17p1 & sprivity17p1	24	.017	.939
8	rprivity17p2 & sprivity17p2	24	.592	.002

Paired Samples Test

Pairs		Paired Differences					t	df	Sig. (2-tailed)	Paired?
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
					Lower	Upper				
2	rprivity1p2 - sprivity1p2	.191	.840	.102	-.0138	.396	1.862	66	.067	yes
3	rprivity5p1 - sprivity5p1	4.831	22.629	4.718	-4.954	14.617	1.024	22	.317	yes
7	rprivity17p1 - sprivity17p1	3.472	10.293	2.101	-.874	7.818	1.653	23	.112	yes
8	rprivity17p2 - sprivity17p2	-2.27	6.383	1.302	-4.973	.41665	-1.74	23	.094	yes

Table (D.8): Nonparametric test

pairs		Hypothesis test summery				
		Hypothesis Test Summary				
			Null Hypothesis	Test	Sig.	Decision
1	rprivity1p1 - sprivity1p1	1	The distribution of v1 is the same across categories of v2.	Independent-Samples Mann-Whitney U Test	.134	Retain the null hypothesis.
		Asymptotic significances are displayed. The significance level is .05.				
		Hypothesis Test Summary				
			Null Hypothesis	Test	Sig.	Decision
4	rprivity5p2 - sprivity5p2	1	The distribution of v3 is the same across categories of v4.	Independent-Samples Mann-Whitney U Test	.787	Retain the null hypothesis.
		Asymptotic significances are displayed. The significance level is .05.				
		Hypothesis Test Summary				
			Null Hypothesis	Test	Sig.	Decision
5	rprivity15p1- sprivity15p1	1	The distribution of v5 is the same across categories of v6.	Independent-Samples Mann-Whitney U Test	.197	Retain the null hypothesis.
		Asymptotic significances are displayed. The significance level is .05.				
		Hypothesis Test Summary				
			Null Hypothesis	Test	Sig.	Decision
6	rprivity15p2 - sprivity15p2	1	The distribution of v7 is the same across categories of v8.	Independent-Samples Mann-Whitney U Test	.806	Retain the null hypothesis.
		Asymptotic significances are displayed. The significance level is .05.				

Table (D.9): Production rate validation summery

Pairs		Normal (chi-squired test)	Non-parametric test (rank sum test)	Natural pairing (paired T test)	Variances are equal (F test)	independency (Independent T test)	Smith-Satterwaith test	validation
1	rprivity1p1& sprivity1p1	no	yes	-----	----	----	----	yes
2	rprivity1p2 & sprivity1p2	yes	----	yes	----	----	----	yes
3	Rprivity5p1& sprivity5p1	yes	----	yes	----	----	----	yes
4	Rprivity5p2 & sprivity5p2	no	yes	-----	----	----	----	yes
5	rprivity15p1& sprivity15p1	no	yes	-----	----	----	----	yes
6	rprivity15p2 & sprivity15p2	no	yes	-----	----	----	----	yes
7	rprivity17p1& sprivity17p1	yes	----	yes	----	----	----	yes
8	rprivity17p2 & sprivity17p2	yes	----	yes	----	----	----	yes

Production rate validation: yes

3. PRODUCED QUANTITIES VALIDATION

Table (D.10): Real produced quantities of some products

product	Product 1	Product 5	Product 15	Product 17
period	Period 1	Period 2	Period 1	Period 1
Normal	Normal	Normal	Normal	Normal
mean	6183.1	311.9	484.906	1598.25
sigma	1702.36	96.9989	144.476	641.843
Chi Squared				
total classes	6	4	4	4
interval type	equal probable	equal probable	equal probable	equal probable
net bins	6	4	4	4
chi**2	6.48	0.8	2.5	9.33
degrees of freedom	5	3	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	11.1	7.81	7.81	7.81
p-value	0.262	0.849	0.475	2.52E-02
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	REJECT
Kolmogorov-Smirnov				
data points	81	20	32	24
ks stat	0.106	0.209	0.133	0.201
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.149	0.294	0.234	0.269
p-value	0.306	0.305	0.582	0.25
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	81	20	32	24
ad stat	1.39	0.967	0.43	1.31
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	0.206	0.375	0.818	0.23
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.11): Simulation produced quantities of some products

product	Product 1	Product 5	Product 15	Product 17
period	Period 1	Period 2	Period 1	Period 1
Normal	Normal	Normal	Normal	Normal
mean	6507.38	532.457	490.182	1371.75
sigma	1083.65	47.5027	76.6564	374.622
Chi Squared				
total classes	6	4	4	4
interval type	equal probable	equal probable	equal probable	equal probable
net bins	6	4	4	4
chi**2	3.67	2.22	1.75	1.33
degrees of freedom	5	3	3	3
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
chi**2(3,5.e-002)	11.1	7.81	7.81	7.81
p-value	0.598	0.529	0.626	0.721
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Kolmogorov-Smirnov				
data points	81	23	32	24
ks stat	9.62E-02	0.139	0.111	0.132
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ks stat(n,5.e-002)	0.149	0.275	0.234	0.269
p-value	0.416	0.713	0.788	0.746
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT
Anderson-Darling				
data points	81	23	32	24
ad stat	1.06	0.413	0.356	0.522
alpha	5.00E-02	5.00E-02	5.00E-02	5.00E-02
ad stat(n,5.e-002)	2.49	2.49	2.49	2.49
p-value	0.326	0.836	0.891	0.724
result	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT	DO NOT REJECT

