INVENTORY MODEL WITH VARIABLE HOLDING COST TO ACCOMODATE PLANNED SHORTAGE

(Study Case at CV. Yopan Ceramics)

THESIS

Submitted to International Program

Department of Industrial Engineering in Partial Fulfillment of

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By

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ABSTRACT

Inventory has become the biggest problem and needs to get extra attention. The inventory problem is associated with products which are stored in the storage for longer term and the higher cost needed to maintain it. In the real problem, the storage cost/holding cost is variable dependent to storage time used and to be increasing function of the time spent in the storage. Two types of variable holding cost are retroactive holding cost and incremental holding cost. Those type created with the purpose of determining optimal quantity ,cycle time, andminimum inventory cost which includes of demand, order cost, demand elasticity to inventory, and holding cost. Based on common real-life condition that sometimes the demand is greater than the inventory level. This condition caused the inventory shortage and anticipated by doing backorder before zero stock inventory in order to meet customer satisfaction. This paper presents the inventory model with variable holding cost using a simple algorithm to determine optimal solution which includes minimizing total inventoy cost and also to accomodate planned shortage to determine the shortage cost which includes backorder cost and administrative backorder cost.

Keywords: variable holding cost, shortage, optimum solution, backorder, total inventory cost

This thesis, I dedicate to my parents,

Thanks to my Dad and Mom for your prayer

sacrifice and advices.

MOTTO

"O you, who have believed, seek help through patience and prayer. Indeed, Allah is with the patient." (Al-Baqarah: 153)

"There is no problem that can not be solved as long as there commitment to resolve"

"Allah has educated me with the best of education."

(HR. by Ahmad)

PREFACE

بسم الله الرحمن الرحيم

Assalamualikum Wr.Wb

Alhamdulillahi robbil a'lamin. First of all, I would like to say thanks to Allah SWT that always give us bless and mercy for all mankind who had faith and worship to God. Because of His bless and mercy, I can finish my thesis with Title **INVENTORY MODEL BASED WITH VARIABLE HOLDING COST TO ACCOMODATE PLANNED SHORTAGE.** This Thesis is part of requirement to get bachelor's degree of Industrial Engineering Department at University Islam Indonesia.

I would also like to express my profound gratitude for the love, support, and faith to my parents, Nurjono, SH and Puji Rahayu. And I'm so thankful for the happiness brought by my sisters, Galuh Hayu Noormalisa, and my brother, Rizda Noor Ali Wicaksono and Swastika Noor Yudha Pratama

In this opportunity I would like to say special thanks and deepest respect to my supervisor Dr. Mirwan Ushada, S.TP, M.App.Life.Sc that always gives support, advice, guidance, and suggestion to me so that I can finish my thesis. Furthermore, my appreciation goes to CV. Yopan Ceramic for the cooperation as my research object.

At last, I would like to thank all my friends in FIT UII, especially IP FIT student's year 2007 for the great experience and opportunity during our school year.

Wassalamualaikum Wr. Wb

Yogyakarta,February 30, 2012

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INVENTORY MODEL WITH VARIABLE HOLDING COST TO ACCOMMODATE PLANNED SHORTAGE

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APPENDIX

Appendix 1.Inventory Condition in CV. Yopan Ceramics

Periode	demand	Production	Inventory	Condition
Oct-10	213	266	53	
Nov-10	209	275	66	
Dec-10	297	282	-15	shortage
Jan-11	213	269	56	
Feb-11	314	295	-19	shortage
Mar-11	196	253	57	
Apr-11	294	283	-11	shortage
Mei-11	287	269	-18	shortage
Jun-11	217	283	66	
Jul-11	212	287	75	
August-11	281	263	-18	shortage
Sep-11	292	275	-17	shortage

Appendix 2.Secant method

Secant method (Q=1670,Q=2369)

x(0)	x(i)	f(x(0))	f(x(i))	term	apx. error	round
1670	2369	-545427,26	63711,33275	2295,889837	29,50612073	29,50612
2369	2295,889837	63711,33275	8450,587216	2284,70968	3,184393321	3,18439
2295,889837	2284,70968	8450,587216	-129,4555102	2284,878366	0,48934694	0,48935
2284,70968	2284,878366	-129,4555102	0,264100873	2284,878023	0,007382712	0,00738
2284,878366	2284,878023	0,264100873	8,2578E-06	2284,878023	1,50307E-05	0,00002

Secant method (Q=2369,Q=2978)

x(0)	x(i)	f(x(0))	f(x(i))	term	apx. Error	round
2369	2978	63779,08683	647554,2756	2302,465	20,44997	20,44997

