PRODUCTION BATCH SIZE OPTIMIZATION AND EFFECTIVE REORDERING POINT FOR APPROPRIATED STOCK LEVEL SYNCHRONIZED WITH DEMAND

By
EKKAMOL ANUPHONGSIRISAKUL

A Proposal of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

January, 2010

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Examination Committee:

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2. Dr. Peeratarat Ittarattanachoke (Member) ....
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Approved for Graduation on: January 28, 2010

Martin de Tours School of Management
Assumption University
Bangkok, Thailand

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Assumption University
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Master of Science in Supply Chain Management

Form signed by Proofreader of the Graduate Project

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Production Batch Size Optimization and Effective Reordering Point for Appropriated Stock Level Synchronized with Demand

Mr. Ekkamol_Anuphongsirisakul

and hereby certify that the verbiage, spelling and format is commensurate with the quality of internationally acceptable writing standards for a master degree in supply chain management.

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Assumption University
Martin de Tours School of Management
Master of Science in Supply Chain Management

Declaration of Authorship Form

_______MR.EKKAMOL ANUPHONGSIRISAKUL______________________________

declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

PRODUCTION BATCH SIZE OPTIMIZATION AND EFFECTIVE REORDERING POINT FOR APPROPRIATE STOCK LEVEL SYNCHRONIZED WITH DEMAND

I confirm that:

1. This work was done wholly or mainly while in candidature for the M.Sc. degree at this University;
2. Where any part of this dissertation has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
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ID: 502-9356

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I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

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Advisor: Dr. Samarn Chantaravarapan

Date

ABSTRACT

Research Basis. 69 percent of stock value (BHT 4,175,663) is impacted by production batch quantities which are unsynchronized with demand quantities. The production batch size has significant impact on overall company costs, since large batch production size requires a high holding cost under a similar demand pattern. Also, the company never determines the effective reordering point in preventing product shortage.

Methodology. This study applies the simulation technique in discovering appropriate batch production size as well as effective production sequence in order to diminish the number of end products. ROP (reordering point) is calculated where demand rate is also generated via simulation.

Contribution. This paper attempts to contribute a better planning of production batch quantity size as well as determining the effective reordering point. The reduction in the number of end products with no reduction in service level is expected from the study.

Scope. The scope of this research is using the real factors which affect the number of end products. Factors such as production lead-time, demand rate, production batch size, and reordering point are observed and recorded. The top five items in sales value are selected in testing for appropriate batch production size and effective ROP.

Findings. This paper applies simulation technique in finding appropriate production batch size as well as effective reordering point. The validation of the data and simulation model are conducted before selecting two cases in which to find proper production batch size. The first case starts at 1,000 units batch production size, and the study manipulates input by increasing the batch size by 1,000 units up to 10,000 units. In the second case, production sequences are set by items 4, 1, 3, 2, and item 5. ROP starts testing by generating random demand via simulation, then ROP for each batch production size is calculated. Appling appropriate batch production size with ROP is conducted before comparing the simulated result with actual data. Evaluation is also done under defined performance indicators.

ACKNOWLEDGEMENTS

This Master of Science in Supply Chain Management degree graduate project represents the essence of my achievement in the course of study at the School of Business, Assumption University. During this study journey, there have been many people who have inspired and guided me in working through the project. Especially, I would like to express my deepest gratitude to my project advisor, Dr. Samarn Chantaravarapan for everlasting enthusiastic support in the simulation program and for his benevolent guidance. Without his constant guidance, supervision and consistent driving force, it would have been impossible to complete my project study which was beyond my expectation.

I would also like to thank Mr.Amornchai, who is both the Director of AMCMOTOR and my beloved father who contributed valuable data and suggestions. Also, I would also like to express my sincere thanks to all my older friends for their support, and for sharing their many wonderful experiences with me. Especially, millions of thanks to Ms.Parinporn who always gave precious recommendations about the study. I really appreciated her, indeed.

Furthermore, I wish to pay tribute to my beloved parents and my family members for their love, support and encouragement during this course of study.

Ekkamol Anuphongsirisakul
Assumption University
January, 2010

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CHAPTER 1

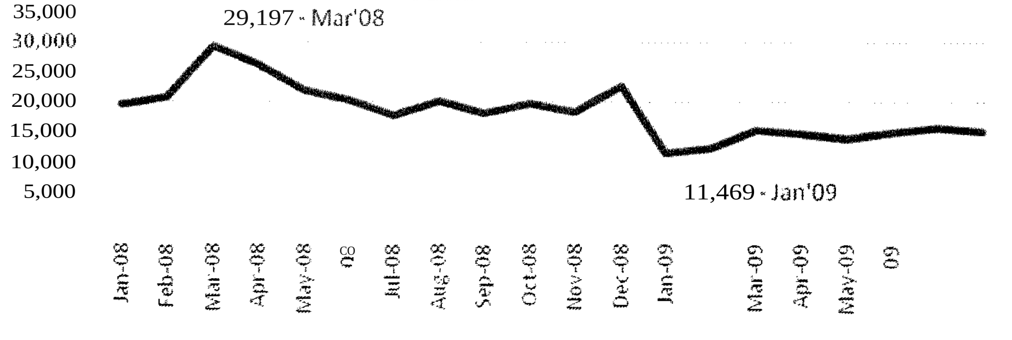
INTRODUCTION

This chapter of the study is to provide reader with general information concerning the background of study; some key concept related to study, research problem as well as overall purpose will be also addressed.

1.1 Background of the Study

Since the global economic downturn was started in 2008, the financial crisis has crucial consequences for the Thai economy and society .Although its direct impacts might not be very great to Thailand, the indirect consequences are quite substantial. Following the slowdowns in the US and EU car industries, Thailand's automotive sector copied directly impact. According to Pickup sale's recorded in 2008, the 1st quarter results being 21.74 % decline from quarter 4/2007 (From BHT88,448 to BHT69,218) The 2nd quarter of the year, however, market began facing a world-wide fuel crisis as well as fuel prices continuing to escalate throughout the next quarter. The initial affects of the global financial crisis beginning to take hold, industry sales, experienced a sharp decline less than the same period of year 2007. Unfortunately, this trend continued through the 4th quarter of 2008, and due to increased political unrest during the final quarter which ended with a decline in sale.

Figure 1.1: Pickup sales during January 2008 to August 2009



Especially, the decline in 2008 major came from the one ton pickup segment. The sharp decreased in pickup trucks was led by high diesel fuel prices, the general economic decline that effected commercial vehicle users. Also, automobile and parts' sale is forecasted to plunge dramatically by 5-20 per cent in 2009 Thai PR (2009)

In the environment of increased competition, raising costs and rapid changing in the market make it all the more difficult to stay profitable. Question is how company will do to survive? For most, it is simple, common sense approach are focusing on cost and number of keeping stock.

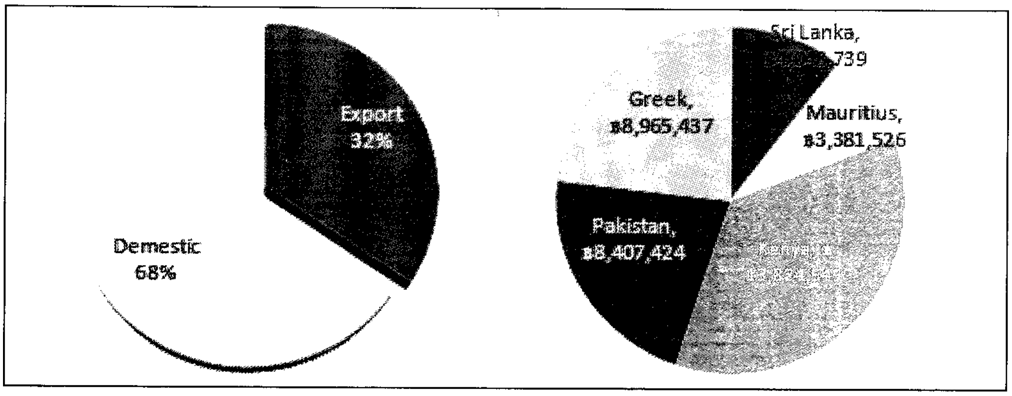
One of inevitably cost variables is the inventories cost or stock cost. Although keeping finished inventory are finally occurred as cost to company, it still vital to have them. Advantages of having inventory are such as gaining benefit of avoiding loss of sale, preventing from unexpected increase in demand, and retaining customer service level. While the disadvantages of having stock are money locked up in inventory as inventory cost. In order word, it can be said that inventory is an angel, but too fat angel can be nightmare to company Therefore, what the appropriate that company should keep inventory are interested studying. Study will be thoroughly based on a case study of AMCMOTOR.

1.2 Company Background

Established in late 1980, AMCMOTOR initiated business at the heart of auto spare parts area in Bangkok, Vorachark road. AMCMOTOR is manufacturing and distributor of automotive replacement lighting parts for aftermarket, mostly for commercial vehicles for example TOYOTA, ISUZU, NISSAN, MITSUBISHI, FORD, and others. Since the products are considered as aftermarket auto spare part, therefore, selling is not obligated to only monopoly customer.

AMCMOTOR do market both in domestic and global. In year 2008, 68% sale value relays on domestic market while another 32% are from exporting.

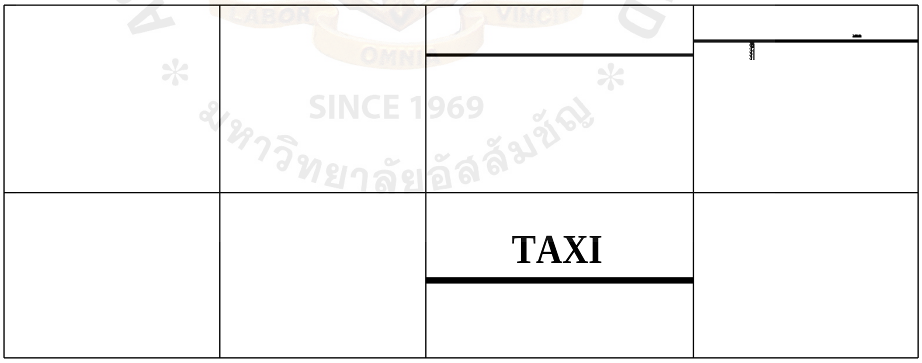
Figure 1.2: Sales portion in domestic and export in 2008 unit in BHT



Source: Sale's department of AMCMOTOR in 2008

Company has more than 200 customers in domestic, and for global, four main customers are situated in the Kenya, Pakistan, Greek, and Sri Lanka, Mauritius. AMCMOTOR has around 200 types of lightning replacement parts product which manufactured multiple products in make-to-stock fashion. The product range from tail lamp, corner lamp, front lamp, bumper lamp, side lamp, and signal lamp.

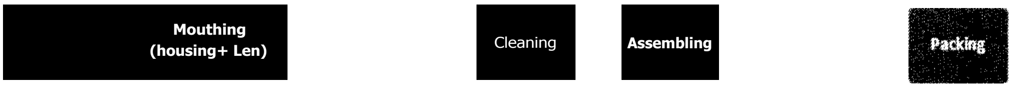
Figure 1.3: Example of AMCMOTOR product range



AMCMOTOR has single manufacturing, warehouse, and one retail shop. Materials are supplied from 5 main suppliers while in-house works are accountable for core competency tasks from assembly process to delivery finished inventory. There are two main sectors in manufacturing process are as following. First, outside factory, supplier supply both plastic part and non-plastic parts to AMC.

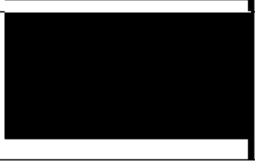
The examples of plastic part are housing, lens. While non-plastic parts consisted of socket set, bulb, box, and carton. AMC have single production line which can be used to produce several products and it cannot afford to run continuous production lines since nature of company is SMEs.

Figure1.4: Sequence in assembling process



The main assembly process starts at housing part ,glued with lens by silicone, then waiting for silicone absorbed into housing, cleaning the lens and housing, assembling socket set , quality checking by testing the bulb ,then final inspecting before sent to packing before keeping in warehouse.

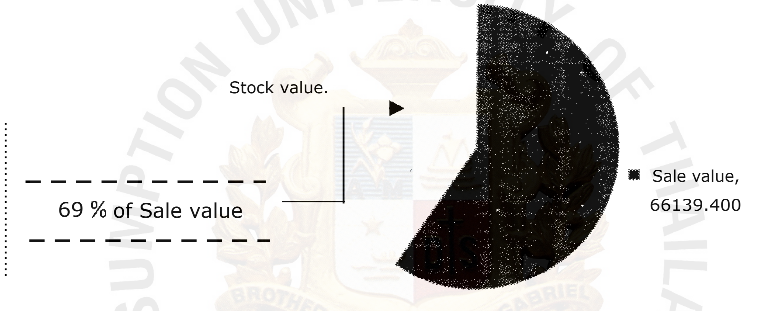
Table1.1: Images of each production process

Process Image	**Processes Description**
	Process 1: Silicone Housing with Lens
	Process 2: Waiting for silicone drying for approximate 15 minutes
	Process 3: Skewing Lens to the housing
	Process 4: Checking for the bulb and final QC
	Process 5: Packing and labeling

1.3 Statement of Problem

According to nature of product, demand pattern always in small volume but combined high production mix. Purchasing order comes in small quantity but high in items mix. Since auto lamp replacement products are not significant different in term of quality, the main competing factors are based on how quick and completeness of product that company can fulfill customers' order. Ensuring to provide high service level has positive relation with the profit that company will be gained.

Figure 1.5: percentagebetween sale and stock value over 8 periods from December 2008 to July 2009



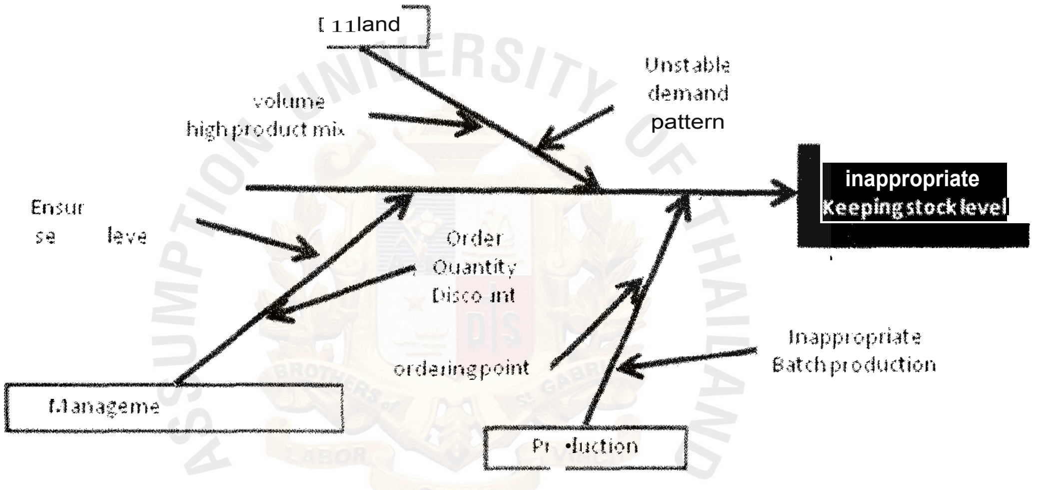
Obviously, average stock value shown up to 69% in average monthly sale value which deriving a question on how can we reduce in stock value. Data show that average inventory cost valued up to BHT4,175,663(calculated from number of ending inventory x production cost) while the average sale per months only BHT6,139,400.It seems that the value finished inventory is inappropriately synchronized with sales value. Therefore, the interview with Mr.Amornchai, Managing Director of AMCMOTOR was taking place.

During interview, the ending inventory data from December 2008 to July 2009 as well as discussion on how to reduce value of stock to be lower than 69 % were presented. Conclusion from interview are conducting analyze in details, finding out what are beneath elements contributed to high number of keeping finished inventory. The production batch size and point of reordering on when and what product should be start will be reviewed.

In order to determine the root causes of a problem as well as indicate possible causes of variation in the problem, study apply cause and effect diagram 'to discover what variations affect to inappropriate finished inventory. Ishikawa(1969) mention that the benefit of cause and effect diagram are facilitating to understand the root cause of problem by identifying possible causes that core problems derived from.

After reviewing and studying in detail by cause and effect diagram as well as self-observation, problems are found that keeping stock levels significantly excess safety stock level and the reordering point also based on experiences only.

Figure 1.6: Cause and effect diagram



Cause and effect diagram develop from observation and field study at shop floor. Then, the core cause or the main research problem is derived from three main variations which are production part, demand part, and management perspective toward stock level.

In Production part, inappropriate batch production size, and order quantity discount are the factors contributing to have inappropriate keeping stock level. In demand part, historical data found that demand pattern is low stabilized, as well as purchasing order always comes in low volume with high in production mix.

Besides, due to management's perspective, ensuring high service level is expected. Notwithstanding that company does not want to lose the sale, comparing the balancing point between cost and profit are never been conducted.

1.4 Research Objective

According to statement of problem, it can be found that problems derive from demand, production, and management policy. Since demand pattern is independent, it is difficult on manipulating demand pattern. Also, the nature of customers' order in low volume with high product mix is also difficult manipulating because customers will shift order to one's who can completely fulfill their bill. Besides, even though service level is vital in business, trading off between cost of lost sale and finished inventory cost have to be considered. When production and demand are properly synchronized, company will no longer need to store excess stock.

Objectively, project will provide a clear solution to the following research objectives

1. To develop appropriated batch production size
2. To reduce number of finished inventory
3. To develop effective reordering point

1.5 Scope of The Research

Study focus on domestic market which production is make-to-stock strategy. Products can be categorized into three groups. The first group or Group A shows 71.41% of overall sale value with only 154 items from overall 1,117 items. Meaning 74.41% of sale value contributed from only 154 items. Therefore, product in Group A is contributing most sale to company. Then, study apply top five sale items in Group A since five items already represent up to 18.59% in sale value from Group A while represent up 13.27% in total sale value which show in figure 1.8

Figure 1.7: percentageof sale volume and value of item 1-5 from Group A

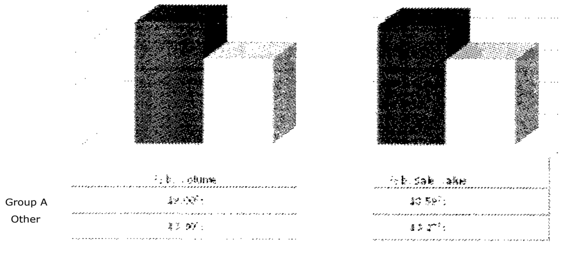
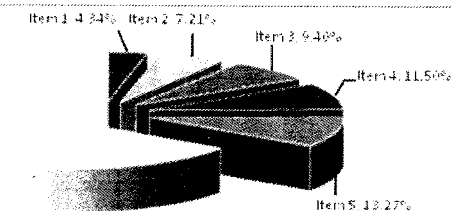


Figure 1.8 percentage in accumulate sales value among items



In figure 1.9, accumulated sale value of selected item 1 to 5 is equal to 13.27% from over product. Since objective of study is getting appropriate stock level, the same approach will be applied to other items in the future study – excluded from the scope of study. Therefore, only five items are selected as represent the possibility in testing whether the method work or not. Also, focused customer group in study are retailers which the purchasing order comes in high product mix with low volume.

1.6 Limitations of Research

First, Information collecting period conducted by human counting based. There is no expert system such as ERP invested. Therefore the data are recorded in excel and software package called Senior Soft ProfessionalV6. Also, some process still by manually recorded in the books. Historical data are available only 8 months period because company installed the software to track the inventory and sales for over 8 months in 2008.

Second, Demand Input demand input were gather from historical demand from December 2008 to July 2009 which might not provide the accurate result for future demand. Since demand pattern is alter along the time. Study will only provide reasonable result for limited period as input data were collected.