Table (D.12): Paired T-Test (produced quantities of some products)

Paired Samples Statistics

pairs		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	rprod1p1	6183.0988	81	1712.97168	190.33019
	sprod1p1	6507.3751	81	1090.39949	121.15550
Pair 2	rprod5p2	311.9000	20	99.51879	22.25308
	sprod5p2	369.2205	20	126.85253	28.36509
Pair 3	rprod15p1	484.9063	32	146.78739	25.94859
	sprod15p1	490.1816	32	77.88298	13.76790

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	rprod1p1 & sprod1p1	81	.011	.925
Pair 2	rprod5p2 & sprod5p2	20	-.324-	.163
Pair 3	rprod15p1 & sprod15p1	32	.483	.005

Paired Samples Test

Pairs		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	rprod1p1 - sprod1p1	-324.27	2020.79	224.532	-771.11	122.55	-1.44	80	.153
2	rprod5p2 - sprod5p2	-57.32	184.89	41.344	-143.85	29.214	-1.38	19	.182
3	rprod15p1 - sprod15p1	-5.27-	128.68	22.748	-51.67	41.120	-.23	31	.818

Table (D.13): Nonparametric test

pairs		
1	rprod1p1 - sprod1p1	

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of mdemand17 is the same across categories of rdemand17.	Independent-Samples Kruskal-Wallis Test	.345	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table (D.14): Demand validation summery

	Pairs	Normal (chi-squired test)	Non-parametric test (rank sum test)	Natural pairing (paired T test)	Variances are equal (F test)	independency (Independent T test)	Smith-Satterwaith test	validation
1	rprod1p1 - sprod1p1	yes	----	yes	------	-----	-----	yes
2	rprod5p2 - sprod5p2	yes	----	yes	------	-----	-----	yes
3	rprod15p1 - sprod15p1	yes	----	yes	------	-----	-----	yes
4	rprod17p1 - sprod17p1	no	yes	------	------	-----	-----	yes

Produced Quantities Validation: yes

APPENDIX E: SIMULATIOM SCENARIOS

1-SCENARIO 1: MARKET DEMAND INCREASING (15%)

Table (E.1): Sales T-test and F-test results (scenario 1)(continue)

Group Statistics					
Groups		N	Mean	Std. Deviation	Std. Error Mean
SP1	1.00	1103	1266.4757	1359.26595	40.92764
	2.00	1018	3155.0027	50315.47104	1576.98533
SP6	1.00	102	146.3936	175.60210	17.38720
	2.00	848	508.9612	7514.11555	258.03579
SP16	1.00	1199	7.3141	7.34402	.21209
	2.00	1199	8.4111	8.41352	.24298
SP20	1.00	898	10.3280	8.88841	.29661
	2.00	1041	21.0145	338.83335	10.50173

Table (E.1): Sales T-test and F-test results (scenario 1)

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
SP1	Equal variances assumed	3.802	.051	-1.246	2119.0	.213	-1,889	1,515.6	-4,860.7	1,083.6
	Equal variances not assumed			-1.197	1018.4	.232	-1,889	1,577.5	-4,984.1	1,207.0
SP6	Equal variances assumed	.684	.408	-.487	948.0	.626	-363	744.4	-1,823.4	1,098.3
	Equal variances not assumed			-1.402	854.6	.161	-363	258.6	-870.2	145.0
SP16	Equal variances assumed	14.692	.000	-3.402	2396.0	.001	-1	0.3	-1.7	-0.5
	Equal variances not assumed			-3.402	2353.0	.001	-1	0.3	-1.7	-0.5
SP20	Equal variances assumed	2.233	.135	-.945	1937.0	.345	-11	11.3	-32.9	11.5
	Equal variances not assumed			-1.017	1041.7	.309	-11	10.5	-31.3	9.9

SPi: Sales of the two populations (ad hoc system and scenario 1 system) of product i.