Appendix3.Scientific analysis for retroactive and incremental

a. changed value β

changed value	%	SENSITIVITY ANALYSIS (RETROACTIVE)			
		Q*	T*	TIC*	%
0,1	0,00%	2068	0,35	1653670,913	0,00%
0,12	20,00%	2203	0,32	1762312,314	6,57%
0,14	40,00%	2351	0,3	1880026,391	13,69%
0,16	60,00%	2510	0,28	2007707,472	21,41%
0,18	80,00%	2683	0,26	2146350,374	29,79%
0,2	100,00%	2872	0,24	2297061,128	38,91%

changed value	%	SENSITIVITY ANALYSIS (INCREMENTAL)			
		Q*	T*	TIC*	%
0,1	0,00%	2369	0,4	1218980	0,00%
0,12	20,00%	2755	0,4	1286054	5,50%
0,14	40,00%	3225	0,4	1366693	12,12%
0,16	60,00%	3801	0,4	1464388	20,13%
0,18	80,00%	4513	0,4	1583658	29,92%
0,2	100,00%	5400	0,4	1730434	41,96%

b. changed value H

changed value	%	SENSITIVITY ANALYSIS (RETROACTIVE)			
		Q*	T*	TIC*	%
3,6,9	-25,00%	2406	0,4	1443004,137	-12,74%
4,8,12	0%	2068	0,35	1653670,913	0,00%
5,10,150	25,00%	1839	0,31	1838035,294	11,15%
6,12,18	50,00%	1670	0,29	2003829,196	21,17%
7,14,21	75,00%	1540	0,27	2155620,689	30,35%
8,16,24	100,00%	1436	0,25	2296372,098	38,87%

changed value	%	SENSITIVITY ANALYSIS (INCREMENTAL)			
		Q*	T*	TIC*	%
3,6,9	-25,00%	2369	0,4	1106764	-9,21%
4,8,12	0%	2369	0,4	1218980	0,00%
5,10,150	25,00%	2369	0,4	1331196	9,21%

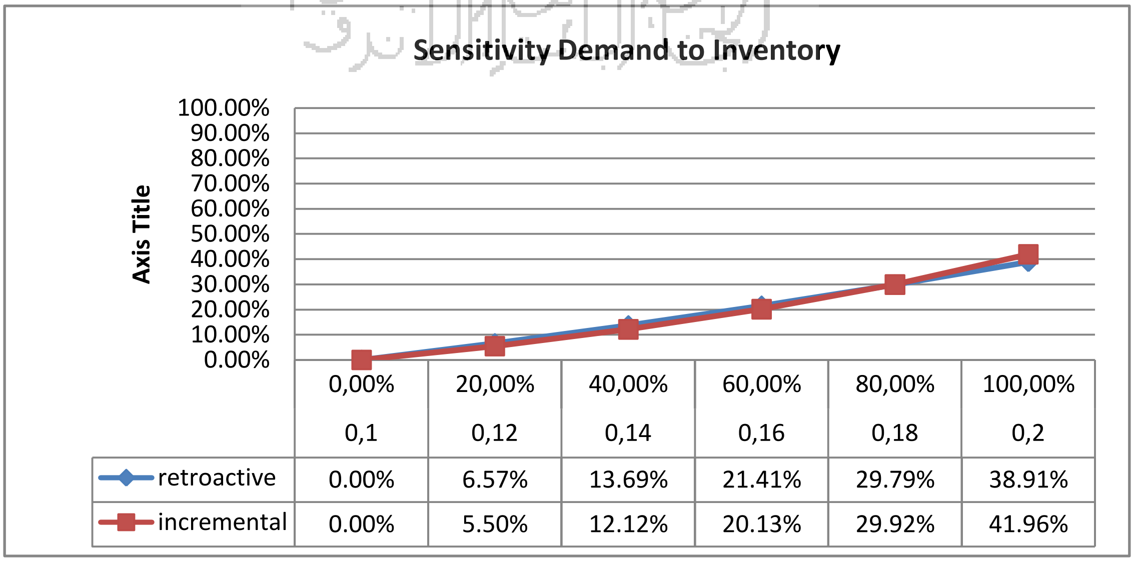
changed value	%	SENSITIVITY ANALYSIS (INCREMENTAL)			
		Q*	T*	TIC*	%
6,12,18	50,00%	2369	0,4	1443412	18,41%
7,14,21	75,00%	2369	0,4	1555627	27,62%
8,16,24	100,00%	2369	0,4	1667843	36,82%