1.7 Constraint of Research

There are three significant constraint of research which is as following;

First, delay order, In case of items are shortages and cannot be delivered, customers are willing to wait until end of working day. Then, approximate 80% of customers reject that items while another 20% accept those delay order without any charged incurred.

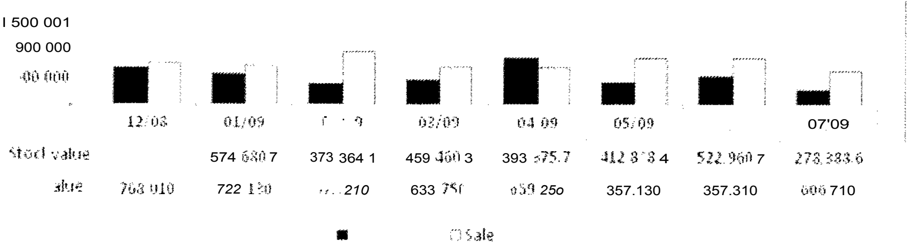
Second, safety stock level, existing safety stock level is a constant rate at 500 units. Although, the current safety level of safety stock may not be the optimal one, historical data and experience of management told that 500 units are adequate for demand during reproduction period. According to historical data, the ending inventory often beyond level of safety stock.

Finally, service level, since, loss sale contribute to long term impact to company's profit as well as policy to remain full service level. Director allow any changes in batch production size, safety stock under condition that service level should not be dropped from current state.

1.8 Significance of the Study

High level of stock locked up large among of money to company. Therefore, the vital of study is reducing the finished goods inventory level. After analyze the root cause of problem, result can be expected that study will develop efficient and sustainable model to synchronize appropriated level between stock levels and independent demand pattern. Consequently, project also provides solution to diminish finish inventory level by simulating the appropriate production batch size as well as developing effective reordering point. The improvements measured by defined performance indicator are expected.

Figure 1.9: Value in BHT of ending stock &sale during December 08 to July 09



To sum up, study provides practical model as developing the decision support in determining quantity and scheduling for production size under batch approach to reduce the finished inventory cost.

1.9 Definition of Terms

Production Batch: A method of production where output emerges in discrete units by creating a component at a workstation before moving to the next step in production process together, a stage at a time.

Cause and Effect Diagram: A graphic tool that can help factories and other organizations to solve problems by conducting an analysis of a situation in a diagram that looks like a fishbone.

Reorder Point (ROP): The reorder point for replenishment of stock occurs when the level of inventory drops down to zero. Factors determine how much delivery time stock and safety stock should be held. In other words, the efficiency of a replenishment system affects how much delivery time is needed. Since the delivery time stock is the expected inventory usage between ordering and receiving inventory, efficient replenishment of inventory would reduce the need for delivery time stock.

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH FRAMEWORKS

This chapter presents a review of the literature and researches related to the study. The themes selected for the literature review were in area of production batch size optimization, reordering point as well as simulation. The related theories and the previous researches can be subdivided into following

2.1 Reordering point

2.2 Production batch size

2.3 Simulation

2.4 Research Conceptual Framework

2.1 Reordering Point

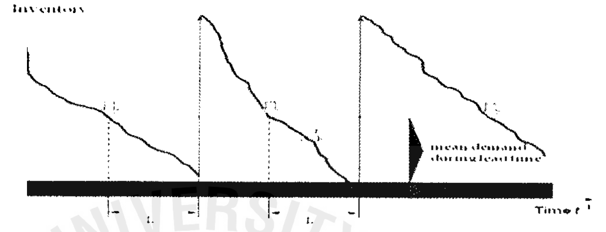
In reality, demand over time period is uncertain. As demand is unstable, a natural question is how low should inventory level go before order was placed? We call the inventory level at which an order should be placed as the reorder point. Obviously, a high reorder point will lower shortage costs and increase holding costs. Meanwhile, a low reorder point will increase shortage costs and lower holding costs. At some intermediate value for the reorder point, the sum of shortage and holding costs will be minimized. The objective of study reordering point is getting effective ROP in answering for production for particular item should be started.

2.1.1 Reorder Point

The reorder point for replenishment of stock takes place when the level of inventory drops down to the certain level. This level is always higher than zero in units because of lead time. Lead time is always a gap time from placing an order to start producing and the date on which production is finished. Placing the order when inventory reaches the reorder point, then the new inventory will arrive before the firm running out of inventory to sell.

There are two factors determine the appropriate order point. First, the delivery time stock or the expected inventory which can be covered sale between the order date and the receipt of the inventory ordered. Second, the safety stock which is the minimum level of inventory that is held as a protection against shortages due to demand unstable pattern.

Figure 2.1: Life cycle of ROP



Source: Original created by author

Figure 2.1 explain the stated of reordering point where blue line is inventory level and horizontally black line is policy reordering point. Martin (2008) stated that reordering point based on the factors as following:

- Effective lead time (ELT) = LTs + LTp + $^1/_2$ R
- Lead time demand (LTD) = ELT X D
- Reorder point (ROP) = SS + LTD
- Order-up-to level = ROP + Q

Each time reviewing the stock, as count:

Stock on hand – real stock on the shelf

Stock on order – the total outstanding orders from the supplier

Back – orders – any stock ordered by a customer

Thus derive:

Effective stock = stock on hand + stock on order – backorders

Placing an order if:

Effective stock <= ROP

The amount to order is:

ROP + Q – Effective stock

Where;

- Forecast demand per period (D) – how much to expect to use
- Supplier lead time (LTs) – time expressed in periods between submitting an order and receiving delivery
- Planned order size (Q) – normal quantity of product to plan to order each time
- Safety stock (SS) – target stock on hand just before to receive an order
- Review time (R) – time interval expressed in periods between reviews of stock levels to determine whether to place an order
- Process lead time (LTp) – time expressed in periods from receipt of goods to their being available to the customer

2.2 Production Batch Size

Definition stated by Schonberger (1982) the optimal batch size is the quantity of products set to production and taken from production at the same time, with minimum cost and maximum usage of resources capacity. However, changing the critical batch sizes will affect only to parameters within a process. For example, changing batch size does not make by speeding up machine or process time, but reduce the idle time when work sits on the workshop floor between process points.

Also, in manufacturing production batch means processing the product in lots size rather than by piece. Inventory buffer is usually used as a mean to maximize the utilization rate of workstations by accumulating several batches of input to the process being done by the workstations. The work of any tasks in batch method divided production into operations where each operation processes though the whole batch before performing in next operation where achieving in specialization of labor can also be possible expected.

The main reasons of batch production method are achieving in high resources utilization because operator will gain concentrate skills and become specialist when performing repeat the same task. Batch production is probably the most commonly used method for organizing manufacture. A good example of batch product is baking bakery where bakers will use ovens to make bread, and then use the same ovens to make cakes, while the production of automotive replacement parts are is produced under batch method.

2.2.1 Characteristic of Batch Production

Ryan (2005) stated that characteristic of batch production is each of worker completes one task and passing down the production line to the next worker. Also, workers are semi-skilled or unskilled and be able to switch from one part of the production line to another. In other work, they are called a flexible workforce. Under batch production, production line can be changed quickly, so that different products can be made. Often individual parts of the product are bought from other companies and assembled on the production line.

2.2.2 Optimal Production Batch Size

Trebuňa (2009) study was published in journal of engineer, stated that optimal batch size can be determined by several approaches which are capacity approach, cost approach, standard frequency of batches approach, and method of static batches.

CAPACITY APPROACH

$$b_s = \frac{t_{pe}}{\alpha \times t_i}$$

a – coefficient ensuring that t_{pe} will not exceed the so-called maximum acceptable rate. It is chosen for a certain components group with the same production conditions. We can determine that the coefficient is in the interval (0.02; 0.12)

Example of coefficient in various batch sizes

- Big and complicated components – a = 0.04
- Middle-size components – a = 0.05
- Small components – a = 0.08
- Automated production – a = 0.10

COST APPROACH

The compromise between fixed cost dispraise for one piece and increase of batch size can be solved by cost approach or can be called as optimization approach.

$$b_s = \sqrt{\frac{2 \times C_{pe} \times Q_p}{C_i \times C_s \times t}}$$

Where;

C_{PE} – costs of preparation and finishing,

Q – planed production quantity in pieces or kilograms,

C _costs of one item in SKK,

C – storage costs.

t – Period of the year depends on Q (for year period t=1)

METHOD OF STATIC BATCH

Items and components are divided to value significant and non-significant. Value significant products are produced in smaller quantity and a predefined batch is corrected by allowance while value of non significant products is mass-produced and their batch size is stable and constant in time. The approximate batch quantity from result of this method is batch size should be interval between minimum to maximum batch quantity.

2.3 Simulation

Computer simulation refers to methods for studying various methods in real world systems by using software designed to mimic the system's operations or characteristics, often over time. Obviously, simulation is more powerful than just using in study the model. For example, simulation model can be allowed in dealing with complex problems while other methods may require stronger simplifying assumptions about the system to enable the analysis.

Due to ability in dealing with very complicated models of correspondingly complicated systems as well as the obvious improving in performance/price of computer which advance in simulation software power, flexibility, and ease of usage are contributed to the variety and popular usage of simulation.

There are also some usages of simulation as tool in countering the problem such as Dacosta (1979) analyze 137 large firms a list of tools and asked them to check off which ones they used. Statistical analysis came in first, with 93% of the firm reporting that they use it, followed by simulation 84%.Simulation came in higher than tools like linear programming, PERT/CPM, inventory theory, and nonlinear programming.

Shannon Long (1980) recorded that surveyed member of operations research division of an American Institute of Industrial Engineers found that among the tools listed, simulation ranked first in utility and interest. Simulation was second in familiarity, behind linear programming, which might suggest that simulation should be given

Forgionne (1983) study the utilization of methods by practitioners in large corporations, statistical analysis was first and simulation was second. Again, academic curricula seem to be behind since linear programming was more frequently taught, as opposed to being used by practitioners, then was simulation.

The National Audit Office (2009) scrutinizes public, spending on behalf of the UK Parliament apply simulation in examine the Inland Revenue's performance in collecting debt and whether the Inland Revenue could collect and enforce debts more quickly and at lower cost. The simulation work was carried out in two phases.

The first phase built an "overall" simulation of the RMS to help the NAO further understand the RMS process. The second phase gathered appropriate data to extend that computer simulation to answer where do peaks of debt occur, when do these occur during the year, and how long do these peaks take to clear.

The simulation assists communication between NAO and Inland Revenue staff in providing a common visualization of the process on which to base discussions. The simulation was also able to contribute to the final report to the British Parliament by the Comptroller and Auditor General. Simul 8 (2009)

Also in the same year, Volkswagen applies simulation in transportation system design. More than US$20 million per year with a custom solution for their plant to distribution center-to-dealer delivery system was saved. Improvements included changing distribution center locations and subsequently replacing some expensive truck routings with cheaper rail or sea routes. Promodel (2009)

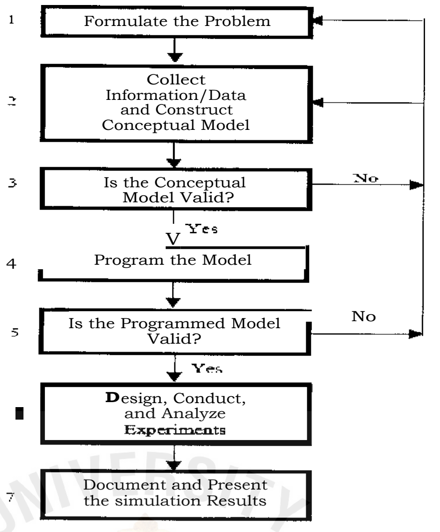
Another usage of simulation that simulation technology has been used to model and improve the complex supply chain for rocket engines and flight hardware between Thiokol's western US facility and Cape Kennedy in Florida. Special logistics are required to handle all the rocket parts, including reusable motor segments in expensive rail cars. Our solution allows them to use fewer rail cars, thus saving time and improving NASA flight schedule reliability. Savings are estimated to be more than US$1 million. Promodel (2009)

2.3.1 Steps in Conducting Successful Simulation Study

Elements in conducting successful simulation study requires an analyst to have, at a minimum, knowledge of simulation methodology which are model validation, selecting input probability distributions, design and analysis of simulation experiments, probability theory, statistics, project management, and the detailed operations of the system.

The seven step approach, applied from Kelton (2000) is illustrated in figure 2.2 the activities that take place in each step are discussed in the following sections.

Figure 2.2: Seven-Step Approach for Conducting a Successful Simulation Study



Source: Kelton (2000)

STEP 1: FORMULATE THE PROBLEM

The problem of interest is stated by the decision maker. When the decision-maker first initiates a simulation study, the exact problem to be solved is sometimes not precisely stated or even completely understood. Thus, as the study proceeds and a better understanding are obtained, this information should be communicated to the decision-maker who may reformulate the problem. Also a need of conducting kickoff meeting(s) for the simulation project with the project manager, the simulation analysts, and subject-matter experts (SMEs) in attendance is expected in discussing the following matters.

- Overall objective of study.
- The specific questions to be answered by the study. Without such specificity, it is impossible to determine the appropriate level of model details.
- The performance measures that will be used to evaluate the efficacy of different system configurations.
- The scope of the model.

- The system configurations to be modeled. This information is necessary to determine the generality that must be built into the simulation computer program.
- The time frame for the study and the required resources.

STEP 2: COLLECT INFORMATION/DATA AND CONSTRUCT A CONCEPTUAL MODEL

- No single person (or document) is adequate. It will be necessary for the simulation analysts to talk to many different SMEs to gain a complete understanding of the system to be modeled.
- Some of the information supplied by the SMEs will invariably be incorrect. Making sure that true SMEs are identified.
- Collect data (if possible) to specify model parameters and probability distributions.
- Document the model assumptions, algorithms, and data summaries in a written conceptual model.
- The level of model detail should depend on project objectives, performance measures of interest, data availability, credibility concerns, computer constraints, opinions of SMEs, and time and money constraints.

STEP 3: CONCEPTUAL MODEL VALIDATION

Perform a structured walk-through of the conceptual model before an audience that includes the project manager, analysts, and SMEs.

- Helps ensure that the model's assumptions are correct and complete.
- Promotes ownership of the model, which can help lessen political problems.
- Takes place before programming begins to avoid significant reprogramming later.

STEP 4: PROGRAM THE MODEL

Program the conceptual model in either a general purpose programming language or in a commercial simulation-software product. Several advantages of a programming language are familiarity, greater program control, and lower software purchase cost. On the other hand, the use of a commercial simulation product will reduce programming time and overall project cost.

STEP 5: PROGRAM MODEL VALIDATION

The compare performance measures from a simulation model of the existing system with the comparable performance measures collected from the actual existing system, or called results validation. It is important that the model be checked to see that it is working properly and providing a good representation of the real world situation. The assumptions of the model should also be checked to see that the appropriate probability distribution is being used.

An analysis of inputs and output should be made to see that the results are reasonable. Besides, the simulation analysts and SMEs should review the simulation results for reasonableness. If the results are consistent with how they perceive the system should operate, then the simulation model is said to have face validity.

STEP 6: DESIGN, CONDUCT, AND ANALYZE SIMULATION EXPERIMENTS.

Decide on tactical issues such as simulation run length, length of the warm up period, and the number of independent model replications. A major pitfall here is to make one replication of the simulation model of some arbitrary length and then to assume that the resulting output statistics are the true performance measures for the model.

STEP 7: DOCUMENT AND PRESENT THE SIMULATION RESULTS.

The documentation for the model and associated simulation study should include the conceptual model. Also, the final presentation for the simulation study should include animations and a discussion of the model building/validation process to promote model credibility.

2.4 Study Related Literature

There are several papers, research which regard to purposed topic are reviewed as per following.

2.4.1 Reordering Point

Keely (2003), developed framework which involves all activities necessary to define customer requirements, designs the logistic network, and fills customer orders.

Keely also mentions that "At the strategic level, the process team designs the operational order fulfillment process. This includes designing the network, establishing policies and procedures, and determining the role of technology in the process." The order fulfillment process needs to be designed around the customer, but within the limits of the firm's business and marketing strategy. When demand is uncertain, the management should compute safety stocks and reorder point.

Silver (2007) also studied reordering point in international producer and distributor of food products, by presenting a novel approach to determine the reorder point. The targets desired of study are customer fill rate and average time between consecutive replenishments. Specifically, the study use a diffusion model (producing normally distributed demand) to convert a periodic review, constant lead time setting into one having continuous review and a random lead time.

2.4.2 Production Batch Size Optimization

Bhaba (1994) studied on the manufacturing batch size to minimize the total cost for meeting equal shipments of the finished products, at fixed intervals. The total cost in determination of optimal batch size are found to be a piece-wise convex cost function. An interval that contains the optimal solution is first determined followed by an optimization technique to identify the exact solution from this interval.

In the study, authors develop an expression for the general cost function coupled with efficient algorithms that may be used to determine an optimal batch size for the production run. Efficient algorithms applied to solve this problem by using an optimization technique. Two theorems are purpose as a foundation of the optimal solution which is totally in algorithms' formula where step in finding the optimal batch size shown in figue2.4

Figure 2.4: Steps in finding optimal batch size under algorithm method

Algorithm finding batch size

Step 0, Initialize and store *1'*. $H_0, \ldots, f$ and x,
Step 1, Compute A and B using (,1 and (12h), respectively.
Step 2. Compute V and Q^*_M using (26) and (27), respectively.
Step 3, Find $= M(1 \quad D_M/2P) - (k^* - 1)x + k^*(k \quad 1)x / 2Q^*_M$ and

$$TC(Q^*_M) \quad D_M \quad) + \cdot D_M \quad Q^*_M \quad H_r.$$

Step 4. Stop.

Once Q^*_M is determined, the optimal order quantity for raw material, Q may be obtained immediately using the conversion factor, f

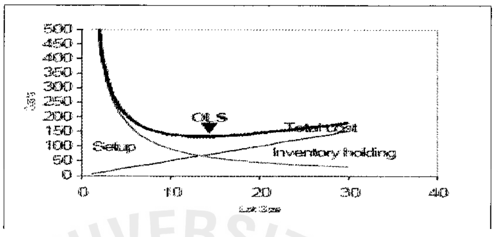
Source: Bhaba (1994)

Solution is found by using the information from Theorems 1 and 2 which are systematically obtained an optimal solution to the problem in a single pass instead of seeking a solution to the problem through an iterative search procedure.

Michael (2000) studied on Optimal lot Size, inventories, prices and JIT (Just in time) The study draws on the optimal batch size model where put interest on monopolistic competition which also introduces inventories into the model of monopolistic competition by incorporating optimized setup and inventory carrying costs into the representative firm's total cost function.

The developing of classic optimal batch size model applies in obtaining optimal batch quantity. The model explains that firm produces its product in batches of size in meeting annual sales. The goods produced in each batch are placed in inventory and gradually sold off. After a batch is sold off and inventory reduced to zero, another lot is produced and the cycle repeats. The sample of logic are shown in figure 2.5

Figure 2.5: Resulting saw-tooth movement of the inventory stock



Source: Michael (2002)

Two types of cost must be balanced in deciding how big a batch to produce which is cost money to set up the machinery in producing a batch and there may be cleanup or shutdown costs at the end of the run. Also, larger batches were produced fewer setup costs each year can be anticipated as well as total annual setup cost will be less. However, the bigger the batches the larger in inventory, reflecting in holding inventory cost.

2.4.3 Simulation

Through simulation, the company can evaluate the manufacturing process under different sets of conditions to identify better the company performance as well as identifying the improvement of company operation performance, measuring the level of work-in-process and finished goods, throughput, resource utilization, operation time, waiting time. There are many reasons why we need to run the simulation program and what the analysis to evaluate the company performance. Simulation also improves the understanding of how the system operates with experimenting on the real system.