SCENARIO 4: OPTIMUM RE-0RDER POINT IN CASE OF STOCHASTIC DEMAND AND LEAD TIME

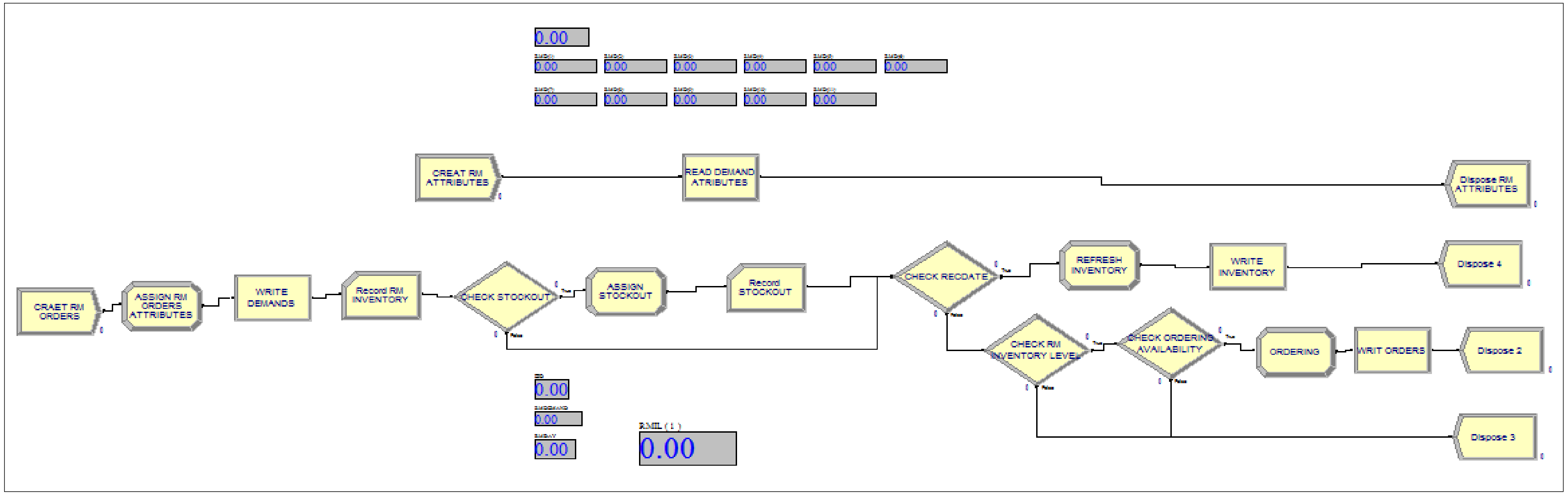

Figure E.1:Scenario 4:Q-based inventory in case of stochastic demand and stochastic lead time

Table (E.2): Fixed Q-based raw material inventory (scenario 4)(continue)

	Theoretical Qopt ×	Reorder point ×	Raw material 1	2	3	4	5	6	7	8	9	10	11
Stock out percentage	0.5	0.5	39%	29%	17%	24%	30%	7%	8%	21%	2%	40%	11%
	0.5	1	9%	3%	2%	2%	15%	1%	2%	3%	1%	22%	5%
	0.5	1.5	9%	3%	2%	2%	15%	1%	2%	3%	1%	22%	5%
	0.5	2	0%	0%	0%	0%	1%	0%	0%	0%	0%	15%	1%
	0.5	2.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%
	1	0.5	10%	5%	4%	6%	7%	2%	2%	3%	0%	27%	4%
	1	1	1%	1%	0%	1%	6%	0%	0%	1%	0%	23%	2%
	1	1.5	0%	0%	0%	0%	3%	0%	0%	0%	0%	11%	1%
	1	2	0%	0%	0%	0%	1%	0%	0%	0%	0%	5%	1%
	1	2.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%
Total inventory cost	0.5	0.5	2,666,898	2,111,065	862,941	3,142,135	60,880	305,491	404,389	3,240,018	266,358	19,198	531,059
	0.5	1	2,670,326	2,043,542	864,909	3,145,796	55,422	291,120	382,285	3,241,586	233,269	15,448	531,313
	0.5	1.5	2,674,088	2,116,636	866,541	3,148,625	55,549	291,306	382,698	3,242,881	233,334	15,448	531,561
	0.5	2	2,760,879	2,124,266	910,946	3,266,473	55,620	291,858	406,176	3,246,902	233,545	17,426	532,174
	0.5	2.5	3,015,068	2,354,960	1,003,873	3,507,454	61,477	322,485	431,683	3,581,641	234,230	19,559	609,792
	1	0.5	2,747,292	2,115,305	865,622	3,254,416	66,519	320,355	405,174	3,242,789	266,752	19,197	531,512
	1	1	2,751,971	1,977,545	867,505	3,041,469	55,508	291,490	360,797	**2,920,268**	**200,548**	15,399	531,802
	1	1.5	2,603,570	2,120,234	869,143	3,044,471	55,652	291,684	361,168	3,245,515	200,625	15,491	532,136
	1	2	2,768,275	2,128,539	874,892	3,270,805	55,721	292,277	407,036	3,249,605	200,823	19,452	532,887
	1	2.5	2,802,801	2,292,522	969,040	3,516,189	56,083	322,934	410,145	3,585,698	201,607	19,646	610,252
Key			2,666,898	Rejected solution , stock out percentage ≠0				**2,920,268**	Optimum inventory cost				