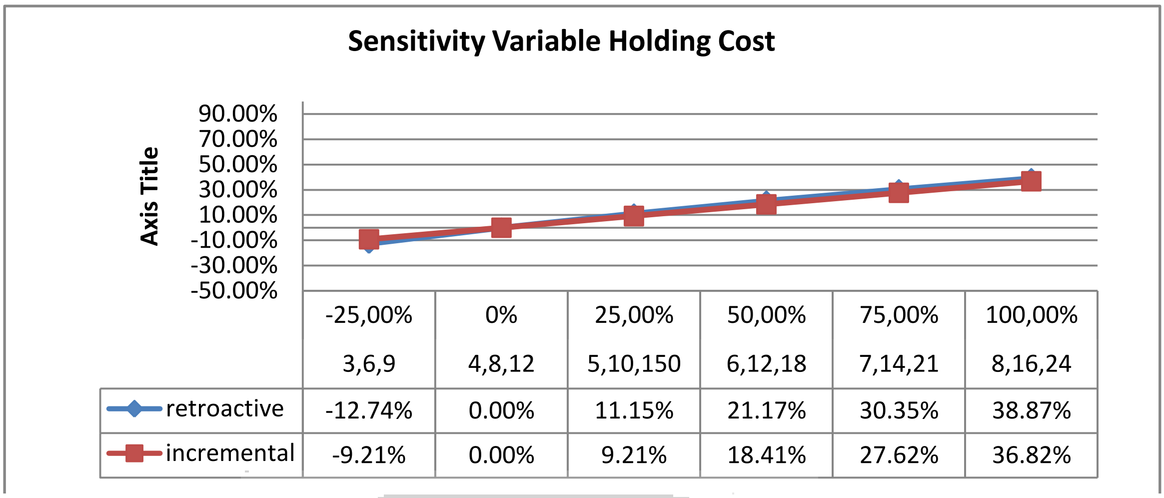
c. changed value T

changed value	%	SENSITIVITY ANALYSIS (RETROACTIVE)			
		Q*	T*	TIC*	%
0,2 0,4 ∞	0,00%	2068	0,35	1653670,913	0,00%
0,25 0,5 ∞	25,00%	1405	0,2	1498208,272	9,40%
0,3 0,6 ∞	50,00%	1839	0,31	1838035,294	11,15%

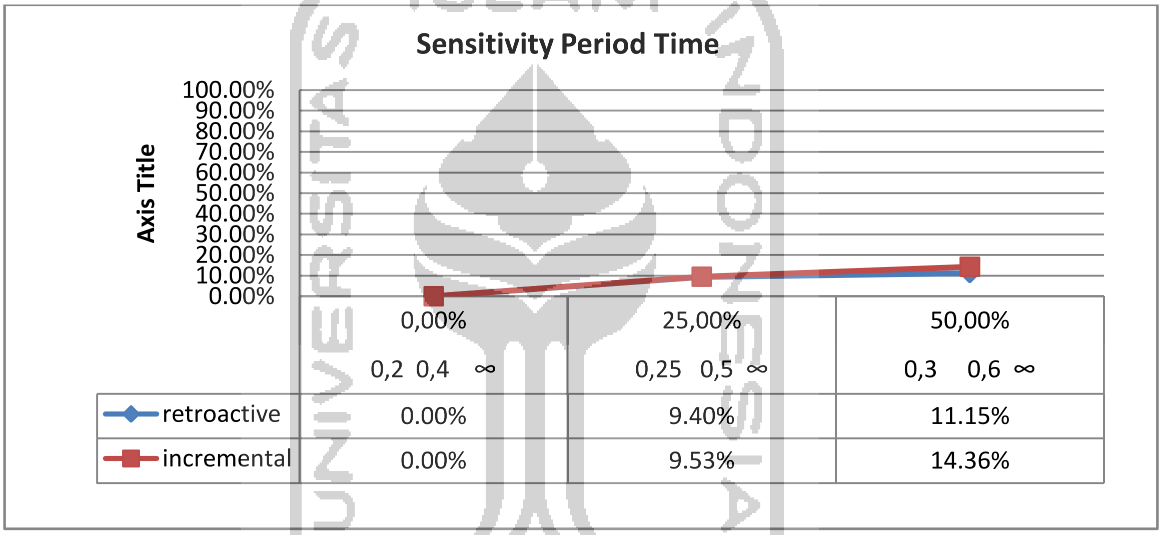
changed value	%	SENSITIVITY ANALYSIS (INCREMENTAL)			
		Q*	T*	TIC*	%
0,2 0,4 ∞	0,00%	2369	0,4	1218980	0,00%
0,25 0,5 ∞	25,00%	3035	0,5	1335142	9,53%
0,3 0,6 ∞	50,00%	2285	0,3	1394019	14,36%

Appendix4.Change Value Graph





	-25,00% 3,6,9	0% 4,8,12	25,00% 5,10,150	50,00% 6,12,18	75,00% 7,14,21	100,00% 8,16,24
retroactive	-12.74%	0.00%	11.15%	21.17%	30.35%	38.87%
incremental	-9.21%	0.00%	9.21%	18.41%	27.62%	36.82%



	0,00% 0,2 0,4 ∞	25,00% 0,25 0,5 ∞	50,00% 0,3 0,6 ∞
retroactive	0.00%	9.40%	11.15%
incremental	0.00%	9.53%	14.36%

CHAPTER I

INTRODUCTION

1.1 Background

The real world observation shows that the product availability is greather than sales, and this create inventory.In company, inventory has become the biggest problem and needs to get extra attention. The inventory problem is associated with products which are stored in the storage for longer term. Therefore, company must has investment cost to stores the product. The longer time to stores the material in the storage, the higher cost needed to maintain it (Alfares, 2007).