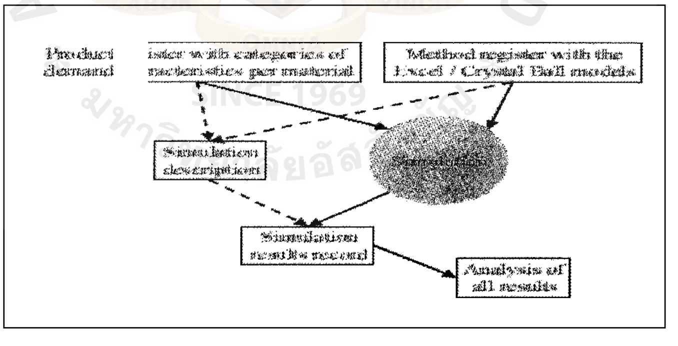
SIMULATION IN MEASURING PRODUCTIVITY

Work measurement is used to find the realistic time required to complete a specific activity. Simulation was also used as a technique to help production planner in making the decision. However, the real advantage of simulation is that it can be used to evaluate and compare the different scenarios with several decisions criteria to select the optimal alternatives. The simulation produced an estimate of activity times and project duration considering uncertainty variables.

SIMULATION IN MANAGING STOCK LINE

Richard (2007) study to solve this problem in managing the stock lines by the quantitative analysis tools used were SAP's R/3, Microsoft's Excel and Decisioneering's Crystal Ball software. The tool used to analyze the performance of the replenishment methods used for managing stock lines and improve the selection of methods was statistics manipulated in Excel. To look at the inventory performance of one site's product ranges, data and reports from SAP were manipulated in Excel as illustrated in figure 2.6

Figure 2.6: Structure of the simulation system



Source: Richard (2007)

Simulation in Reordering Point

Duangpun (1999) mentioned that "A procedure for establishing a reference state in qualitative simulation of operational systems". Duangpun used the simulation model to investigate the generic properties and behavior of different classes of order fulfillment process. It has three major functions – raw material provision, forecasting production and order processing. The raw material provision function comprises of raw material arrival and raw material storage.

SIMULATION IN BATCH SIZE OPTIMIZATION

Simulation was also used as a technique to help the production planner in making the decision. However, the vivid advantages of simulation are that it can be used to evaluate and compare the different scenario with several decision criteria to select the optimal alternative. The simulation produced an estimate of activity times and project duration considering uncertainty variables.

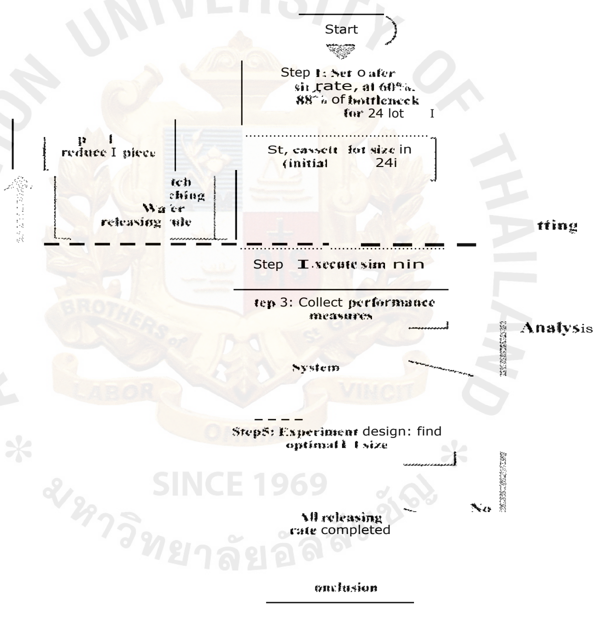
Hei-Chia Wang and Yi-Shen (2005). studied on garment supply chain in proposing a method that first uses a mathematical model, extended with simulation to find the possible best solution. The simulation system is utilized in manipulating the parameters, improving on the limitations of math model. Study presents a batch-size decision method to determine the optimal batch size in minimizing the total cost of a supply chain at a reasonable service level. The methods first applied a mathematical model to finding the possible solutions and then used a simulation tool to model the real-world situation.

Three major research variables are involved in the mathematical model: (1) materials ordering batch size, (2) production batch size, and (3) product distribution batch size. The performance indicators in the study are operational cost, system total cost, and service level.

The result of study in (1) the optimization model shows the economic order batch and economic product batch of the supply chain system can be determined by trying to get the best batch size with the minimal systematic total cost. Therefore, the best raw material purchase quantities and production quantities can be acquired. (2) In the simulation part, the main factor affecting the total cost of the supply chain system is the variation in customers and companies. To reduce the total cost of the supply chain system efficiently and enhance the service level, use of the simulation system can help understanding relation between total cost and service level under different decisions.

(3)To achieve the minimum cost in the supply chain system, calculation of the individual enterprise's purchase quantities of raw material, production quantities and product delivery quantities was mentioned in the paper. Simulated model for cycle time reduction by acquiring optimal batch size in semiconductor manufacturing by Wang (2005) explain benefit of simulation in proposing a simulated model for analysis of lot sizing involved in deriving the optimal lot sizes under different bottleneck utilization conditions. The optimal batch size result derives in the minimal cycle time with respect to specific bottleneck utilization. The study framework main five steps where simulation executed in step 2.

Figure 2.7: Steps in Batch size study



Source: Hei-Chia Wang and Yi-Shen (2005).

After optimizing lot size under different loading levels are determined through simulation experiments; the results are divergent when batch size has little change, and the cycle time increases dramatically in simulation. Improvement after advocating simulation and find optimal batch size are reduced manufacturing cycle time, lower WIP level, increased on-time delivery due to smaller cycle time variance under a lower WIP level, improved customer service because of a smaller allowable customer order volume, increased capability of quick response to market demands and changes, shorten the lead time of new products to market, increased yield due to shorter manufacturing cycle time, as well as lower production risks and costs with less scrap and rework.

SIMULATION IN ANALYSIS BATCH PRODUCTION SYSTEM

Ronan (2001)study on Modeling, Simulation and Analysis of Batch Production Systems. Study stated the main cause of the complexity of the discrete aspect in batch processes where analyzing based on the improvement in validation process of formal specification of batch production systems. Not only based on informal discussions about specify scenarios among all the people involved in the project, but simulation also take significant step in validation process. Therefore the paper simultaneously stress on simulation analysis issue.

Study start at introduction an overview of net modeling techniques for batch systems. Model explained in regard to place of automata to address in an explicit way resource allocation policies which are the main cause of the complexity of the discrete aspect in batch processes. Then a discussion about the trade-offs between modeling power and simulation efficiency is developed. Finally it is shown that formal verification of properties in a batch system represented by a Petri net associated with differential algebraic equations in levels.

1. The ordinary Petri net considered as a qualitative model.

2. T-time Petri net for which decidability is preserved, or the detailed model.

Study mentioned two basic approaches for simulation. First one is based on discrete event models with timing considerations. Second is consisting in extending the principle of continuous simulation. Also, simulation advocates possibly deriving in an algebraic explicit way. The time of all the enabled transitions when they turn enabled or when some global parameter is changed.

2.5 Conceptual Framework

Building a set of concepts linked to existing methods, functions, relationships as well as objects which explained the main studies are defined as "Conceptual Framework" Silverman D. (2000)

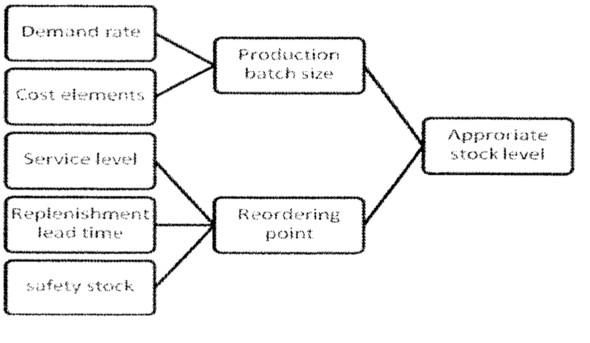
1. ELEMENTS OF PRODUCTION BATCH SIZE

- Demand rate: level of fluctuate in demand, and dependent or independent.
- Loss sale cost: lost in sale opportunity. Value of lost sale equal sale price.
- Inventory cost: value of finished inventory.
- Quantity order discount: raw material discount if order were in quantity.

2. ELEMENTS OF REORDERING POINT

- Service level: the percentage that customers receive goods within limited period.
- Replenishment lead time: period of time that order for reproduction goods were placed, which including length from supplier delivering raw material to production ready for sale.
- Safety stock: Number of finished goods in units, buffering for unusual demand.

Figure 2.8: Appropriate stock level Elements



CHAPTER III

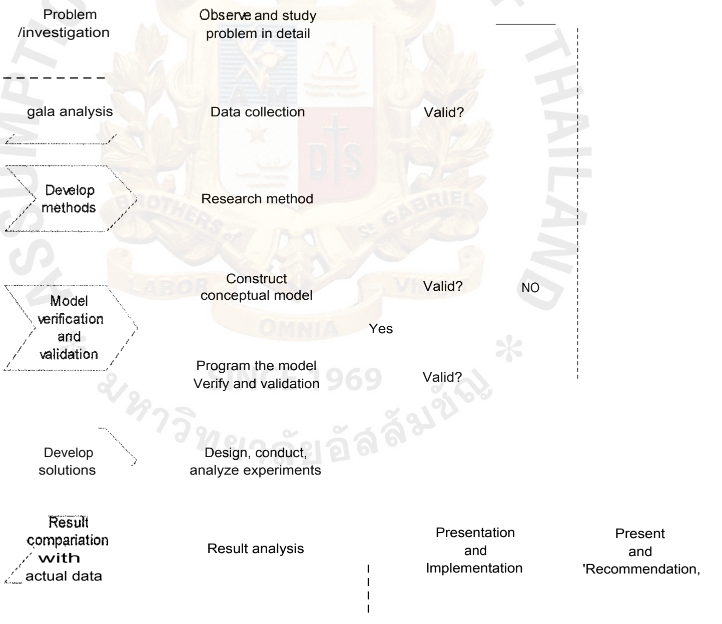
RESEARCH METHODOLOGY

In this chapter, the researcher will explain relevant concepts and methodologies for undertaking this research.

3.1 Research Design

Referred to William M.K. Trochim (2006) research design is used to structure the research in showing how all of the major parts of the research project - the samples or groups, measures, treatments or programs, and methods of assignment ,work together to try to address the central research questions.

Figure 3.1: Research Process of Study



3.2 Study the Problem

After observing and studying toughly production line. The problem state that inappropriate stock level indirectly charged company in term of opportunity cost and holding cost. According to cause and effect diagram in Chapter 1, the problems arise from following factors.

3.2.1 Production Batch Size and Order Quantity Discount

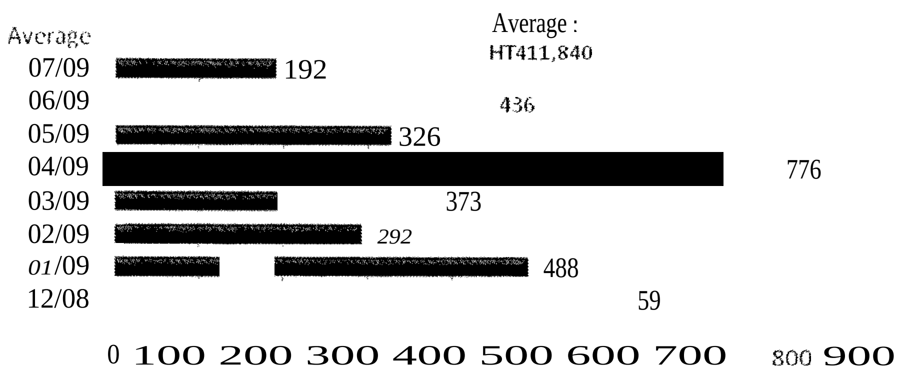
Production batch is schedule based on non-quantitative approach as production will be started whenever finished inventory reached the reorder point. Production batch size usually produces in large quantity because the order quantity discount is expected. The quantity order discount ranked from 1.5% to 4% Material allowed for discount is only lens while housing and other components are constant in price level.

Table 3.1: Order quantity discount in percentage

Quantity discount in Len part only	5,000 units	10,000 units	15,000 units
Item]	2%	3%	4%
Item2	0%	3%	4%
Item3	0%	3%	4%
Item4	2%	3%	4%
Item5	2%	3%	4%

Furthermore, study found that finished inventories value during December 08 to July 09 shows average value of BHT 411,840 exceed of safety stock In order word, large batch production size effect to large stock level.

Figure 3.2: Value in BHT of finished inventory excess safety stock during 12/08 to 07/09 in thousands



3.2.2 Reorder Point

Current reorder point is set to 500 units for all items, regardless of how much sale pattern for each item would be. Although, the longest lead time for in-house production takes less than a day, longest lead time in waiting for raw materials takes up to **10** days. According to managing director's experiences, reordering point of 500 units seldom made product shortage unless unordinary demand were taking place. The current reorder point also effect to number of finished inventory:

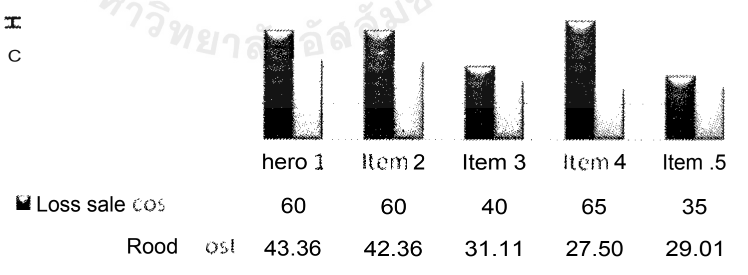
3.2.3 High Product Mix and Low in Volume

Since customers in study group are retailers, they expect getting all items contain in purchasing order to ensure high service level to their customers also. Selling of auto lamp replacement items historically recorded as high in product mix. Therefore, purchasing order usually occurred in high mix with low volumes.

3.2.4 Ensuring In High Service Level

Although the policy pay important on ensuring high service level to customer, company ignores considering on balancing between cost of maintain high service level and finish inventory cost. Showing in figure 3.4

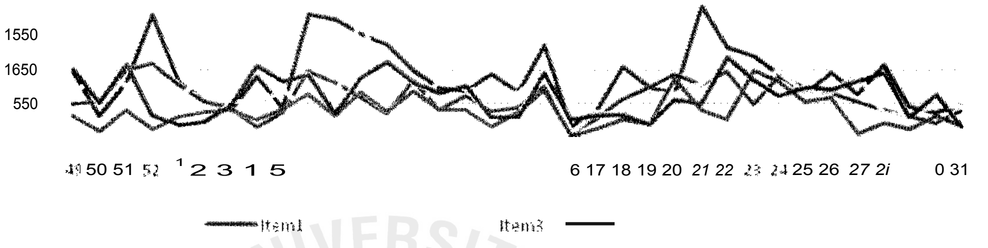
Figure 3.3: Value of loss sale and finished goods inventory per unit



3.2.5 Demand Pattern

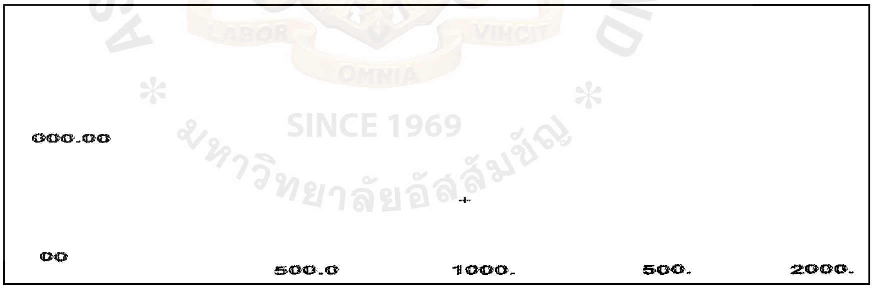
The difficulty in predicting demand pattern is unable to manipulate demand. Since the nature of the product are mainly depended on the accident rate of commercial vehicles which can't not be anticipated. Customers place the orders only when they also have order from their customers. Most of customers keep low stocks levels, therefore promotion are not much help to manipulate demand pattern, thus far. The nature of goods is inelastic to the price.if one's car tail lamp is not broken, will that people buy in advance for the spare one? Most and simply answer is NO!

Figure 3.4: Weekly demand pattern of item 1-5 during December 08 to July 09



Besides, the rapid rose in demand in some weeks because huge in quantity orders were taking place while sharply dropping down of demand from week 14 to week 16 also due to long holiday during April2008. Statically demand rate is scatter in form of continuous probability distribution since there is not replication in value.

Figure 3.5: Scatter chart of demand for item1 under continuous probability



3.3 Method of Research Used

Notwithstanding that many methods are popular for dealing with stock level; the advantages of simulation over other methods provide flexibility to inherit complexity of the problems given. Simulation facilitate in answering what if scenarios by observing the forward moving into the future while other research methods look backwards into history ,finding out what and how happened.

Since study's objective is discovering optimal point of keeping stock as well as optimize reordering point by developing scenarios via simulation. Under simulating the process, adjusting of input parameter such as production batch size is allowed company to offset the risk of production disruption, and money charged less than real adjusting production batch size. Therefore, as robust and flexibility of computer simulation approach, study applies computer simulation as the research tool in finding out the questions of when to place the order to re produce the goods, and how many quantities for each production batch sizes should optimizing be.

3.4 Gathering Data Procedures

Figure 3.6: Data collection process

3.4.1 Determine What Data Need

After analyzing the problem, developing performance indicator, selecting methodology and research instrument, determining what data needed is important step. Question on which data are needed as well as how significant of that data are stated below.

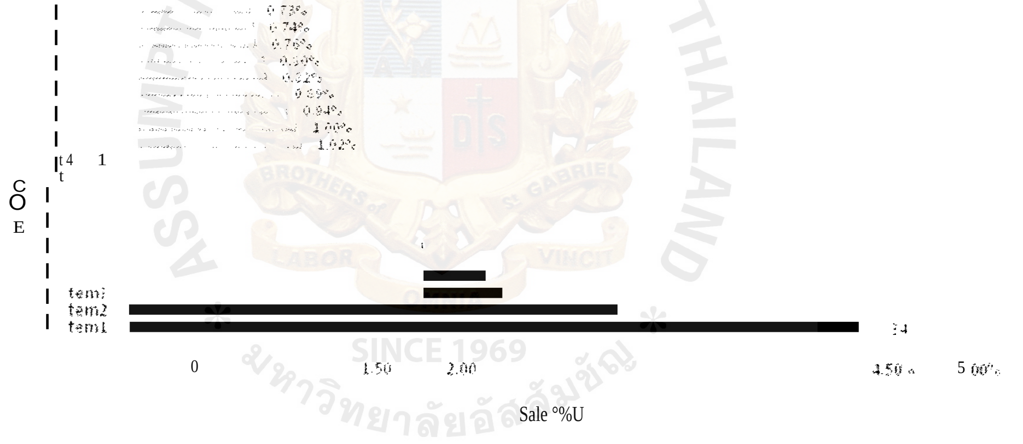
Table 3.2: Type and significance of data

Type of data	Unit	Significance of data
Customer demand	Units	Indicator for determining how many unit of finish goods inventory should be kept.
Production quantity	Units	Effect to number of finished inventory
Work station process time	Second	Required in simulation model as well as imply process cycle time
Number of operators	Man	Required in simulation model as well as imply utilization rate
Finish inventories	Units	Main indicator in project objective.