Table (E.2): Fixed Q-based raw material inventory (scenario 4)(continue)

	Theoretical Qopt ×	Reorder point ×	Raw material										
			1	2	3	4	5	6	7	8	9	10	11
Stock out percentage	1	2	0%	0%	0%	0%	1%	0%	0%	0%	0%	5%	1%
	1	2.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%
	1.5	0.5	3%	2%	2%	2%	3%	1%	1%	2%	0%	11%	2%
	1.5	1	1%	1%	0%	0%	1%	0%	0%	0%	0%	10%	1%
	1.5	1.5	0%	0%	0%	0%	1%	0%	0%	0%	0%	10%	1%
	1.5	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%
	1.5	2.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%	0%
	2	0.5	1%	0%	0%	1%	1%	0%	0%	0%	0%	2%	1%
	2	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	1%
	2	1.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%
Total inventory cost	1	2	2,768,275	2,128,539	874,892	3,270,805	55,721	292,277	407,036	3,249,605	200,823	19,452	532,887
	1	2.5	2,802,801	2,292,522	969,040	3,516,189	56,083	322,934	410,145	3,585,698	201,607	19,646	610,252
	1.5	0.5	2,753,338	2,119,700	947,174	3,261,253	66,731	306,360	406,216	3,407,714	300,665	23,161	456,535
	1.5	1	2,757,351	1,911,152	832,025	2,939,788	50,266	**262,936**	339,438	2,923,457	201,349	17,442	456,812
	1.5	1.5	2,761,113	2,125,068	833,657	2,942,658	50,305	263,102	339,776	2,924,683	201,439	17,442	456,985
	1.5	2	2,545,329	2,133,475	839,172	3,277,975	50,340	263,639	407,928	2,928,773	201,608	17,447	**457,852**
	1.5	2.5	2,545,329	2,133,475	839,172	3,277,975	50,340	263,639	407,928	2,928,773	201,608	17,447	457,852
	2	0.5	2,771,853	2,135,710	959,747	3,279,322	67,345	351,534	409,932	3,903,908	401,774	23,599	459,280
	2	1	2,775,435	**1,716,080**	**727,530**	2,634,025	**34,415**	264,618	**276,009**	2,934,266	202,944	12,171	459,488
	2	1.5	2,779,197	2,138,951	729,239	2,636,770	34,493	264,783	276,280	2,935,765	202,944	12,171	459,834

Table (E.2): Fixed Q-based raw material inventory (scenario 4)

	Theoretical Qopt ×	Reorder point ×	Raw material										
			1	2	3	4	5	6	7	8	9	10	11
Stock out percentage	2.5	0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	2.5	1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	2.5	1.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	2.5	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	2.5	2.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total inventory cost	2.5	0.5	2,380,534	2,183,825	1,234,855	3,339,455	85,939	444,133	689,582	4,910,803	512,113	30,904	580,288
	2.5	1	2,384,923	1,132,367	652,133	**1,720,169**	86,028	226,556	354,156	2,484,802	512,307	30,939	580,115
	2.5	1.5	2,388,057	2,187,370	653,298	1,722,041	86,028	226,659	354,494	2,485,824	512,307	30,939	580,115
	2.5	2	2,401,851	2,192,941	657,571	3,350,686	86,028	227,125	355,282	2,489,232	512,307	30,939	580,115
	2.5	2.5	2,432,574	2,216,743	671,165	3,378,764	86,028	228,521	357,986	2,499,796	512,307	30,939	582,195

Table (E.3): Raw material inventory level T-test and F-test results (ad hoc and scenario 4 models)

Group Statistics											
RM		N	Mean	Std. Deviation	Std. Error Mean	RM		N	Mean	Std. Deviation	Std. Error Mean
RM 1	1.00	312	41,248	17,971	1,017	RM8	1.00	312	16,498	7,935	449
	2.00	312	36,816	9,443	535		2.00	312	14,555	5,230	296
RM 4	1.00	312	47,359	22,551	1,277	RM11	1.00	312	4,378	1,890	107
	2.00	312	24,786	7,187	407		2.00	312	2,677	866	49

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
RM1	Equal variances assumed	108.7	.000	3.9	622.0	.000	4,432	1,149	2,175	6,689
	Equal variances not assumed			3.9	470.6	.000	4,432	1,149	2,174	6,690
RM4	Equal variances assumed	269.9	.000	16.8	622.0	.000	22,572	1,340	19,941	25,204
	Equal variances not assumed			16.8	373.5	.000	22,572	1,340	19,937	25,207
RM8	Equal variances assumed	56.9	.000	3.6	622.0	.000	1,943	538	886	2,999
	Equal variances not assumed			3.6	538.3	.000	1,943	538	886	3,000
RM11	Equal variances assumed	149.6	.000	14.5	622.0	.000	1,702	118	1,471	1,933
	Equal variances not assumed			14.5	436.1	.000	1,702	118	1,470	1,933

SCENARIO 5: OPTIMUM FIXED- TIME INVENTORY REVIEW IN CASE OF STOCHASTIC DEMAND AND STOCHASTIC LEAD TIME

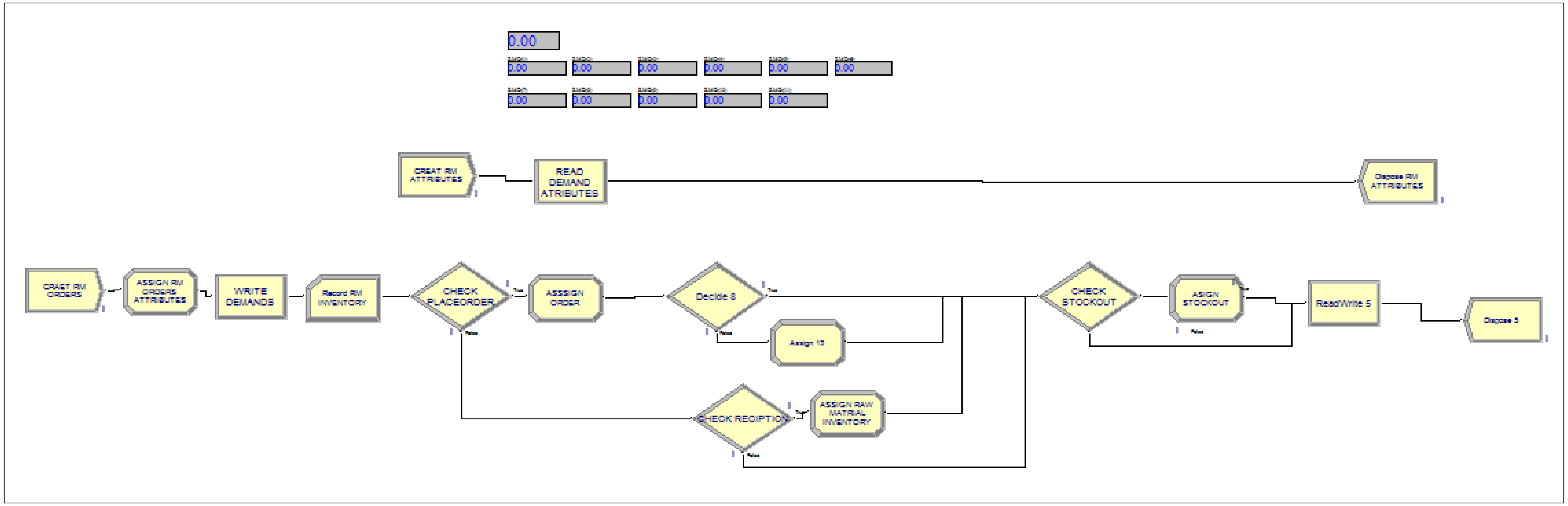

Figure E.2: Scenario 5:Inventory fixed-time revweing in case of stochastic demand and stochastic lead time

Table (E.4): Optimum inventory fixed-time reviewing in case of stochastic demand and stochastic lead time (continue)

Raw material		Reviewing and ordering time T (day)							
		5	6	7	8	9	10	11	12
1	stock out %	42.5%	43%	10%	0%	0%	0%	0%	0%
	total cost	9,719,160	9,716,960	5,098,668	3,058,575	**2,045,316**	3,067,746	3,027,250	3,116,649
2	stock out %	40.3%	40%	2%	0%	0%	0%	0%	0%
	total cost	5,100,685	3,674,573	1,976,641	**1,288,781**	1,773,011	1,612,707	1,552,440	1,600,339
3	stock out %	99.4%	99%	4%	2%	0%	0%	0%	0%
	total cost	21,399,094	13,540,672	1,182,095	791,134	670,058	598,027	787,890	682,746
4	stock out %	57.3%	57%	2%	0%	0%	0%	0%	0%
	total cost	10,207,537	7,990,716	4,061,777	2,492,439	2,500,251	2,574,286	2,368,649	2,440,505
5	stock out %	95.6%	96%	0%	0%	0%	0%	0%	0%
	total cost	2,832,610	1,924,184	180,740	103,608	112,392	63,431	70,502	69,022
6	stock out %	99.7%	100%	0%	0%	0%	0%	0%	0%
	total cost	4,977,059	3,806,122	130,015	125,366	176,057	**117,748**	150,974	176,430
7	stock out %	11.9%	12%	0%	0%	0%	0%	0%	0%
	total cost	1,338,967	918,306	483,560	261,580	**253,568**	267,807	324,271	321,202
8	stock out %	99.9%	98%	2%	2%	4%	0%	0%	0%
	total cost	96,514,801	75,184,743	6,627,841	4,604,975	4,710,409	2,857,106	3,160,645	3,439,663
9	stock out %	99.8%	100%	100%	0%	0%	0%	0%	0%
	total cost	6,261,157	3,892,185	2,543,281	221,332	148,477	154,218	**140,777**	184,707
10	stock out %	0.0%	97%	97%	97%	1%	0%	0%	0%
	total cost	3,245	346,821	282,569	258,057	20,046	10,360	9,444	13,411
11	stock out %	0.6%	1%	0%	0%	0%	0%	0%	0%
	total cost	1,439,281	1,028,547	547,082	470,286	509,478	434,759	477,919	403,379