Finish good inventory cost	Units	Indicator for balancing point between inventory cost and cost of loss sale
Production defect rate	%	Effect to number of finished inventory
Loss sale cost	BHT	Indicator for balancing point between inventory cost and cost of loss sale
Safety stock level	Units	Cutting point when determine value of excess finish good inventory from demand. Value of finish inventory calculate starting beyond safety stock point

3.4.2 Determine Scope of Data

Figure 3.7: Value of sales in %ages for 20 items



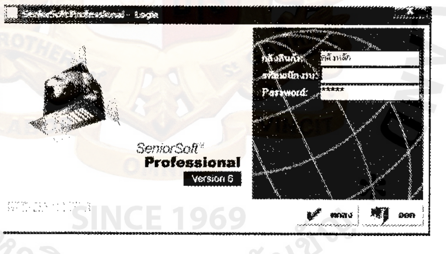
AMCMOTOR do market for both local and global, the production strategy on two markets is difference. For exporting, production is under making-to-order fashion while making to stock applied for domestic market. The study is emphasis on domestic customers group, since objectives are in regard of keeping stock level. Also, under short period of time constrain as well as having more than 200 types of lightning parts in categories which required periods of time in reviewing and getting the full data for analysis, study emphasis on top 5 highest in sales value. Five items were already representing up to 13.27% in sale value where data show only 0.45% in total number of units sale. Thereby, managing the units' sale only 0.45% from overall which represent the sale value up to 13.27% is reason why only five items are chosen.

Data collecting conduct for 8 months period. Work station process time, production defected rate were observed and recorded up to 50 sample size. Meanwhile demands for selected items were also collected in a daily basis over 8 month period.

3.4.3 Select Data Collection Tool

Data collection conduct via software package named "Senior Soft Professional 6" Company use this software for tracking stock level, issue the invoice as well as tracking raw material inventory. Demand rate, Finish inventory in units were also collected via software while process time for each work stations were recorded manually. Also, we use spread sheet software in classifying data before transferring into distribution.

Figure 3.9: In-house program called Senior Soft Professional



3.4.4 Data Collection

According to limitation of data collecting in Chapter 1, data collection conducts up to eight months period.

Table 3.4: Data collection period

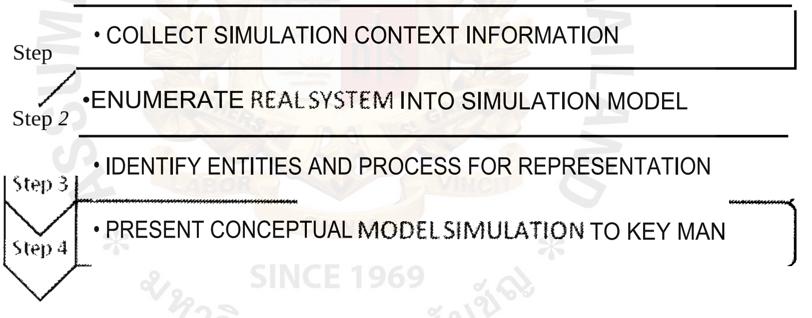
Data collection	Collection period
Customer demand	8 months
Production in unit	8 months

Work station process time	Observed for 16 hours for each items 50 sample sized are collected
Product defect in unit	Observed for 16 hours for each items
Number of operators	Fixed number
Finished inventories in unit	8 months

3.5 Construct Simulation Conceptual Model

Before completion of the simulation requirement, the conceptual model may even be developed. The important of conceptual model is to clarify and ensure that model satisfy all problem's requirement. The conceptual model develops according to four steps as following.

Figure 3.10: Steps in conducting conceptual model



Step1: Collect Simulation Context Information

Data needed are work processing cycle time, number of recourses, waiting time along the continuous process, and units sale or demand rate in units. Before complied in simulation conceptual model, these data need to be completely collected.

Step2: Enumerate Real System into Simulation Model

The challenge in contraction the simulation model is how to enumerate the complexity of real problem in to the model. This step required fully understanding the problem as well as enlighten on the logics which are also programmed in the model. There are four complicated logics in the study which are as following.

1. SEQUENCE IN PRODUCTION AND BATCH PRODUCTION SIZE.

In order to plan the sequences of production, model provides the input flexibility by synchronizing with spread sheet software. Also, quantity of each items are different as we can't not fix batch size quantity directly in to model, but assigning label to each input entities provide solution on this matter.

2. DIFFERENT IN PROCESS CYCLE TIME

Even though each work center consist same number of operator, process time for each item is different. Represent distribution was assigned to each entities' label. When entity reach work center, process time will be equal to value in label. Each label represent the process cycle time where distribution were assigned.

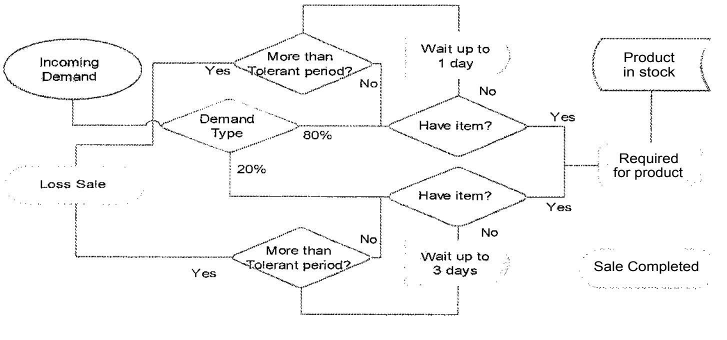
3. CHANGE OVER TOOK PLACE ONLY WHEN ITEM CHANGED

Change over only appear in process 1 and process 3, and also taking place only when items changed. Change over time was assigned in single distribution where value assigned directly to the program.

4. DEMAND HAVE TOLERANT PERIOD

In the case, record show eighty % of customers are not willing to wait product more than a day. They will cancel the order and shift demand to others. In simulation model, the logic to manage demand expire is shown in figure 3.11

Figure 3.11: Logic for demand structure



Transferring logic into model, starting from incoming demands was assigned by represent distribution, then decides whether required products are available or not. If having products in stock, demands will be completely fulfilled. While unfulfilled demand shift to waiting buffer where demands are divided into 80% group and 20% group. Then, label was assigned accordingly. Model has real time logic in scanning for condition on whenever required products are available, demand will be fulfilled. The demands in buffer are waiting up to tolerant period, then shifted to test whether that demand type is in 20% group or 80% group. The 20% group which can wait up to 3 working days will return to waiting buffer, while another 80% consider as loss sale to company.

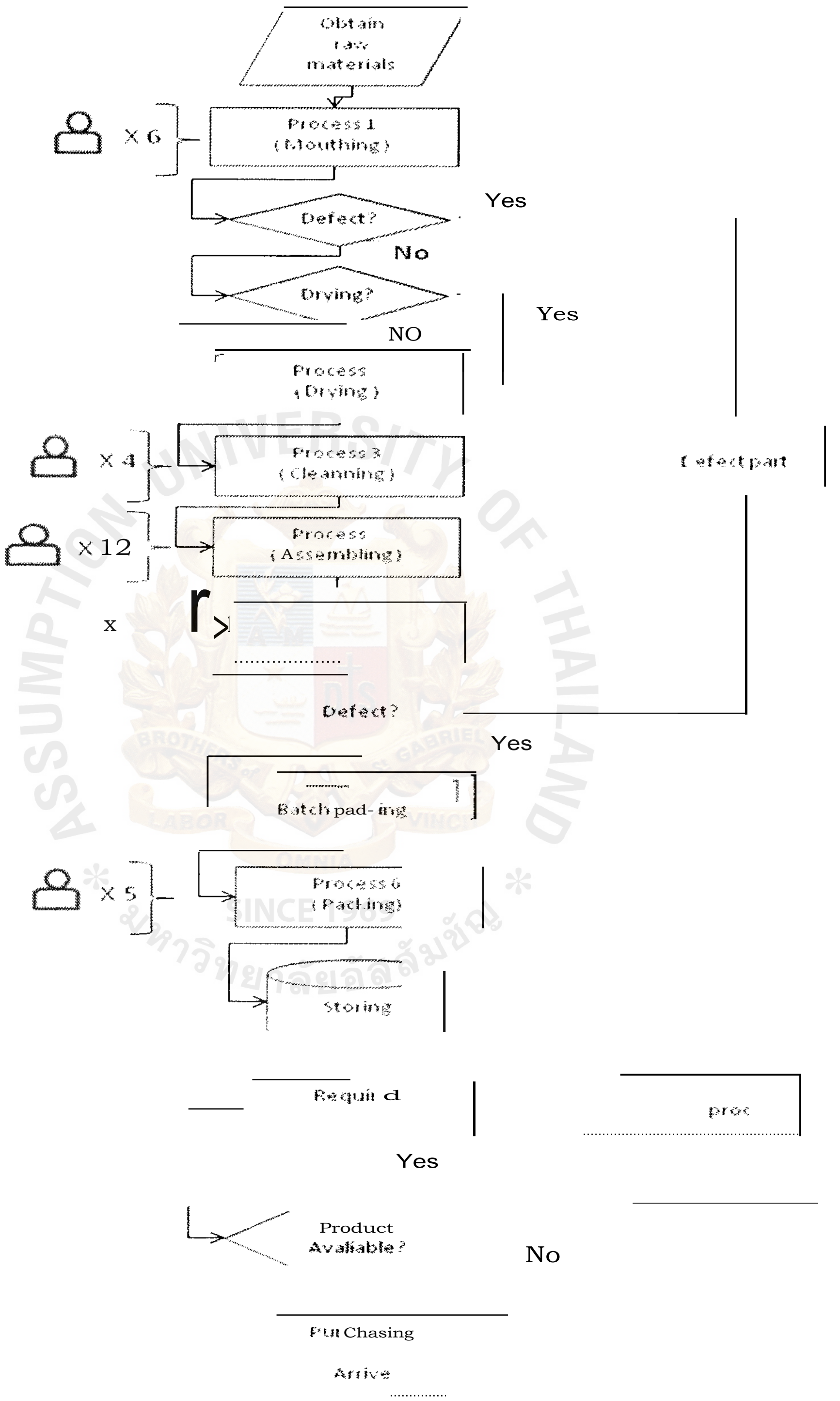
Step3: Identify Entities and Process for Representation

Starting from identify entities and process in the model, all collected data were represented into entities as well as enumerate work process into model logic. In production part, entities represent the production in units while in demand part is product required in units. Besides, actual work stations are represented as six work center in the model.

Step4: Present Simulation Conceptual Model to the Key Man

Model is presented and discussed to the managing director of the company. Since, all conditions in the study are enumerated to simulation model as well as given clear explanations of logic behind the model; the key man advocated that the model is accurate and connected to reality. The verification can answer to question "Did the model right?" On the other hand, validation can answer "Did model is the right model?" Only after key man is convinced that the model is consistently valid, then model will be tested before proceeding to next steps.

Figure 3.12: Sequence in production process with number of operators



Source: Original created by author

3.6 Simulation Model Verification and Validation

In the development of a simulation model, the important steps are checking the model to confirm working properly as well as providing a good representation to the real world situation. Therefore, model needed to be verify and valid before enumerating problem into simulation.

3.6.1 Verification

Verification conducts in ensuring that the model reflects to the modeling assumptions. In other words, it's known as debugging the model. There are various techniques in verify the model such as developing a simulation model, write and debug computer program in modules or subprograms, having more than one person review the model since composer may get into rut after a periods of time in developing model. Running variety of setting of input parameters, and check to see whether the outputs are reasonable are approaches to verify the model. Besides, animation technique was widely used to observe an animation of the simulation output as well as computing the sample mean and sample variance for each simulation input distribution in comparing them with the historical data.

However, verification is not complex when developing small scale in problem ms, before expanding to the larger one because result may never 100% sure on very large models. When apply verification to the study, not only verify the model by presenting model to key man and get approved that model are consistently connected to reality, the verification also be run in various sets of process time parameters as well as reviewing the model in details by simulation expertise.

3.6.2 Validation

Since, simulation approach is a broad collection of methods and applications to mimic the behaviors of real system where input parameters such as work center process time, demand rate in units, as well as changeover time should be also represented in random value. Therefore, input data into simulation should be represented all value of sample group. To do this, historical data need to be transferred into single probability distribution before preceding the validation step.

The main objective in model validation is establishing output data reflected to the actual system where assumptions of the model should also be checked to see that appropriate probability distributions are being used. An analysis of input and output should be made to see that the results are reasonable. We do compare the output data to those from the existing system itself, if the two sets of data compare closely in output value, the model of the existing system is considered "valid". If error rate or different value of simulation's throughput and existing value occurred in acceptable range, the model is also valid in represent to reality. In the case, in validating the model, there are three criteria set in comparing between existing value and value derived from model. Percentages error show tolerant range that study accepts is up to five percent because model was tested on units' sale. Historical data shows highly fluctuated in demand as well as work process time which is based on human.

3.6.3 Data Validation

The important of data validation checking that the data is sensible before processed in future steps. Data of product sales in unit, work centers processing time, and change over time are needed to be validation. After obtaining the single distribution that represent collected data, validation process is comparing the percentage error between actual output rate and distribution that represent the data. We use Stat::fit in order to fit the data to single appropriate distribution. Mentioned that Stat::fit program is software package using in transforming raw data into single probability distribution that represent collected data. For example, the work center process time can be automatically fitted into a single distribution. When model is running the distribution will force it to behave as if it were using the real collected information.

3.63.1 Work center Process Time

Work process time in each process was recorded from 50 sample units where data were transferred into probability distribution. The result show Binomial distribution is 100% fitted to existing process value because P-value shows greater than level of significant (0.05)

Table 3.5: Represented distribution for item1 to 5

Item I	Represent Probability Distribution
Process I	Binomial(26,0.94)
Process 2	Fix(1800)
Process 3	Binomial(13,0.875)
Process 4	Binomial(95,0.964)
Process 5	Binomial(25,0.845)
Process 6	Binomial(105,0.954)

Step In Testing Distribution of Item 1 In Process 1

STEP 1: INPUT THE DATA IN STAT::FIT.

After click on "Auto fit"

Auto::Fit of Distributions

distribution	rank	acceptance
Binomial(26., 0.94)	100	do not reject
screte niform(22., 26.)	14.9	do not reject
Poisson(24.4)	5.03e-003	reject
Geometric(3.93e-002)	7.2e-010	reject

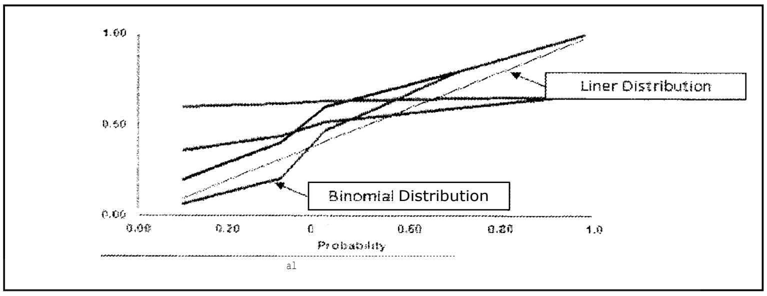
STEP 2: SELECT REPRESENT DISTRIBUTION

Binomial (26, 0.94) was selected, since binomial distribution is the best fit of distribution. Click on Fit 4 select Goodness of fit

Binomial	26. 0.94	
Chi Squared		
total classes		5
interval type		equal probable
net bins		4
chi**2		10.3
degrees of freedom		3
alpha		5.e-002
chi**2(3,5.e-002)		7.81
p-value		1.63e-002
result		REJECT
Kolmogorov-Smirnov		
data points		50
ks stat		0.117
alpha		5.e-1102
ks stat(50,5.e-002)		0.188
p-value		0.463
result		DO NOT REJECT

Represented value of 26, 0.94 is selected as input distribution to simulation. Since, the data of item 1 has 50 sample sizes, using P-value of Kolmogorov-Smirnov (0.463) is failed to reject.

Figure 3.13: Binomial distribution is selected which is best of fitting data



Source: Original created by author via Stat::fit v2.

The good represented data is data that aggregated close to the linear line. Therefore, Binomial is the best fit of distribution.

Example of data validating is test on item 1.

3.6.2 Throughput

We found that total production output after a single working day or 27,000 seconds equal to 950 units while average existing production rate is 960 units. Also, queue for assembling process shows 535units in existing rate while 521units in represent distribution. The gap between actual and simulation represent only 1.041%, and 2.618% respectively. Then, similar validate approach is also applied to remain item2 to item 5.

3.6.3 Changeover Time

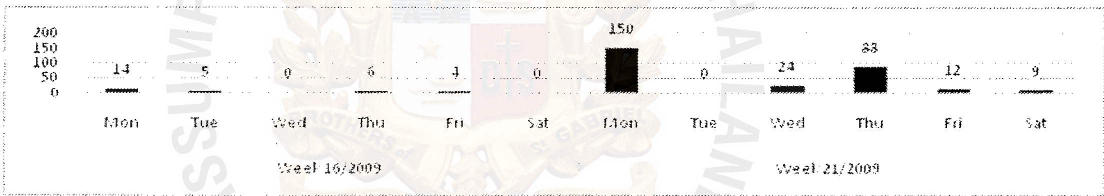
On average change over time from assembling among items are not significant different, since we have single flexible production line. When changing production in line, only raw materials are changed while machine and labors are still the same. Validation conducted via simulation by developing model in testing of requirement of single unit changeover time. Actual change over time is on average of 30 sample size, comparing with represent statistical distribution. Result found that only 3.17% different between represented distribution and actual time.

Table 3.6: Represent probability distribution and validation percentage error for change over time

Change over time	Distribution	Rank Fit	
Change over 1 (Mouthing)	Triangular(10.54,20.36,22.78)	94.0%	
	Triangular(12.55,34.20,36.05)		
Validation	Change over I	Change over 2	Total
%			

3.6.4 Number Of Sale In Units

Figure 3.14: Sale units on week 16 and 21 in 2009



Although sales are recorded in daily basis, the highly in demand 'fluctuated. From figure 3.17, Daily unit sale pattern are totally different. In order to make smoother in data to be valid, units' sale classify in average unit which is based on weekly demand. The average sale units equal to 137 units per day. The 35 set of sample sizes are transform into single distribution ,Gamma(3.7377,34.9312) Validation result show only 3.66% different between represent distribution and average actual demand rate.

Table 3.7: Represent probability distribution and validation percentage error for demand rate

	Units per day	Total sale in 35 week
Average actual	136.54	4779
Represent distribution	Gamma(3.7377,34.9312)	4604
Error °A)	3.66%	

3.7 Program the Simulation Model

After conceptual model are verify, problem was transformed in to simulation model. The model was classified into two parts. First part is demand from customers, and second is production line. Convergent point between production line and customer demand is appropriate level of keeping stock which study emphasis on. An optimal point of keeping stock derives from many developing scenarios. Variables such as number of batch size, the sequence of production batch in each scenario are manipulated. Model architecture is developing by simulation software called ARENA

3.7.1 Demand Section

Beginnings from demand inter-arrival based on represent distribution. When demand entities enter model, label was assigned on how many demand requests for each items. The decision on whether demand will be fulfilled is based upon the available of product in stock. If product is not available or less than demand required, demand entity still wait in buffer until all requested in units are available. However, demand entities have limited time tolerant which 80% of demand will cancel the order while another 20% are willing to wait up to 3 working days. Unfulfilled demand entity considered as loss sale and be recorded before exit the system. Otherwise, if stock level excess or equal to demand request, that stock item will be fulfill demand request before exit that model.