Keys	553,536	Rejected solution according to stock out percentage ≠ 0	**1,829**	Optimum total inventory cost

Table (E.4): Optimuminventory fixed-time reviewing in case of stochastic demand and stochastic lead time (continue)

Raw material		Reviewing and time between orders T (day)								
		21	22	23	24	25	26	52	78	104
1	stock out %	1%	1%	1%	1%	1%	1%	7%	13%	21%
	total cost	3,013,274	3,158,882	3,110,858	3,260,648	3,142,885	3,262,009	3,274,892	3,898,754	4,191,434
2	stock out %	1%	2%	2%	2%	3%	3%	9%	18%	27%
	total cost	1,628,227	1,392,329	1,938,273	1,513,935	1,572,980	1,808,903	766,786	2,153,710	2,876,963
3	stock out %	0%	0%	0%	0%	0%	1%	5%	12%	19%
	total cost	632,484	790,240	826,172	**585,171**	605,081	783,538	1,615,166	1,231,862	1,018,073
4	stock out %	1%	1%	1%	1%	1%	1%	8%	14%	22%
	total cost	2,943,626	2,151,752	2,486,648	2,843,562	2,973,045	2,528,181	1,862,002	3,507,696	3,575,190
5	stock out %	0%	0%	0%	0%	0%	0%	1%	4%	8%
	total cost	72,290	70,992	78,794	82,819	85,893	82,952	4,393,857	85,292	110,747
6	stock out %	1%	1%	1%	2%	2%	2%	9%	16%	24%
	total cost	124,452	152,080	204,831	237,019	246,748	308,419	2,813,646	317,688	323,313
7	stock out %	1%	1%	1%	1%	1%	1%	6%	11%	18%
	total cost	296,870	282,492	360,301	308,725	319,217	368,372	1,790,707	459,434	615,258
8	stock out %	2%	1%	2%	1%	2%	2%	7%	14%	20%
	total cost	3,072,848	3,242,669	3,632,374	3,242,307	3,374,216	2,964,226	2,330,467	3,924,470	5,360,464
9	stock out %	1%	1%	1%	1%	1%	1%	7%	14%	23%
	total cost	172,783	122,283	167,537	155,200	159,525	168,331	1,957,554	217,015	366,951
10	stock out %	0%	0%	0%	0%	0%	0%	3%	0%	0%
	total cost	1,879	2,060	1,924	1,895	**1,829**	15,704	4,839	4,892	7,950
11	stock out %	1%	1%	1%	1%	1%	1%	5%	11%	16%
	total cost	553,536	453,374	468,170	546,794	550,978	535,416	4,859,470	703,698	979,213

Table (E.4): Optimuminventory fixed-time reviewing in case of stochastic demand and stochastic lead time (continue)