Figure 3.15: Model structure in demand section

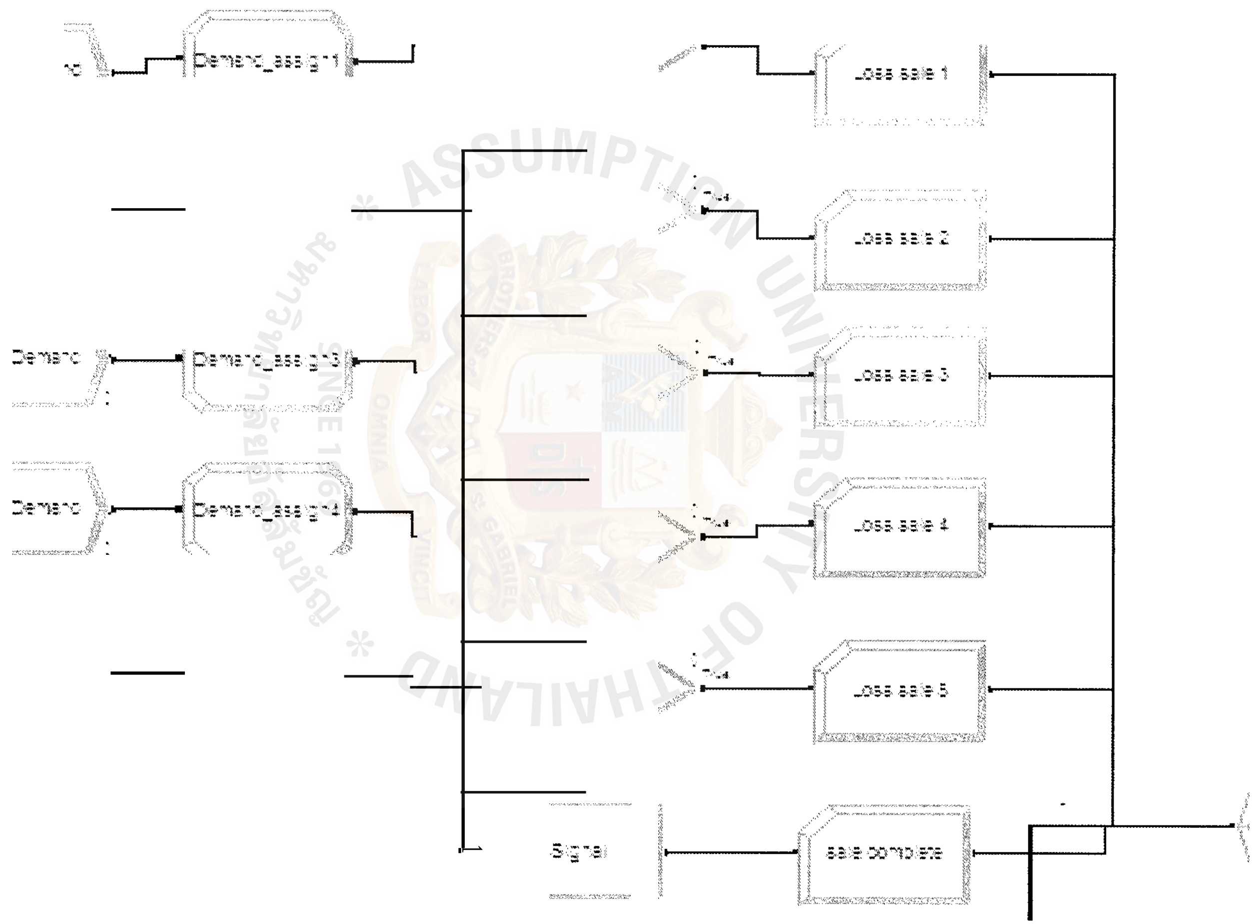
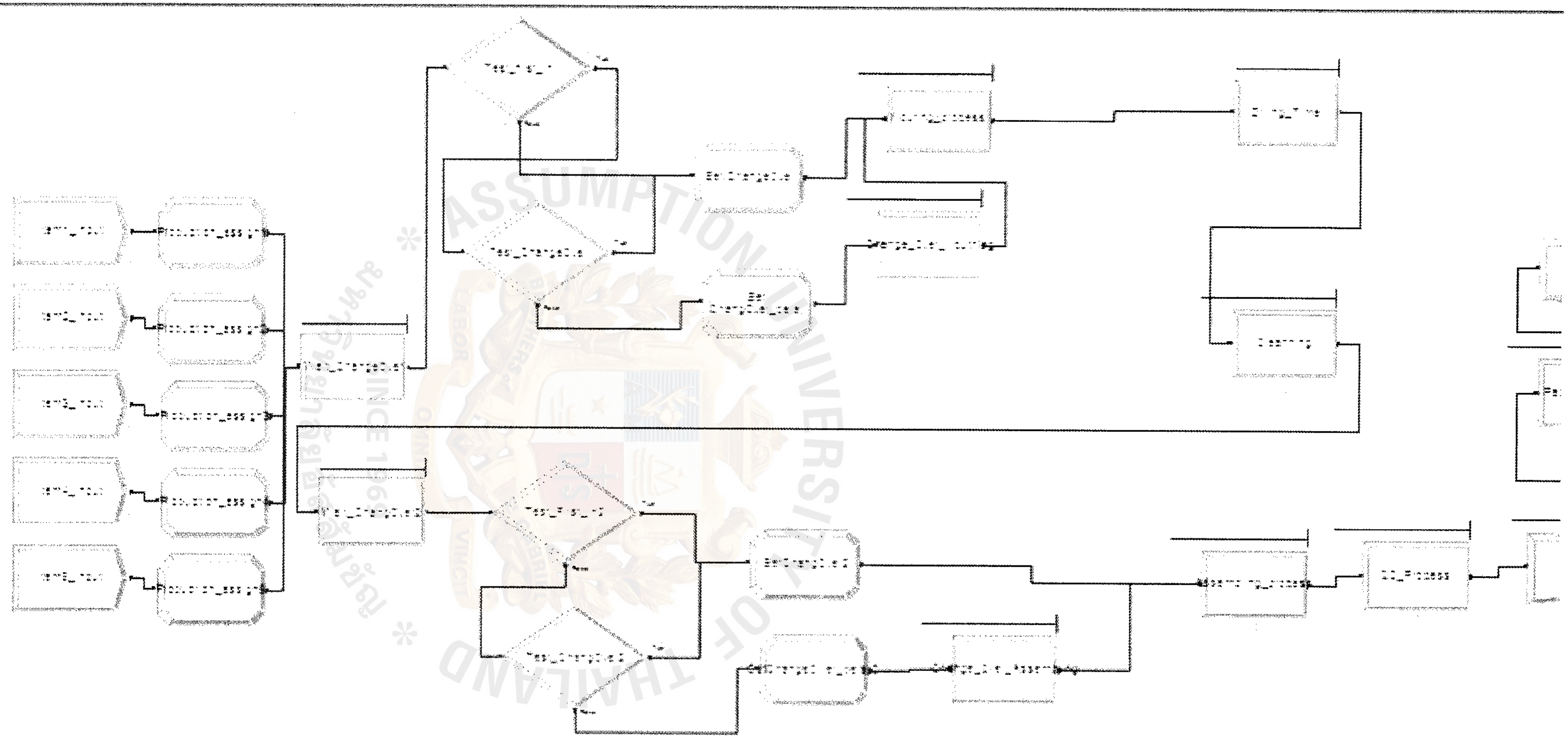


Figure 3.16: Model structure in supply section



3.7.2 Supply Section

Company has single production line with batch production policy. The production process flow consisted of six main work centers, classified as mounting housing with lens, waiting for silicone absorbed into housing, cleaning and checking, assembling socket set, quality checking for light, and final quality checking before sending to packing station. The production process has two changeover points which are on mounting and assembling process. Also, in packing process requires different number of boxes per carton. Thereafter, products are sent to warehouse, waiting for demand request, and ship to customers.

After enumerating problem into model architecture, the logic of model set the input of production batch size and sequent in production for 5 items from spreadsheet into model. Assigning single represent distribution process time for each work process to attribute is recorded in the label. Work process time in each work station also get from its label. Although number of resource required for each work station are similar, change over time are require only in process 1 and 3 which time are also represent in single distribution.

Before entity reach first station that is mounting the housing with lens, entity will pass logic of change overtime. If different attribute of entities were detected, change over time will occur. Then, go to drying process, cleaning process, before entering assembling process where change over time takes place. After entities were loading to packing process, items are qualitatively batched by their attribute type. Then, items shipped to warehouse waiting for demand request from demand section.

3.8 Design and Analyze Experiments

We develop the plan for using in comparing "As-is" simulation result to the alternatives which are "To-be" model. According to the reviewing literature, we develop three alternatives in developing "To-be" model which are optimal production batch size, re-ordering point under heuristic approach, powered by simulation program.

3.8.1 Optimal Production Batch Size

The batch method can be an advantage in produce a range of products. Batch production will be cheaper to produce a number of each item in one go because machines can be used more effectively, the materials can also be bought in bulk and the workers can become specialist in that task.

Initially, we calculate for average current production batch size, and then scenarios are developed in comparing with demand for each item. If demand in unit excesses the unit stock, production batch size will be increase or even remain in small batch size, but more often in production per month.

Table 3.8: Example of alternatives in production batch size

Production batch size	Average current batch size in units	Scenario I	Scenario II	Scenario III	Scenario IV
Item 1	12,243	-10%	-8%	-3.33%	-9%
Item 2	4,808	-12.5%	-8.5%	-10%	-5%
Item 3	14,181	-10%	-5%	-2%	0
Item 4	5,173	-3%	-5%	0	-10%
Item 5	8,739	-12.5%	-5%	-2%	0

Thereafter, scenarios will be coded as manipulating input batch size. Logic to accept the number is maintaining positive parameter, and continuing changes other parameters. Therefore, optimal production batch size is expected to obtain after testing various set of scenarios.

3.8.2 REORDERING POINT

In order to determine the point of time in placing order to reproduce the goods before facing product shortage which lead to loss in sale, the effective reordering point must be determined. Elements in calculate ROP are as the example of item on 1. Calculating the ROP by formula is as following.

Effective lead time (ELT) = LTs LTp + ½ R
Lead time demand (LTD) = ELT x D
Reorder point (ROP) = SS LTD
Order-up-to level = ROP Q

Where

Forecast demand per period (D) – how much we expect to use/sell
Supplier lead time (LTs) – time expressed in periods between submitting an order and receiving delivery
Planned order size (Q) – normal quantity of product we plan to order each time
Safety stock (55) – target stock on hand just before we receive an order
Review time (R) – time interval expressed in periods between reviews of stock levels to determine whether to place an order
Process lead time (LTp) – time expressed in periods from receipt of goods to their being available to the customer

Since existing safety stock locked up to 500 units, which ROP never be quantitatively verified, the reordering point start whenever stock level nearly reach to safety stock level. Thereby, study develops an appropriate ROP based on existing safety stock.

We found that longest lead time of item1 equal 5 days, average process lead time plus review time never more than a day. While average daily demand is 136 units per day. The ROP comes up to 1,316 [500+(136 x 6) = 1,316] Therefore, whenever stock level of item1 reach to 1,316 units, production of item1 must be start in order to prevent shortage of product, and could probably lead to loss sale.

Table 3.9: Material lead time for item 1

Material /Lead time	Day1	Day2	Day3	Day4	Day5
Housing	X	X			
Lens	X	X			
Socket set	X	X	X	X	X
Box/Carton	X	X	X	X	X

After getting the ROP in unit, applying the number will be programmed in simulation model. Whenever stock level reaches the ROP, then order raw material from supplier will be placed. However, ROP is not mention in how many items per order would be, but order quantity will determine by appropriate batch size from simulation result in batch size level.

CHAPTER IV

PRESENTATION AND CRITICAL DISCUSSION OF RESULTS

According to research objective as synchronizing the demand and stock level by discovering the appropriated production batch size, simulation technique is applied in finding the solution for purposed objective. In order to make the simulation's result closer to reality, data and model validation need to be firstly conducted.

Chapter IV consisted of four main points which explained as following;

4.1&4.2 starts with explain the methods for simulation validation. Elements need to be validated are production lead time, and incoming demand quantities because those parameters have direct influential in deriving appropriated production batch size. Besides, measurements in 4.2 are defining performance indicators, used as measurement the result.

In 4.3, study develops appropriated production sequences from item1 to item5 before testing on which level of appropriated batch production size should be. Developing effective reordering point under unstable demand pattern is also conducted in order to suggest when company should start reproducing the goods.

In 4.4, the cost elements which are holding cost ,loss sale value, profit, and shortage in units are used as performance indicators in comparing "To-be model" with "As-is model"

Table 4.1: Overall outline in chapter IV

4.1 Data and model validation
4.2 Performance indicators
4.3 Experiment of Each Cases

Case	Explanation	Production batch size	Safety stock level
[redacted]	Produce 5 items in sequence from item I to 5.	Batch size at 1,000 units and increasing by lot size by 1,000 units	[redacted]
II	Revised production order by item 4, item1, item 3, item 2, and item 5 respectively.	Batch size at 1,000 units and increasing by lot size by 1,000 units	Fixed at 500 units
III	Production sequence is rank from item 4,3,2, to 5 respectively	Item1 : 7,000 units Item2 : 3,000 units Item3 : 6,000 units Item4 : 5,000 units Item5 : 4,000 units	2,500 units 1,000 units 2,500 units 500 units 2,000 units

4.3.2 Reordering point: Test daily demand for each item to find the reordering point that product quantity can cover demand during production period.

Case	Explanation	Production batch size	Safety stock level
[redacted]			

4.4 Result Evaluation and Analysis

Case	Explanation	Performance indicators
	Measure the improvement after purposed batch production size	4. Cost of stock at end of month 5. Service level 6. Loss sale value 7. Production shortage in unit(s)

4.1 Model Validation

4.1.1 Demand validation

In the study, demand can be classified into two groups which are first, demand that can be wait up to three days from purchasing order was issued. Second demand that need promptly fulfilled unless company could copied loss sale.

Demand pattern of each item is transformed into single distribution and compared to the actual demand in order to test whether represent distributions are validated.

Large number in replications shows low in error between actual and simulated value. The result is conducted by using the average value of simulated output in various numbers of replications compare to actual value. Step increasing in replications is shown in figure 4.1.

Figure 4.1: Determined number of replication where criteria is error between actual data and item 1 simulated value of **item1**

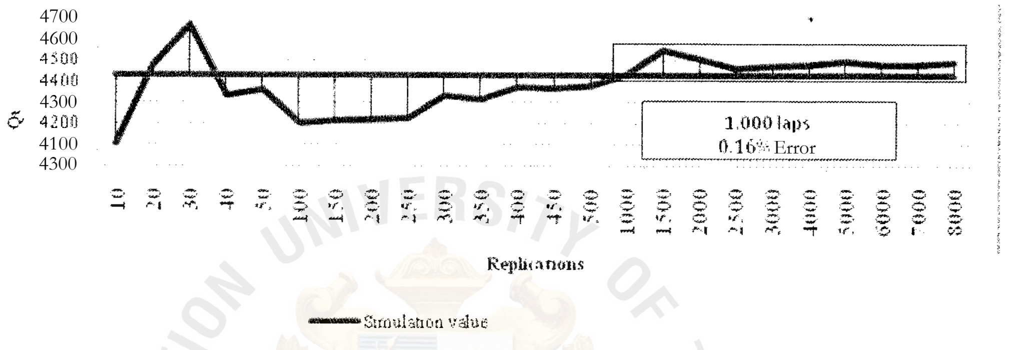
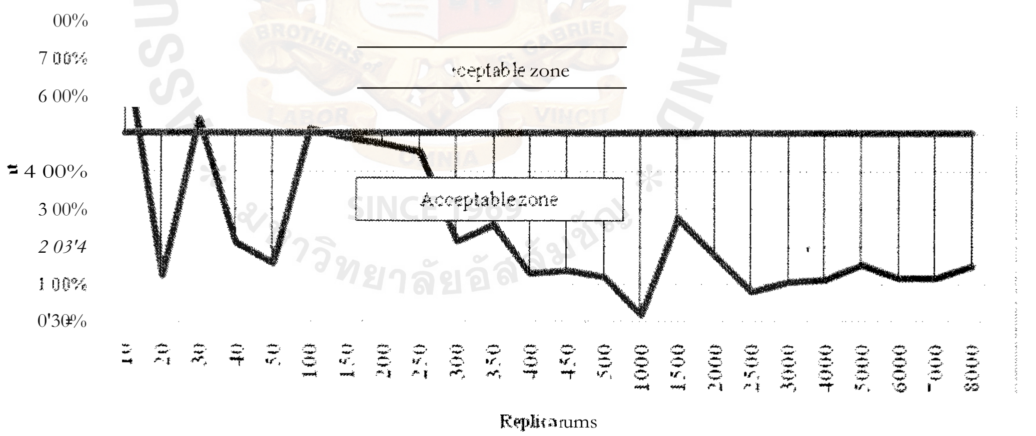


Figure 4.2: Accept percentage error between actual data and simulation of **item1**



As purposed in Chapter I, study allowed up to 5 % in error between actual data and simulated data. In order word, acceptable zone is range from zero to 5 % while more than 5 % is unacceptable. Simulated data starts stabilizing after 1,000 replications. Since error at 1,000 replications show only 0.16 %, therefore the result through the research will be obtained from average value of 1,000 replications.

Table 4.2: Represented distribution of each demand for item 1-5

Demand Represented Distribution	**Item 1** Negative Binomial (3,0.017)	**Item 2** Negative Binomial (7,0.078)	**Item 3** Negative Binomial (7,0.041)	**Item 4** Negative Binomial (2,0.021)	**Item 5** Negative Binomial (8,0.065)
Sale Actual	4,426	2,046	4,195	2,388	2,978
Simulation	4,433	2,048	4,216	2,502	2,929
% Error	**0.16%**	**0.10%**	**0.50%**	**4.77%**	**1.65%**

After input represented distribution into simulation program, result shows that the maximum error still less than 5 % while minimum error is only 0.10 %. Not only average percentage error between simulation model and actual value is less than 1.43 %, but model can also be convinced that represented distribution are more than 95 % reflected to reality.

4.1.2 Production lead time validation

The production lead time derived from two elements. First, lead time from suppliers or starting from placing order to receiving material from suppliers. Second, the production lead time that required for in house production where different items required different production lead time. Also, difference in batch production size shows difference in production time required. While, the lead times from suppliers are different among items where the large quantities size longer lead time than small quantities size. Company has single supplier who supply each type raw material parts where longest lead time is box and carton.

Table 4.3: Lead time in day from suppliers with tolerance up to 10,000 units

Lead time	Housing	Lens	Socket set	Box/Carton	Maximum Lead time
Item 1	2	2	5	5	5
Item 2	2	2	5	5	5
Item 3	5	2	5	6	6
Item 4	2	3	2	3	3
Item 5	5	4	5	3	5

In the study, production lead time among work centers needed to be transferred into single represented distribution and tested for validation before input into the simulation program.

Table 4.4: Represented distribution of each process cycle among item.

Item	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6
Item I	Lognormal (24.94,0.00448)	Fix (1800)	Poisson (11.9)	Poisson (93)	Poisson (22)	Binomial (105,0.95)
Item2	Lognormal (34.12,0.75343)	Fix (1800)	Poisson (24.2)	Poisson (83.6)	Poisson (30.3)	Binomial (128,0.66)
Item3	Lognormal (0.994,12.4)	Fix (1800)	Binomial (11,0.83)	Poisson (40.1)	Poisson (22.6)	Poisson (26.6)
Item4	Lognormal (20,0.8445)	Fix (1800)	Binomial (17,0.69)	Poisson (25.9)	Binomial (77,0.236)	Binomial (71,0.734)
Item5	Lognormal (30.02,0.68)	Fix (1800)	Poisson (32.2)	Poisson (110)	Poisson (29.9)	Binomial (123,0.30)

Source: Original created by author via Stat::fit V.2

Table 4.5: Actual data versus represented distribution in seconds

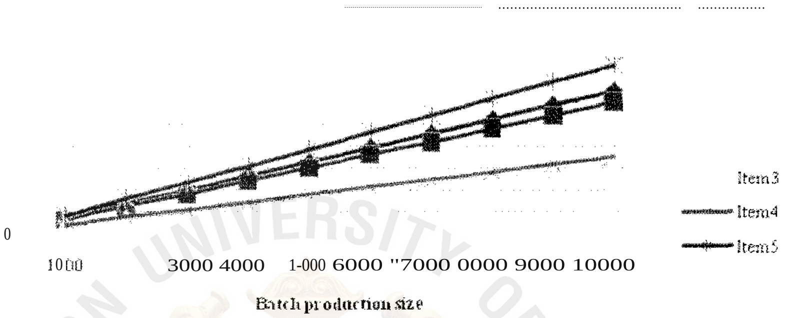
		Actual data (time unit in se				
Process time	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6
Item 1	24.94	1800.00	11.88	92.96	22.02	100.28
Item 2	34.12	1800.00	24.16	83.60	30.26	85.02
Item 3	12.40	1800.00	9.16	40.14	22.60	26.56
Item 4	19.94	1800.00	11.85	25.86	18.14	52.08
Item 5	30.02	1800.00	32.32	109.76	29.86	37.42
		Represented distribute (time unit in seconds)				
Item	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6
Item 1	25.14	1800.00	12.21	94.38	22.58	100.26
Item 2	34.38	1800.00	24.69	84.85	30.47	85.28
Item 3	12.42	1800.00	9.25	40.14	22.61	26.38
Item 4	20.15	1800.00	11.81	26.07	18.58	51.81
Item 5	30.27	1800.00	32.42	111.70	30.21	36.97

Table 4.6: percentage difference between actual data versus represented distribution

Item	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6	Average data error
Item 1	0.80%	0.00%	2.78%	1.53%	2.54%	0.02%	1.53%
Item 2	0.76%	0.00%	2.19%	1.50%	0.69%	0.31%	1.09%
Item 3	0.16%	0.00%	1.03%	0.00%	0.04%	0.68%	0.38%
Item 4	1.05%	0.00%	0.30%	0.81%	2.43%	0.52%	1.02%
Item 5	0.83%	0.00%	0.31%	1.77%	1.17%	1.20%	1.06%

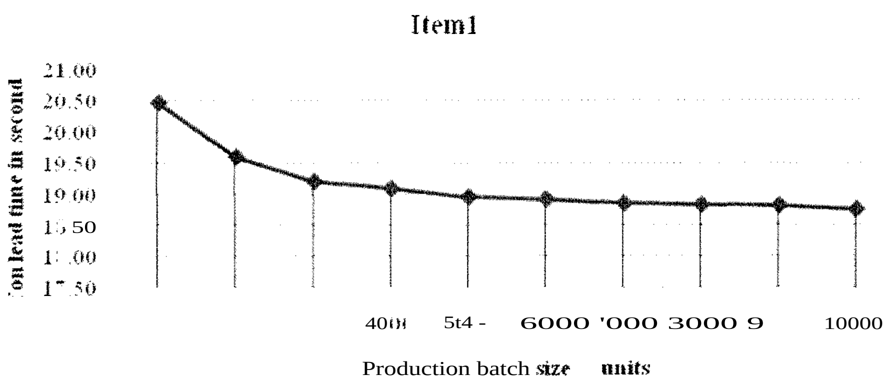
Table 4.6 shows that maximum difference between actual data and simulated data shows only 1.53% with minimum of 0.38%.The average error is 1.02%. Hence, simulation model can be assured to be validated. After getting those distributions, we do input distribution into the simulation model. The results in required production time of each batch production size are shown in figure 4.3.

Figure 4.3: Production required period among batch production size of item 1-5



Production lead time tend to be raised when increased in batch production size, while production lead time per unit is dramatically decreased because less time in process changeover period. Thereby, a larger batch production size, a faster in production lead time per unit can be expected. Figure 4.4 shows that when producing batch of 10,000 units ,the production lead time per unit takes around 19 second while batch size of 1,000 production lead time per unit takes nearly up to 21 second.

Figure 4.4: Production lead time per unit of **item1** under level of batch production size



After getting all validated input parameter, the simulation result is tested against actual value. By duplicating production input value from actual production rate to simulation model, result shows less than 1 % in different between actual production and simulation. To sum up, there are no significant different between simulations and actual as shown in table 4.7

Table 4.7: Actual production output versus simulation output unit in day

Item	Actual output	Day in used	Simulation output	Day in used
Item 1	12,243	9	12,240	
Item2	4,808	3	4,800	3
Item3	14,181	5	14,180	5
Item4	5,173	2	5,170	2
Item5	8,739	7	8,740	7

4.2 Measurement Structure

Cost elements can be classified into selling price, production cost which are including raw material cost, production cost, and storing cost as well as profit and loss margin.

Table 4.8: Sale price, product cost, and profit/loss sale value per unit of item1-5

Item On	Sale price	Production cost	Profit/loss sale value
Item 1	60	43.36	16.64
Item 2	60	42.36	17.64
Item 3	40	31.10	8.89
Item 4	65	27.5	37.5
Item 5	35	29.01	5.99

4.2.1 Cost of stock at end of month: Measure the value of product at end of month. The value of products is calculated by quantities of each item multiply by product cost.

4.2.2 Percent service level: If demand is fully 100 percent served, it considered as 100 % service level. In contrast, unfulfilled demand means service level is not 100 % served. Service level measure in term of quantities that demand can be served divided by total demand quantities.

4.23 Loss sale value: Measure by number of loss sale quantities multiply loss sale value (opportunities loss)

4.2.4 Product shortage in unit: Measure the product shortage which are taking place only when demand is greater than available product in stock.

4.3 Experiment of Cases

4.3.1 Production batch size

Study develop two cases in testing the appropriate production sequences and batch production size where the safety stock is, according to policy, unchanged at level of 500 units which is applied to all cases in study.

Case I: Production batch start at 1,000 unit with increased by lot size of 1,000 units with fixed safety stock at 500 units.

Initially, simulating the production batch size at 1,000 units total profit / loss, product shortage in unit and service level are recorded as indicators. Output data shows as figure 4.5-4.7.In figure 4.5, line chart mention total profit or total loss in varies batch production size.

Figure 4.5: Profit/loss of item 1-5 varies from production batch size of 1,000 to 10,000 units

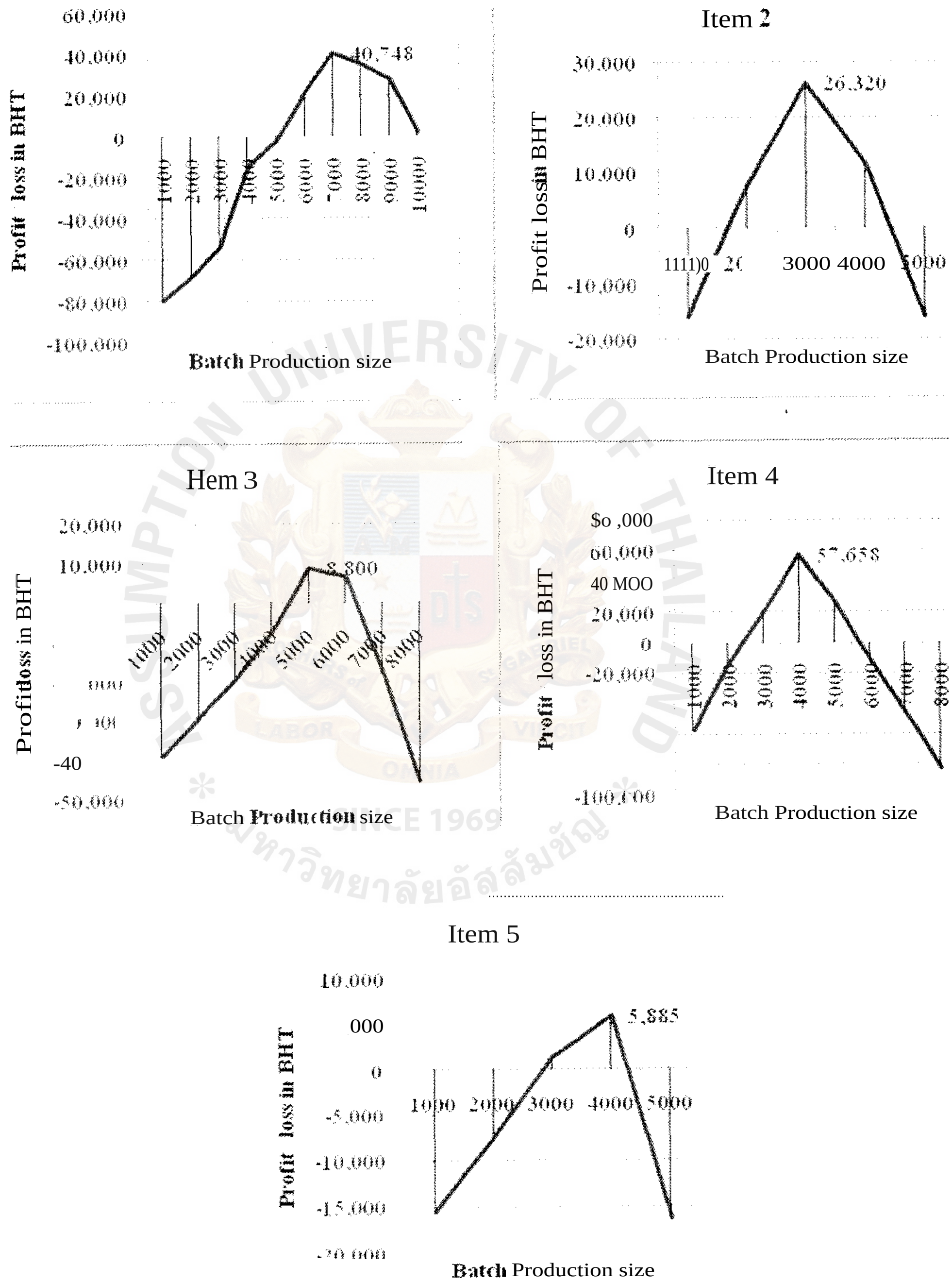
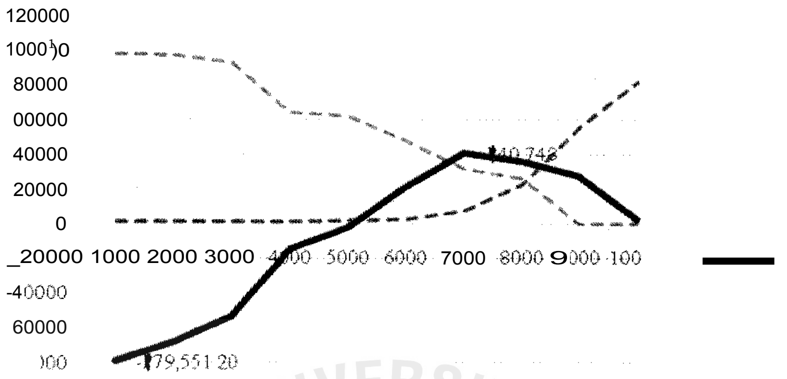


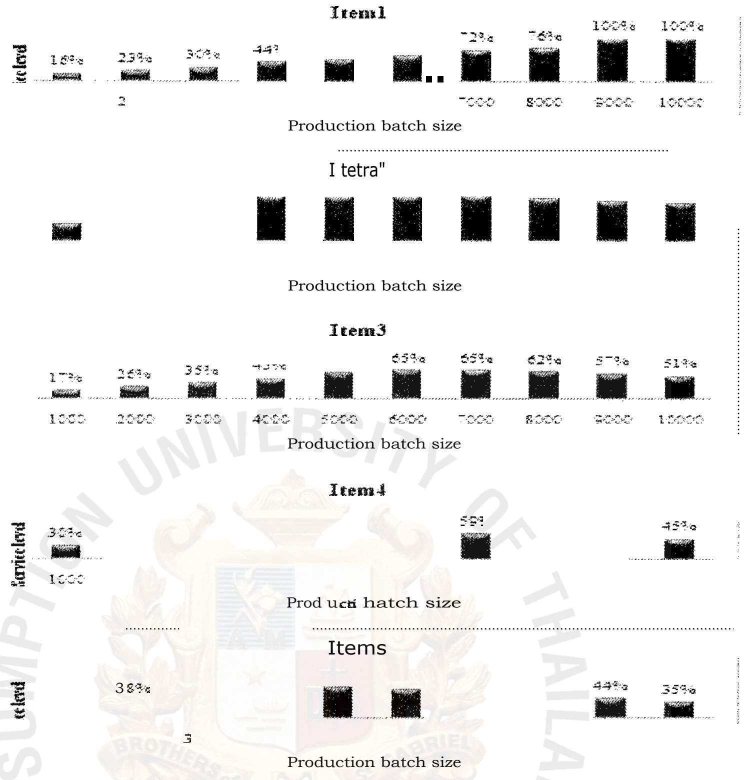
Figure 4.6: Profit/Loss of item 1 showing profit, holding cost, loss sale, and total profit/loss line where highest profit at BHT40,748 at batch production size of 7,000



The profit/loss is conducted from sale's profit deducted by total cost of ending product with loss sale cost. Batch production size less than 1,000 units are reflecting profit level in negative value. The monthly demand always greater than 1,000 units affect to ending products which are approached closed to zero in quantities. Therefore, the total profit appeared in negative value.

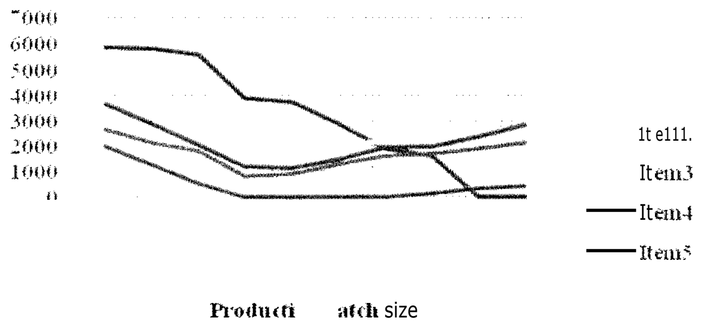
When batch production size reached up to particular level where production size plus safety stock nearly close to demand quantities, the profit can be expected at the optimal point before profit start dropped to negative value, because holding cost is greater than gained profit from sales.

Figure 4.7: Service level of item1-5 amount production batches level.



Even though, large production batch size can serve demand in high service level, holding cost for ending inventories have positive correlation toward service level.

Figure 4.8: Demand rate, total reject demand, completed sale volume, production defect, and ending inventories of item 2.

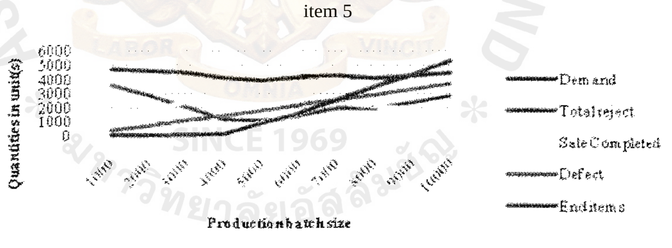


Logically, producing in larger batch size than demand can possibly serve all demand where high service level can also be expected as shown in figure 4.8

Figure 4.8 shows that sale volume tangle to demand quantities at batch production size of 3,000 where total demand reject dropped to zero. While ending items start raised up which affect to increase in holding cost. Actually, the optimal batch production size for item 2 can be concluded at level of 3,000 units where total profit reach highest yield at BHT 26,320.Then, total profit are dramatically dropped until started loss at batch production size of 5,000 units.

However, this logic is not always correct since the production lead time need to be also considered. Figure 4.9 is good example of decreasing of service level under large production batch size. In other word, large production batch size, product shortages can be occurred.

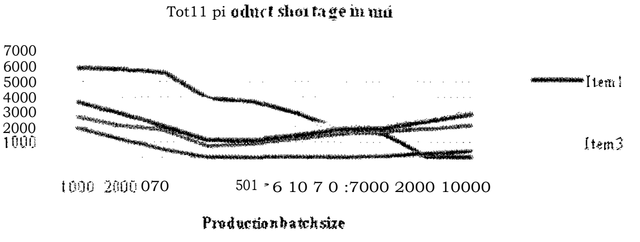
Figure 4.9: Demand rate, total reject demand, completed sale volume, production defect, and ending inventories of item 5.



Although production batch size is greater than demand quantities, the demand reject still taking place. The reason is item 5 was set in the last sequence in production schedule. Also, demand pattern is in dairy basis and early demand cannot be fulfilled because production is not yet finished on that particular day. Finally it leads to loss in sale opportunity and eventually incurred loss opportunity cost to the firm. Therefore, the production sequence is important because production lead time play vital role in determining which item should be placed in first priority in production sequence.

Figure 4.10 shows production shortages in unit appeared in large quantities in late production sequence. Item 1show nearly zero shortage in unit, while item 5 appear in most product shortage in units.

Figure 4.10: Total product shortage in units among production batches level.



To sum up, service level approaches closely to 100 % when batch production appears in larger size than total monthly demand where production sequence in that particular item is placed in first production sequence. Large batch production size requires longer production lead time than small batch production size. Therefore, loss sale of items in late production sequence may take place during production lead time of large batch production size of items in prior sequence.

Although, service level is important indicator as it reflect to the profit, appropriated batch production size ,and to total cost as well. Thereby, study also measure the total profit/loss among items in varies batch production size.

Table: 4.9: Total profit/loss value in BHT of separated item 1— 5.

(Total profit/loss = Sale profit – Ending product cost -Sale opportunity loss)

	Total Profit / loss				
Batch	Item1	Item2	Item3	Item4	Item5
1000	-79.551	-16,004	-39,024	-57.048	-15.552
2000	-68M90	7,824	-29,287	-13,433	-7,564
3000	-53,624	**26,320**	-19.741	20,788	1,271
4000	-14,549	**11,654**	-7.122	**57,658**	**5,885**
5000	-2.596	-15.944	**8,800**	26,975	-16.284
6000	21,308	-41.551	6,363	-11,713	-39,176
7000	**40,748**	-67.863	-17,976	-46.620	-71,614
8000	35,569	-96.466	-45,593	-82,863	-99,174
9000	27,816	-128.530	-80.480	-117.480	-127.906
10000	2,343	-161.502	-115,782	-154.915	-160.805

Table 4.9 shows that batch production sizes that yield highest in return among item 1 to item 5 are 7, 000 units, 3, 000 units, 5, 000 units, 4, 000 units ,and 4,000 units respectively. Therefore, under production sequence from item1 to item5, the recommended batch production size is shown in table 4.10.

Table: 4.10: Total profit/loss value in BHT of separated item 1— 5.

Item On.	Batch size	Service level	Total gain in BHT
Item1	7,000	71.75%	40,748
Item2	3,000	81.40%	26,320
Item3	5,000	60.03%	8,800
Item4	4,000	77.31%	57,658
Item5	4,000	70.94%	5,885
Total		72.28%	139,410

Comparing to existing value, result from case I shows average service level equal to 72 % which is dropped by 28 % from existing value. While percentage in stock value on sale deduced by 94%. Although, 94 % decreased in stock value toward sale is festinated, ultimately, cost of loss customers has significant negatively impact to company in the long term loss sale.