Raw material		Reviewing and time between orders T (day)							
		13	14	15	16	17	18	19	20
1	stock out %	0%	0%	0%	0%	0%	0%	0%	0%
	total cost	3,128,874	3,095,813	3,022,980	3,047,155	3,100,135	3,122,897	3,104,562	3,082,277
2	stock out %	0%	1%	1%	1%	1%	1%	1%	1%
	total cost	1,467,005	1,474,685	1,781,880	2,014,530	1,670,328	1,519,914	1,593,897	1,820,990
3	stock out %	0%	0%	0%	0%	0%	0%	0%	0%
	total cost	620,551	706,983	673,083	626,558	611,052	753,253	742,210	833,377
4	stock out %	0%	0%	0%	0%	1%	1%	1%	1%
	total cost	2,646,733	**2,109,466**	2,570,936	2,239,768	2,570,904	2,325,501	2,849,477	2,803,843
5	stock out %	0%	0%	0%	0%	0%	0%	0%	0%
	total cost	67,847	67,408	66,659	69,858	64,522	72,938	**62,017**	68,425
6	stock out %	0%	0%	0%	0%	1%	1%	1%	1%
	total cost	190,870	206,329	147,592	188,632	217,214	106,762	131,389	255,251
7	stock out %	0%	0%	0%	0%	0%	0%	1%	1%
	total cost	311,736	336,146	338,149	406,161	312,903	356,345	270,123	311,610
8	stock out %	0%	0%	0%	1%	0%	1%	1%	1%
	total cost	3,308,842	**2,274,874**	3,026,473	3,107,781	3,409,455	3,159,459	3,247,114	2,756,837
9	stock out %	0%	0%	0%	0%	0%	1%	1%	1%
	total cost	165,580	153,722	189,918	161,901	156,483	133,001	174,873	163,274
10	stock out %	0%	1%	0%	0%	1%	0%	0%	1%
	total cost	2,090	10,811	13,658	2,098	13,007	13,707	2,317	11,923
11	stock out %	0%	0%	0%	0%	0%	0%	0%	1%
	total cost	541,220	**393,307**	508,206	512,488	446,001	543,336	503,350	601,206

Table (E.4): Optimum inventory fixed-time reviewing in case of stochastic demand and stochastic lead time

Raw	1		2		3		4		5		6	
T	stock out %	total cost	stock out %	total cost	stock out %	total cost	stock out %	total cost	stock out %	total cost	stock out %	total cost
5	~~42.5%~~	~~9,719,160~~	~~40.3%~~	~~5,100,685~~	~~99.4%~~	~~21,399,094~~	~~57.3%~~	~~10,207,537~~	~~95.6%~~	~~2,832,610~~	~~99.7%~~	~~4,977,059~~
6	~~43%~~	~~9,716,960~~	~~40%~~	~~3,674,573~~	~~99%~~	~~13,540,672~~	~~57%~~	~~7,990,716~~	~~96%~~	~~1,924,184~~	~~100%~~	~~3,806,122~~
7	~~10%~~	~~5,098,668~~	~~2%~~	~~1,976,641~~	~~4%~~	~~1,182,095~~	~~2%~~	~~4,061,777~~	0%	180,740	0%	130,015
8	0%	3,058,575	0%	1,288,781	2%	791,134	0%	2,492,439	0%	103,608	0%	125,366
9	0%	2,045,316	0%	1,773,011	0%	670,058	0%	2,500,251	0%	112,392	0%	176,057
10	0%	3,067,746	0%	1,612,707	0%	598,027	0%	2,574,286	0%	63,431	0%	117,748
11	0%	3,027,250	0%	1,552,440	0%	787,890	0%	2,368,649	0%	70,502	0%	150,974
12	0%	3,116,649	0%	1,600,339	0%	682,746	0%	2,440,505	0%	69,022	0%	176,430
13	0%	3,128,874	0%	1,467,005	0%	620,551	0%	2,646,733	0%	67,847	0%	190,870
14	0%	3,095,813	~~1%~~	~~1,474,685~~	0%	706,983	0%	2,109,466	0%	67,408	0%	206,329
15	0%	3,022,980	~~1%~~	~~1,781,880~~	0%	673,083	0%	2,570,936	0%	66,659	0%	147,592
16	0%	3,047,155	~~1%~~	~~2,014,530~~	0%	626,558	0%	2,239,768	0%	69,858	0%	188,632
17	0%	3,100,135	~~1%~~	~~1,670,328~~	0%	611,052	1%	2,570,904	0%	64,522	1%	217,214
18	0%	3,122,897	~~1%~~	~~1,519,914~~	0%	753,253	1%	2,325,501	0%	72,938	1%	106,762
19	0%	3,104,562	~~1%~~	~~1,593,897~~	0%	742,210	1%	2,849,477	0%	62,017	1%	131,389
20	0%	3,082,277	~~1%~~	~~1,820,990~~	0%	833,377	1%	2,803,843	0%	68,425	1%	255,251
21	~~1%~~	~~3,013,274~~	~~1%~~	~~1,628,227~~	0%	632,484	1%	2,943,626	0%	72,290	1%	124,452
22	~~1%~~	~~3,158,882~~	~~2%~~	~~1,392,329~~	0%	790,240	1%	2,151,752	0%	70,992	1%	152,080
23	~~1%~~	~~3,110,858~~	~~2%~~	~~1,938,273~~	0%	826,172	1%	2,486,648	0%	78,794	1%	204,831
24	~~1%~~	~~3,260,648~~	~~2%~~	~~1,513,935~~	0%	585,171	1%	2,843,562	0%	82,819	2%	237,019
25	~~1%~~	~~3,142,885~~	~~3%~~	~~1,572,980~~	0%	605,081	1%	2,973,045	0%	85,893	2%	246,748
26	~~1%~~	~~3,262,009~~	~~3%~~	~~1,808,903~~	1%	783,538	1%	2,528,181	0%	82,952	2%	308,419
52	~~7%~~	~~3,274,892~~	~~9%~~	~~766,786~~	5%	1,615,166	8%	1,862,002	1%	4,393,857	9%	2,813,646
78	~~13%~~	~~3,898,754~~	~~18%~~	~~2,153,710~~	12%	1,231,862	14%	3,507,696	4%	85,292	16%	317,688
104	~~21%~~	~~4,191,434~~	~~27%~~	~~2,876,963~~	19%	1,018,073	22%	3,575,190	8%	110,747	24%	323,313

Table (E.5): Scenario5: Raw material inventory level T-test and F-test results

Group Statistics										
RM		N	Mean	Std. Deviation	Std. Error Mean	RM		N	Mean	Std. Deviation	Std. Error Mean
RM1	1.00	41,248	17,971	1,017	41,248	RM8	1.00	312	16,498	7,935	449
	2.00	21,496	8,195	460	21,496		2.00	312	8,449	3,965	223
RM4	1.00	47,359	22,551	1,277	47,359	RM11	1.00	312	4,378	1,890	107
	2.00	15,462	7,399	416	15,462		2.00	312	928	332	19

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
RM1	Equal variances assumed	108.7	.000	3.9	622.0	.000	4,432	1,149	2,175	6,689
	Equal variances not assumed			3.9	470.6	.000	4,432	1,149	2,174	6,690
RM4	Equal variances assumed	269.9	.000	16.8	622.0	.000	22,572	1,340	19,941	25,204
	Equal variances not assumed			16.8	373.5	.000	22,572	1,340	19,937	25,207
RM8	Equal variances assumed	56.9	.000	3.6	622.0	.000	1,943	538	886	2,999
	Equal variances not assumed			3.6	538.3	.000	1,943	538	886	3,000
RM11	Equal variances assumed	149.6	.000	14.5	622.0	.000	1,702	118	1,471	1,933
	Equal variances not assumed			14.5	436.1	.000	1,702	118	1,470	1,933

جامعة النجاح الوطنية

كلية الدراسات العليا

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إعداد

احمد عدلي شويكه

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د. أمجد غانم

قدمت هذه الأطروحة استكمالا لمتطلبات درجة الماجستير في الإدارة الهندسية بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس- فلسطين.

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الملخص

تهدف هذه الأطروحة إلى تطوير أنظمة المحاكاة الصناعية في مجالات سلسلة التزويد ونظم الإنتاج وإدارة المخاطر وذلك في حال وجود متغيرات عشوائية لعوامل مؤثرة في هذه الأنظمة المعقدة بوجود متغيرات مترابطة فيها حيث تكون الأساليب التحليلية والرياضية غير كفؤة في تحليل هذه النظم.

ولفهم سلوك سلسلة التزويد ونظم الإنتاج وإدارة المخاطر تم تطوير نظام لمحاكاة العمليات في شركة سنقرط للمواد الغذائية كحالة دراسية طبقاً لمنهجية إعداد نظم المحاكاة التي تشمل جمع البيانات وتحليلها، وتطوير نظام المحاكاة باستخدام برنامج أرينا بالإضافة إلى مايكروسوفت اكسل، والتحقق من تطويره والتثبت منه، وتصميم التجارب الإحصائية، وتحليل مؤشرات أداء النظام. كما تم تطوير نظم محاكاة لإدارة الحالات (السيناريوهات) لتحليل النظام الحالي وتحليل القرارات قبل اتخاذها على جميع المستويات: طويلة الأمد ومتوسطة الأمد وقصيرة الأمد للوصول الى تحقيق أهداف المؤسسة مثل القرارات المتعلقة بزيادة مبيعات منتجات محددة، أو تحديد منتجات لخط معين، أو تصميم مواصفات إدارة المستودعات، وهكذا..

كما تم تطوير نظم محاكاة لتحديد الأمثلة (الأعظمية) عند تحديد مواصفات إدارة المستودعات ومتغيراتها، وذلك بهدف تقليل تكاليف المستودع الكلية، وتقليل المعدل اليومي لحفظ المواد اعتمادًا على فلسفة الإنتاج الرشيق عند الأخذ بعين الاعتبار أن تكون نسبة عدم تحقيق الطلب أقل من حد معين (مستوى الخدمة). وتعتبر هذه الأنظمة من أهم المساهمات العلمية والعملية والتي تم تطويرها في هذه الأطروحة في هذا المجال، وأخيرا فقد تم استنتاج أهمية نظم

المحاكاة في تطوير سلسلة التزويد ونظم الإنتاج وإدارة المخاطر والخروج بتوصيات لتطوير هذه النظم.