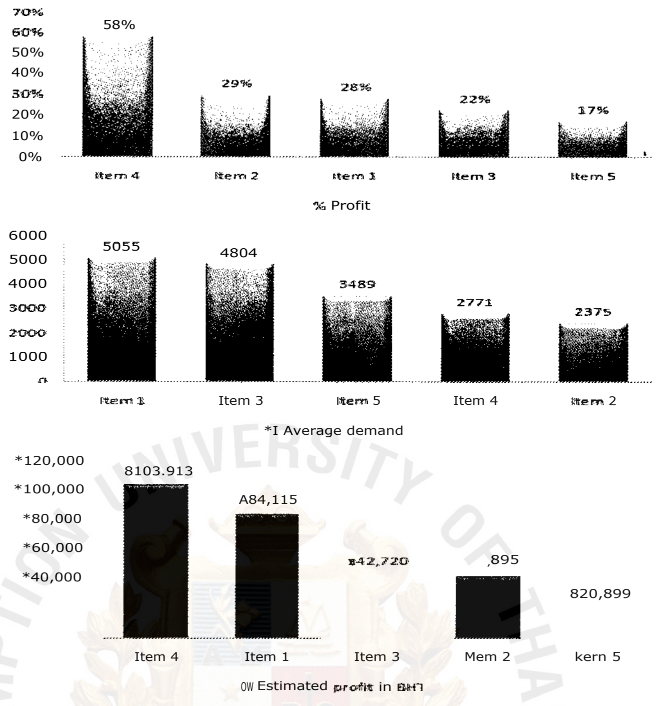
If service level dropped, customers will shift to buy from competitors, and perhaps company will lose them in long term. Since remaining in high service level is vital, second case is developed in order to discover the better in profit and service level.

Study found that more profit might be gain as well as better in service level after setting proper production sequences as the following logic.

1. Profit margin: ranking from highest profit margin to low margin, therefore Item 4, item2, item 1, item3, and item 5, respectively.
2. Estimated demand: ranking from large demand quantities to low demand. Items ranked from 1, 3,5,4,2 respectively.
3. Total profit from estimated demand: ranking from high profit to low profit. Items are ranked from item4, item1, item3, item2, and item5 respectively.

Therefore, arranging production order in the sequence of item 4, 1, 3, 2, and 5 are developed and tested in case II

Figure 4.11: Criteria in production sequence arranged by profit margin, demand, and estimated profit arrange from maximum to minimum value.



Case II: Revise production order by item 4, item 1, item 3, item 2, and item 5 respectively where production batch started at 1,000 units with increased by lot size of 1,000 units with fixed safety stock fixed at 500 units.

Figure 4.12: Profit/loss of item 1-5 varies from production batch of 1,000 to 10,000

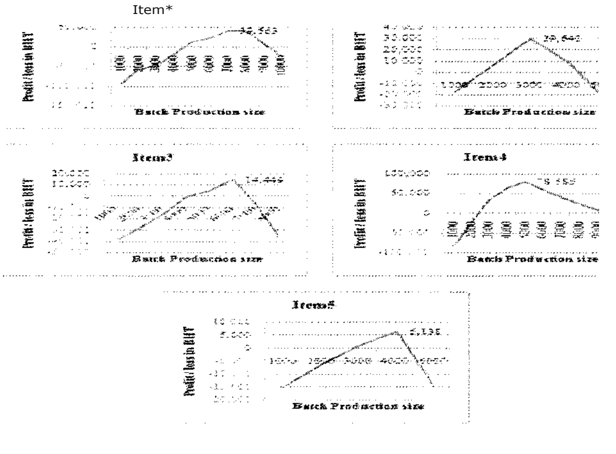


Table 4.11: Total profit/loss of item 1- 5

			Total P / loss		
Batch	Item1	Item2	Item3	Item4	Item5
1000	-95.1^{2}3	-17,383	-38,317	-83.300	-15,143
2000	-57,780	6,477	-27,766	-24,608	-6,501
3000	-49.181	29,640	-16.308	33,040	639
4000	-17.569	8,401	-893	64,285	6,138
5000	12,146	-24.348	4,918	78,585	-14.715
6000	22,561	-60.486	14,449	59,975	-43,217
7000	39,563	-99,002	-8,140	40,323	-75,182
8000	38,773	-131,511	-36,343	24,033	-104,308
9000	7,345	-166,022	-66.115	7,595	-129,573
10000	-^{2}5.703	-210.675	-90,197	-9,725	-163.259

Case **II,** high yield in batch production size changed from 7,000 units, 3,000 units, 5,000 units, 4,000 units, and 4000 units in item 1, 2, 3, 4, and 5 respectively to 7,000 units in item 1, 3,000 units in item 2, 6,000 units in item 3 5,000 units in item 4, and 4,000 units in item 5.Total gain from case **II** is BHT 168,375 which is BHT 28,965 higher than BHT 139,410 in case I.

Figure 4.13: Service level of **item1-5** amount production batches level.

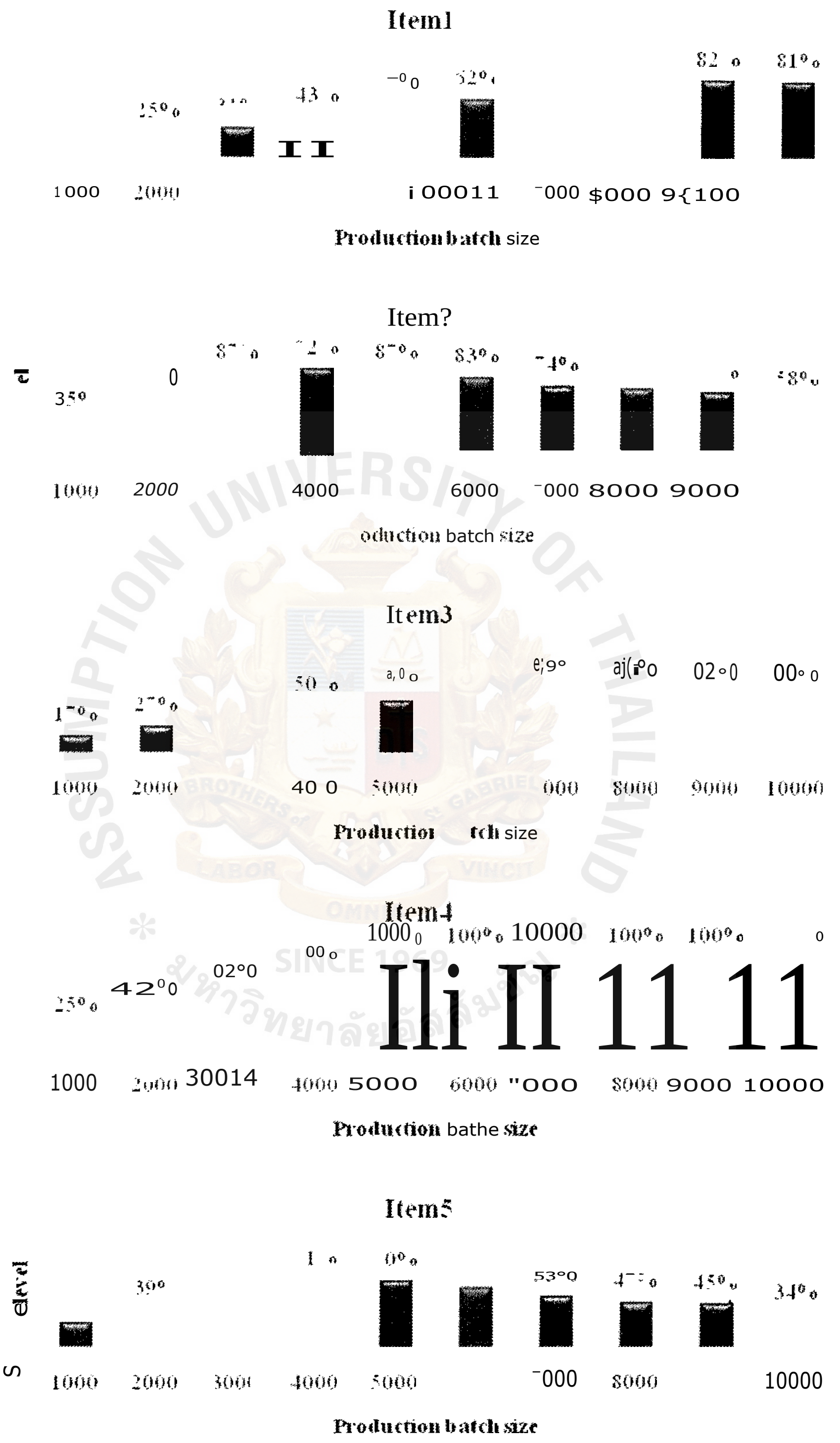
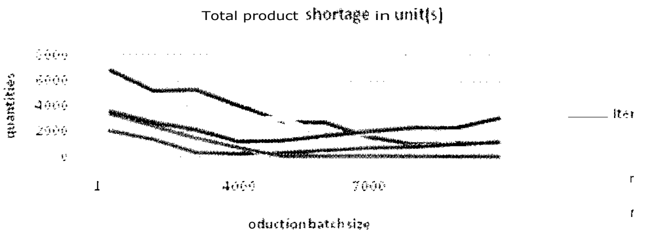


Figure 4.14: Total product shortage in units among production batches level.



Through, the total gain which is 21 % higher than case I, as well as improving in service level by 9 % from 72 % to 80.51 %, result still not good enough in management point of view. Director of company insisted that service level should close to 100 %. Then, approach to get full 100 % service level is still being the question. Thus, case III is developed.

Table 4.12: Service level, total gain in BHT as suggested batch production size.

Item On.	Batch size	Service level	Total gain in BHT
Item1	7,000	74.79%	39,563
Item2	3,000	86.56%	29,640
Item3	6,000	70.07%	14,449
Item4	5,000	100.00%	78,585
Item5	4,000	71.15%	6,138
Total		**80.51%**	**168,375**

Case III: Production batch size and production sequences are similar to case II while safety stock is only changed.

In order to serve 100 % in services level, any single loss sale must not be occurred. Only case I and II applied fixed safety stock at 500 units, and result show that loss sale occurred from product shortages during production lead time. Therefore, adjusting initial safety stock level should improve service level. Then study attempt changing initial safety stock which value changed is based on loss sale in units from case II.

Table 4.13: Production batch size, loss sale in unit, initial safety stock, and purposed safety stock of item 1-5

	Item 1	Item 2	Item 3	Item 4	Item 5
Production Batch size	7,000	3,000	6,000	5,000	4,000
Loss sale in unit	1,577	359	1,747	0	1,178
Initial Safety stock	500	500	500	500	500
New Safety stock	2,500	1,000	2,500	500	2,000

Result from simulating 1,000 replications via simulation program show service level reach to 100 % while average holding increased by 398 % from case II. Although increasing of holding cost may seem high %age, but only BHT 42,107 is increased. In reality, losing a single the customers could yield higher loss than increased in holding cost. Therefore, level of batch production size, and initial safety stock quantities are reasonable enough to be convinced. The comparison between results from case III with existing value is shown in 4.4

Figure 4.15: Service level in % among item 1 -5

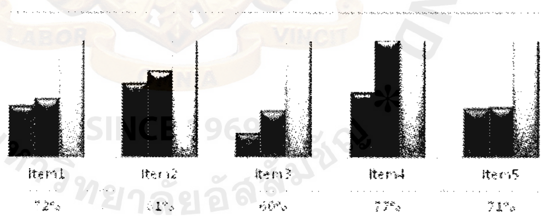
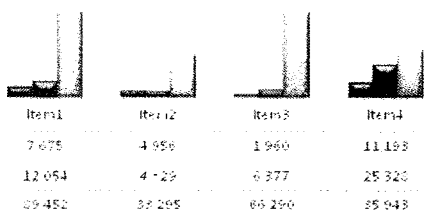


Figure 4.16: Holding cost in BHT cost among item 1 -5



4.1.5 Reordering point

Study adept simulation to model the effective reordering point. Starting from simulated value of production lead time for each item under various batch production sizes as well as lead time from suppliers, then incoming demand is also generated via simulation where randomness of demand rate under validated represent distribution can be expected.

Table 4.14: Result from simulation in generating random demand quantities in daily basis

Item	1	2	3	4	5
Random set	8,869	8,937	8,981	9,063	8,755
Average demand	170	79	159	93	114
Standard deviation	99	30	61	68	42
Minimum	4	28	18	0	15
Maximum	821	130	470	555	292

The simulated process lead time as well as demand is input into reordering point to get the appropriated ROP at level of each production batch size.

Table 4.15: Example of ROP for Item 1 only

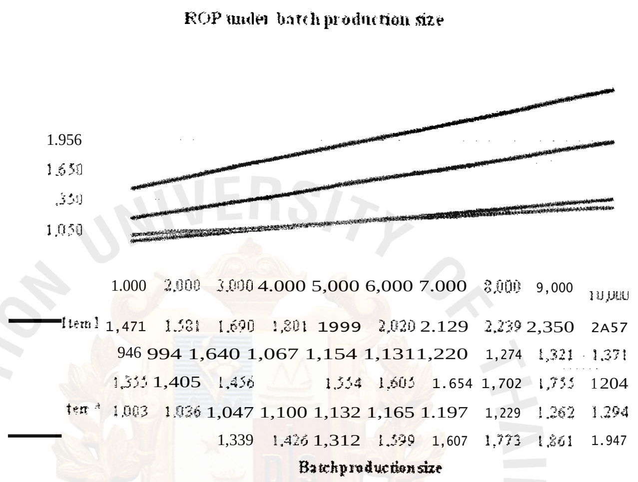
Item 1

Batch	LTs	LTp	0.5R	ELT	D	LTD	SS	ROP
1000	5	0.71	0	5.71	170	971	500	1471
2000	5	1.36	0	6.36	170	1081	500	1581
3000	5	2	0	7	170	1190	500	1690
4000	5	2.65	0	7.65	170	1301	500	1801
5000	5	3.29	0	8.29	170	1409	500	1909
6000	5	3.94	0	8.94	170	1520	500	2020

Noted: ROP of item 2-5 are shown in appendix

Under average demand rate of 170, longest lead time from supplier takes up to 5 days while safety stock is set at 500 units. Although, average daily demand and lead time from supplier are unchanged, ROP varies among production batch size. Lead time for large batch production size required longer than small batch production size. In other word, ROP have positive relationship with production batch size.

Figure 4.17: **ROP** under different batch production size



Linked to effective batch production size in case III, the appropriated ROP is shown in table 4.15.

Table 4.16: **ROP** in units on appropriated batch level.

Item	Batch production size	ELT in days	ROP in units
Item1	7,000	9.58	2,129
Item2	3,000	6.84	1,040
Item3	6,000	6.95	1,605
Item4	5,000	6.80	1,132
Item5	4,000	8.12	1,426

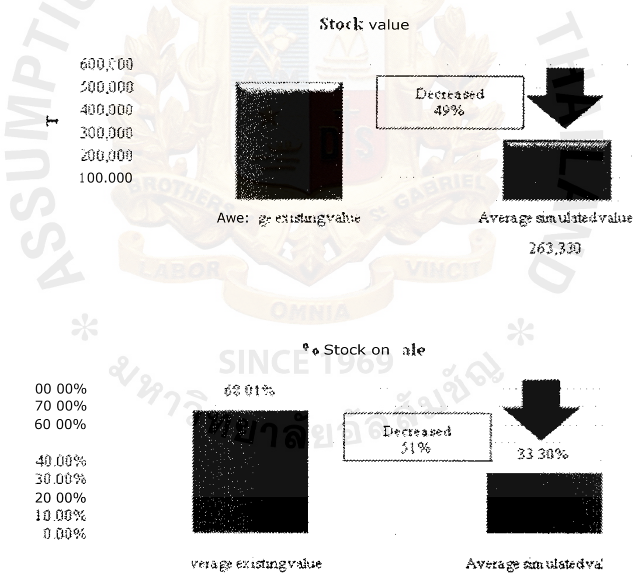
To sum up, reordering point in table 4.15 imply that when stock level reach to indicated level ,the order to reproduce should be placed in order to prevent the product shortage which probably lead to loss sale may be taking place.

4.4 Result Evaluation and Analysis

Referred to existing value which shows average stock value of 68% toward sale value, company kept large quantities of stock in order to prevent the loss sale. The indicators used in comparing the result are cost of stock at end of month, loss sale value, production shortage in unit, and service level.

4.4.1 Cost of ending stock

Figure 4.18: Comparing stock value at end of month and percent stock on sale value between existing value and case III over a single month.

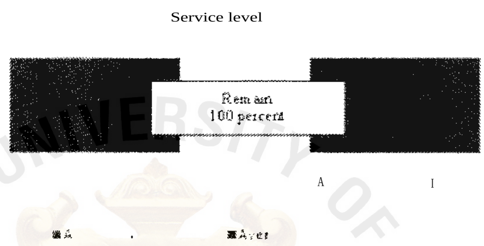


Although large in existing stock quantities ensure service level at 100 %, company never conduct quantitative analysis on demand as well as inefficient in communication between production department and sale department. Therefore, 51 % decreasing in stock value toward sale is reasonable if demand and production are well synchronized.

4.4.2 Service level

Thereby, after conducting systematic analysis under simulation technique by setting production sequences with appropriated batch production size, the ending number of product in unit and percent stock on sale value could be decreased up to 49% while service level still remain at full 100 %.

Figure 4.19: Comparing service level between existing value and case III value over a single month.



4.4.3 Loss sale value

No loss sale occurred as service level equal to 100 %.

4.4.4 Production shortage in unit

Production always available as stock level is enough for demand.

CHAPTERV

CONCLUSIONS AND RECOMMENDATIONS

According to the research objective that purposed as providing clear solution for production batch size optimization and effective reordering point in getting appropriate stock level where effective synchronized between production and demand is also expected, the summary after programming simulation model and analyzing the simulation result are illustrated as per following;

5.1 Research Conclusion

Study starts from finding the core problem by applying root cause analysis technique as well as conducting interview with managing director. The problems are transferred into single main objective, measured by set of performance indicators. Five items were selected in the study.

Study applied simulation approach as the research tool since the problem consisted of many complex conditions such as fluctuation of demand pattern as well as two difference type of demand which also have difference in expired period. Then, data which are needed as input parameter were collected and transferred into single represented distribution before programming the simulation models as well as conducting verify and validation both input data and simulation model.

Initial production batch size is input into simulation model where parameters were manipulated. Study starts increase batch production size from 1,000 to 10,000 units for each item where increased step is in a lot size of 1,000 units. Besides, the reordering point was also discovered by simulating up to 9,000 units of demand for each items.

After getting the result, study applied performance indicators which are value of ending products, service level, loss sale value as well as number of loss sale in unit in comparing existing value with simulation result.

Study develops three cases in finding appropriated batch production size which is show in table 5.1.

Table 5.1: Case I - III

Case	Explanation	Production batch size	Safety stock level
I	Produce 5 items in sequence from item 1 to 5.	Batch size at 1,000 units and increasing by lot size by 1,000 units	Fixed at 500 units
II	Revised production order by item 4, item], item 3, item 2, and item 5 respectively.	Batch size at 1,000 units and increasing by lot size by 1,000 units	Fixed at 500 units
III	Production sequence is rank from item 4,3,2, to 5 respectively	Item1 : 7,000 units Item2 : 3,000 units Item3 : 6,000 units Item4 : 5,000 units Item5 : 4,000 units	2,500units 1,000 units 2,500 units 500 units 2,000 units

Also, reordering point was calculated where demand is generated via simulation. The recommended reordering point in case III shows in table 5.2

Table 5.2: Recommended Batch production size and reordering point

Item	Batch production size	ELT in days	ROP in units
Item1	7,000	9.58	2,129
Item2	3,000	6.84	1,040
Item3	6,000	6.95	1,605
Item4	5,000	6.80	1,132
Item5	4,000	8.12	1,426

After getting appropriated batch production size, safety stock, and reordering point, the result was compared to existing value under following indicators.

5.1.1 Cost of stock at end of month

Total stock cost after set production sequence by item 4, 1, 3, 2, and 5 with batch production size of 4,000 units, 7,000 units, 6,000 units, 3,000 units, and 4,000 units respectively. Total ending stock value could drop by 49 % against existing value or money can be saving up BHT 258,628 for a single month. Also, this saving in cost dominated only item1-5 which is weighted only 13.27%. In other word, if applied this number to remaining 86.73%, company could approximately save the ending stock cost up to BHT 1,948,968 for a single month or up to 13 million annually.

5.1.2 Percent service level

Under suggested batch production size, company still can ensure full service level at 100 % as existing.

5.1.3 Loss sale value

After conducting case III, simulation result shows no loss sale was occurred as study can serve up to full service level.

5.1.4 Production shortage in units

No production shortages occurred

5.2 Recommendation

5.2.1 Safety stock level

Currently safety stock fixed at 500 units for all products; however it not guarantees that this level is effective. For example item1, demand rate is quite fluctuated as the simulation result shows very scattered in demand. Also, the difference between minimum and maximum range up to 817 where standard deviation equal 99, the safety stock should be quantitatively reviewed. The fixed level of 500 units, applied to all items seem not be the effective level to all items.

The company should also have the accurate demand forecasting to predict the demand from customer. The forecasting technique can generate many ways. Forecasting can prevent the company from shortages in product. Beside simulation, company can expect the customer demand by using forecasting technique for domestic market. Seasonality forecasting technique may predict for each month or quarter.

5.2.2 Production line

Another approach to improve the batch production size is the lean manufacturing concept in order to reduce in production lead time and diminish the defect parts. Lean manufacturing concept realize on eliminating wastes. There are 7 wastes which derive from overproduction, defects, transportation, waiting, inventory, motion and processing. Becoming Lean, there are several approaches to eliminate wastes. The important thing that company should be focused is reducing defects. The root causes of defect derive from both supplier and from the production line itself. The training as well as setting the work standard will be the solution for this matter.

Besides, Poka-yoke technique is suggested to study in order to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. When shorter lead production time, smaller batch production could be expected, and finally lead to lower in inventories cost.

5.2.3 Periodically review for input demand

Since study use historical data for demand input, result shows based on input demand data. Even, study manage input demand in form of represent distribution which the randomness of demand can be expected, still result is effective only under set of input demand over collecting period. The accuracy of result depends on how the input data reflect closely to reality. In other word, the more accurate of input data, more reliable on result, generated from simulation.

Therefore, study must periodically review for input demand data in expect of reasonable of outcome. Demand forecasting also play vital role in getting the demand input data. As more accurate of demand forecasting, the more sensibility in appropriate batch production size and reordering point.

BIBLIOGRAPHY

Bhaba, R.S. (1994). Manufacturing batch size to minimize the total cost for meeting equal shipments of the finished products, at fixed intervals. *The Journal of the Operational Research Society,* 891- 900.

Chia-Nan W, Chih-Hong W. (2005) Mathematical Model with Simulation to Find the Optimal Batch Size For A Supply Chain. *Journal of the Chinese Institute of Industrial Engineers,* 262-271.

Duangpun, K. (1999). A procedure for establishing a reference state in qualitative simulation of operational systems. *International Journal of Operations & Production Management.*

Edward, A.S (2007). *Determining the Reorder Point and Order-Up-To-Level in a Periodic Review System.* Haskayne School of Business.University of Calgary.

Forgionne (1983).Corporate Management Science Activities. *An update inferfaces, Vol* 13,20-23.

Georigia (1998). *Modern,Y.Toyota Production system:An Integrated Approach to just-In Time.* Engineer and management Press,3 Edition

Hei-Chia W., Yi-Shen (2005). Garment supply chain in proposing a method that first uses a mathematical model, extended with simulation to find the possible best solution. *Journal of the Chinese Institute of Industrial Engineers*, 22(3), 262-271

Bourne, et. al. (1991), Shafer, and Logan. (1987). *Ishikawa Diagram.*

Retrieved August 5,2009 from Quality library website:

http://mot.vuse.vanderbilt.edu/mt322/Ishikawa.htm

Kaoru, I (1993).*Identifying and arranging the causes of an event or problem.* Retrieved August 5,2009 from 12Manager Website:http://www.12manage.com/methods_ishikawa_cause_effect_diagram.html

Keely, L.C. (2003). The order fulfillment process. *The International Journal of Logistics Management, 4-5.*

Law, A. M., Kelton W. D. *Simulation Modeling and Analysis.* McGraw-Hill, New York.3 edition,

Malcolm Tatum (2009). *What is a cost structure?*
Retrieved August 5,2009 from Conjecture corporation Web site:
http://www.wisegeek.com/what-is-a-cost-structure.htm

Martin A.(2008). *How reorder point control works?.*
Retrieved August 10, 2009,
from: Supply Chain View Website:
http://www.supplychainview.com/blog/2008/11/inventory-managagement-101-how-reorder-point-control-works/

Michael C. L. (2002). *Optimal Lot Size, Inventories, Prices and JIT (Just in time).* Wesleyan University.

Morgan (1989). Survey of MS/OR Surveys. *Interfaces Journal*, 1995-103

Peter, T. (2009). Factors Influencing Batch Size. *Annals of the Faculty of Engineering Hunedoara – Journal of Engineering.* TOME VII
Fascicule 2 (ISSN 1584 – 2665)

Promodel Corporation(2009).*Supply chain and logistic support 2009.*

Retrieved August 10, 2009, from: Promodel Website: http://www.promodel.com/

Richard, S. (2007), *Reducing Inventory on Stock Lines.* Retrieved August 10,2009, from: Handel System website: http://hdl.handle.net/1826/2519

Ronan, C., Robert,V., Jean-Claude ,H.,& Herve,P. (2001). Modeling, Simulation and Analysis of Batch Production Systems. *Discrete Event Dynamic Systems-Theory and Applications Journal, 11, 119-136.*

Schonberger, R. J., (1982) Japanese manufacturing techniques: Nine hidden lessons in simplicity. *The Free Press* (pp 18-20). Free Press: 1st edition

Silverman D.(2007). *Doing Qualitative Research: A Practical Handbook.* SAGE Publication Inc.

Simul8 Corporation (2009).*Case study* Retrieved August 10, 2009, from: Simul8 Website : http://www.simul8.com/solutions/case studies/nao.htm

Shannon,L. Buckles(1980).Operation research Methodologies in industrial Engineering. *AIIE Trans*.12, 364-367.

ThaiPR(2009).*Automotive section.* Retrieved September 5, 2009, from: ThaiPR Website: http://www.thaipr.net/nc/readnews.aspx

Thomas., Dacosta(1979).A sample survey of corporate operations reseach. *Interface journal*, 9,102-11

V. Ryan(2005).*Batch production.*Retrieved September 5, 2009, from: Technology student's Website: http://www.technologystudent.com/joints/bat1.htm

William, M.K.T. (2006) .*Research Methods Knowledge Base.* Soft cover Publications 2nd Edition.

APPENDICES

APPENDIX A

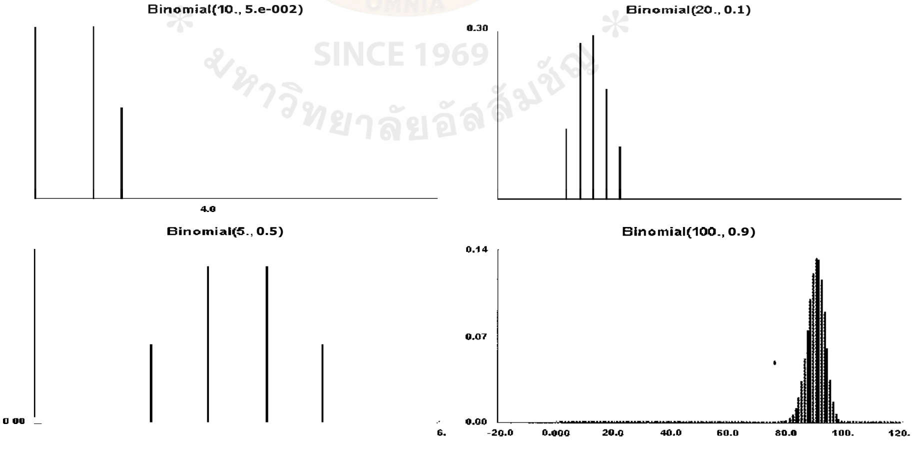
TYPE OF DISTRIBUTIONS

Binomial distribution

The Binomial distribution is a discrete distribution bounded by [0,n]. Typically, it is used where a single trial is repeated over and over, such as the tossing of a coin. The parameter, p, is the probability of the event, either heads or tails, either occurring or not occurring. Each single trial is assumed to be independent of all others. For large n, the Binomial distribution may be approximated by the Normal distribution, for example when np>9 and **p** <0.5 or when np (1-p)>9.

As shown in the examples, low values of p give high probabilities for low values of x and vice versa, so that the peak in the distribution may approach either bound. More examples can be viewed by using the Distribution Viewer capability.

The binomial distribution has had extensive use in games, but is also useful in genetics, sampling of defective parts in a stable process, and other event sampling tests where the probability of the event is known to be constant or nearly so.



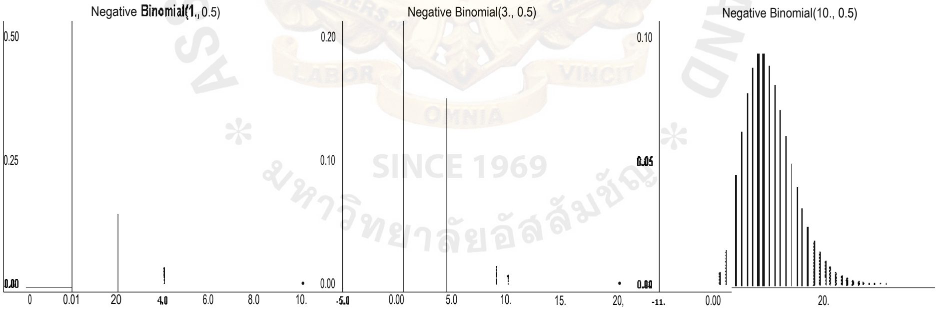
Source: Univariate Discrete Distributions", Norman L. Johnson, Samuel Kotz, Adrienne W. Kemp, 1992, John Wiley & Sons, p.134

Negative binomial distribution

The Negative Binomial distribution is an discrete distribution bounded on the low side at 0 and unbounded on the high side. The Negative Binomial distribution reduces to the Geometric Distribution for k = 1. The Negative Binomial distribution gives the total number of trials, x, to get k events (failures...), each with the constant probability, p, of occurring.

The Negative Binomial distribution has many uses; some occur because it provides a good approximation for the sum or mixing of other discrete distributions. By itself, it is used to model accident statistics, birth-and-death processes, market research and consumer expenditure, lending library data, biometrical data, and many others

Several examples with increasing k are shown below. With smaller probability, p, the number of classes is so large that the distribution is best plotted as a filled polygon. Note that the probabilities are actually weights at each integer, but are represented by broader bars for visibility.



Source: Univariate Discrete Distributions, Norman L. Johnson, Samuel Kotz, Adrienne W. Kemp, 1992, John Wiley & Sons, p.223

Poisson distribution

The Poisson distribution is a discrete distribution bounded at 0 on the low side and unbounded on the high side. The Poisson distribution is a limiting form of the Hyper geometric distribution.

The Poisson distribution finds frequent use because it represents the infrequent occurrence of events whose rate is constant. This includes many types of events in time or space such as arrivals of telephone calls, defects in semiconductors manufacturing, defects in all aspects of quality control, molecular distributions, stellar distributions, geographical distributions of plants, shot noise, etc..It is an important starting point in queuing theory and reliability theory. Note that the time between arrivals [defects] is Exponentially distributed, which makes this distribution a particularly convenient starting point even when the process is more complex.

The Poisson distribution peaks near lambda and falls off rapidly on either side.

Source: Univariate Discrete Distributions, Norman L. Johnson, Samuel Kotz, Adrienne W. Kemp, 1992, John Wiley & Sons, p.151

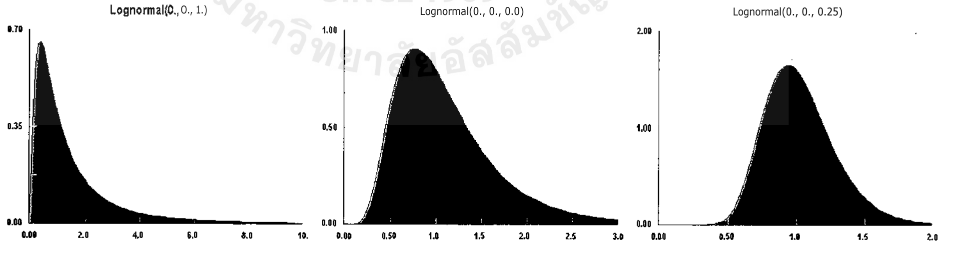
Lognormal distribution

The Lognormal distribution is a continuous distribution bounded on the lower side. It is always 0 at minimum x, rising to a peak that depends on both mu and sigma, then decreasing monotonically for increasing x.

By definition, the natural logarithm of a Lognormal random variable is a Normal random variable. Its parameters are usually given in terms of this included Normal.

The Lognormal distribution can also be used to approximate the Normal distribution, for small sigma, while maintaining its strictly positive values of x [actually (x-min)].

The Lognormal distribution is used in many different areas including the distribution of particle size in naturally occurring aggregates, dust concentration in industrial atmospheres, the distribution of minerals present in low, concentrations, duration of sickness absence, physicians' consultant time, lifetime distributions in reliability, distribution of income, employee retention, and many applications modeling weight, height, etc.
The Lognormal distribution can provide very peaked distributions for increasing sigma, indeed, far more peaked than can be easily represented in graphical form.



Source: Continuous Univariate Distributions, Volume 1", Norman L. Johnson. Samuel Kotz, N. Balakrishnan, 1994, John Wiley & Sons, p207

APPENDIX B

REORDERING POINT FOR ITEM 1-5

Item	1	2	3	4	5
Random set	8869	8937	8981	9063	8755
Average	170	79	159	93	114
SD	99	30	61	68	42
Min	4	28	18	0	15
Max	821	130	470	555	292

Item 1

Batch	LTs	LTp	0.5R	ELT	D	LTD	SS	ROP
1000	5	0.71	0	5.71	170	971	500	1471
2000	5	1.36	0	6.36	170	1081	500	1581
3000	5	2	0	7	170	1190	500	1690
4000	5	2.65	0	7.65	170	1301	500	1801
5000	5	3.29	0	8.29	170	1409	500	1909
6000	5	3.94	0	8.94	170	1520	500	2020
7000	5	4.58	0	9.58	170	1629	500	2129
8000	5	5.23	0	10.23	170	1739	500	2239
9000	5	5.88	0	10.88	170	1850	500	2350
10000	5	6.51	0	11.51	170	1957	500	2457

Item 2								
	LTs	**LTp**	0.5R	ELT	D	LTD	SS	**ROP**
1000	5	0.65	0	5.65	79	446	500	946
2000	5	1.25	0	6.25	79	494	500	994
3000	5	1.84	0	6.84	79	540	500	1040
4000	5	2.43	0	7.43	79	587	500	1087
5000	5	3.02	0	8.02	79	634	500	1134
6000	5	3.62	0	8.62	79	681	500	1181
7000	5	4.21	0	9.21	79	728	500	1228
8000	5	4.8	0	9.8	79	774	500	1274
9000	5	5.39	0	10.39	79	821	500	1321
10000	5	6.03	0	11.03	79	871	500	1371

Item 3								
	LTs	**LTp**	0.5R	ELT	D	LTD	SS	**ROP**
1000	5	0.38	0	5.38	159	855	500	1355
2000	5	0.69	0	5.69	159	905	500	1405
3000	5	1.01	0	6.01	159	956	500	1456
4000	5	1.32	0	6.32	159	1005	500	1505
5000	5	1.63	0	6.63	159	1054	500	1554
6000	5	1.95	0	6.95	159	1105	500	1605
7000	5	2.26	0	7.26	159	1154	500	1654
8000	5	2.58	0	7.58	159	1205	500	1705
9000	5	2.89	0	7.89	159	1255	500	1755
10000	5	3.2	0	8.2	159	1304	500	1804

Item 4

	LTs	LTp	0.5R	ELT	D	LTD	SS	ROP
1000	5	0.41	0	5.41	93	503	500	1003
2000	5	0.76	0	5.76	93	536	500	1036
3000	5	1.1	0	6.1	93	567	500	1067
4000	5	1.45	0	6.45	93	600	500	1100
5000	5	1.8	0	6.8	93	632	500	1132
6000	5	2.15	0	7.15	93	665	500	1165
7000	5	2.49	0	7.49	93	697	500	1197
8000	5	2.84	0	7.84	93	729	500	1229
9000	5	3.19	0	8.19	93	762	500	1262
10000	5	3.54	0	8.54	93	794	500	1294

Item 5

	LTs	LTp	0.5R	ELT	D	LTD	SS	ROP
1000	5	0.83	0	5.83	114	665	500	1165
2000	5	1.6	0	6.6	114	752	500	1252
3000	5	2.36	0	7.36	114	839	500	1339
4000	5	3.12	0	8.12	114	926	500	1426
5000	5	3.88	0	8.88	114	1012	500	1512
6000	5	4.64	0	9.64	114	1099	500	1599
7000	5	5.41	0	10.41	114	1187	500	1687
8000	5	6.17	0	11.17	114	1273	500	1773
9000	5	6.94	0	11.94	114	1361	500	1861
10000	5	7.69	0	12.69	114	1447	500	1947

APPENDIX C

PRODUCTION BATCH SIZE FOR ITEM 1-5 UNDER PRODUCTION SEQUENCE BY ITEM 4, 1, 3, 2, AND ITEM 5

			Item1		
Batch	**Demand**	**Total reject**	**Sale Completed**	**Defect**	**End items**
1000	4946	3826	1120	356	24
2000	4977	3215	1762	716	22
3000	5148	2762	2386	1085	29
4000	5135	2109	3026	1438	36
5000	4954	1295	3659	1793	48
6000	5020	767	4253	2151	96
7000	4987	308	4679	2543	278
8000	5056	96	4960	2898	642
9000	5091	164	4927	3258	1315
10000	5022	175	4847	3638	2015

Batch	Demand	Total reject	Item2 Sale Completed	Defect	End items
1000	2376	1266	1110	364	26
2000	2376	622	1754	719	27
3000	2374	61	2313	1073	114
4000	2359	6	2353	1455	692
5000	2386	86	2300	1814	1386
6000	2352	168	2184	2171	2145
7000	2390	323	2067	2542	2891
8000	2360	387	1973	2926	3601
9000	2361	468	1893	3295	4312
10000	2387	708	1679	3651	5170

Batch	Demand	Total reject	Item3 Sale Completed	Defect	End items
1000	4852	3744	1108	362	30
2000	4759	3005	1754	723	23
3000	4839	2454	2385	1087	28
4000	4879	1856	3023	1440	37
5000	4914	1274	3640	1818	42
6000	4865	776	4089	2206	205
7000	4889	858	4031	2565	904
8000	4857	996	3861	2927	1712
9000	4827	1152	3675	3300	2525
10000	4842	1275	3567	3681	3252

			Item4		
Batch	Demand	Total reject	Sale Completed	Defect	End items
1000	2798	1669	1129	361	10
2000	2779	1020	1759	723	18
3000	2703	345	2358	1078	64
4000	2760	60	2700	1439	361
5000	2771	0	2771	1808	921
6000	2758	0	2758	2162	1580
7000	2726	0	2726	2523	2251
8000	2747	0	2747	2881	2872
9000	2767	0	2767	3236	3497
10000	2762	0	2762	3618	4120

			Item5		
Batch	Demand	Total reject	Sale Completed	Defect	End items
1000	3417	2299	1118	357	25
2000	3425	1672	1753	717	30
3000	3400	1030	2370	1094	36
4000	3381	476	2905	1450	145
5000	3444	594	2850	1806	844
6000	3438	817	2621	2183	1696
7000	3493	1188	2305	2546	2649
8000	3453	1387	2066	2895	3539
9000	3382	1538	1844	3282	4374
10000	3405	1838	1567	3620	5313