Most of companies have limitation in space to store the product in the storage. Thus, the inventory level must be organized well in order to reduce the cost of storing the material. Many researchers have been trying to conduct the research related to controlling the inventories. Chung (2003) has studied about the inventory level which can be developed by an algorithm to find the optimal order quantity. The study aims to reduce the inventory cost based on optimal order quantity.

In the real problem, the holding cost increases since longer time is needed in the storage. It means that holding cost is variable dependent to storage time used (Singh, et.al., 2010). There are two types of time-dependent holding cost which are retroactive and incremental. Retroactive means the unit of the holding cost rate of the last storage applied to all storage time otherwise incremental is the holding cost rate of each period, including the last period apllied only to unit stored in particular period. Alfares (2007) considers the variable holding cost which higher for longer storage time in the inventory model to determine optimal inventory policy related to cycle time .

Many researchers assume the inventory model without any shortages occured. It means that the company can fulfill the demand. In fact, this condition is not represent the real system (Shamsi, et.al., 2010). The demand uncertainty will cause the difficulties in controlling the inventory. Sometimes the demand is greater than the inventory level. Therefore, shortages is occured (Hu and Liu, 2010). To overcome this problem, the shortage of inventory must be anticipated in order to meet customer satisfaction by doing backorder before zero stock inventory.

This research concerns with the case on a CV. Yopan Ceramics, that has less space to store the material. This company has high order and production quantity so it requires much space to store the material and it will impact to the higher inventory cost. In addition, the problem is not only less space of warehouse but also the number of demand exceeds the capacity. Therefore, CV. Yopan Ceramics needs more service in organizing the inventory associated with determining the optimal quantity (order and production) and cycle time. Meanwhile, the optimal quantity is being ordered or produced, it does not always meet the customer demand because of its uncertaintiy and this causes shortage condition occurred. Thus, the company needs to accomodate planned shortage in order to respond the customer requirement.

To overcome this problem, this research proposes a development of inventory model by combaining Alfares (2007)'s model to determine the optimal quantity and cycle time as decision variable to minimize inventory cost and Shamsi, et.al., (2010) by considering the shortage that consist of time dependent and time independent shortage cost.

1.2 Problem Formulation

Based on the above background, the problem formulated could be seen as follow:

a. How is the model of variable holding cost in retroacive and incremental?

b. How to accomodate planned shortage?

c. How is the influence of variable holding cost to inventory cost?

1.3 Research Limitations

A limitation of the research is required to focus the research being conducted so that the goal can be achieved. The boundaries of the research are:

a. The research object is focused on CV. Yopan Ceramic as ceramic producer

b. This research concern on optimal order quantity for planned shortage.

c. The level of accuracy of the output resulted from the implementation of the proposed model firmly depends on the input or data provided by the company.

1.4 Research Objective

The objectives of this research are:

a. Tocompare the result of retroactive and incremental as effect of inventory cost

b. To accomodate planned shortage

c. To determine the influence of variable holding cost to inventory cost

1.5 Research Significance

The significance of this research is:

a. Implementation of inventory model based on real world problem

b. To be evaluation for company in controlling the invetory

1.6 Thesis Structure

The thesis structure is as follows:

CHAPTER II LITERATURE REVIEW

Literature review provides information on previous studies. The objective is to seek the novelty of this research. Besides, it also explains the background theory.

CHAPTER III RESEARCH METHODOLOGY

This chapter will present the research methodology, model development and the data necessary. Furthermore, this chapter will explain about the techniques of data collection and analysis. The final section of this chapter contains the framework of the research.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter presents information of data that have been collected during the research. It also contains problem solving using the proposed model or tools that are implemented in the data processing as well the analysis using the proposed model.

CHAPTER V DISCUSSION

This chapter provides a discussion after data analysis. Furthermore, it also discuss about the result in order to see the ability of the proposed model to overcome the problem.

CHAPTER VI CONCLUSION AND RECOMMENDATIONS

The conclusion and recommendations for further research will be described in this chapter.

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CHAPTER II

LITERATURE REVIEW

2.1 Previous Research

Research issue concerning inventory problem has been studied by many researchers. Chang and Dye (2000) constructed an inventory model considering stock dependent demand to determine the optimal ordering period to maximize total cost savings. In real world, the demand rate is usually influenced by the amount of the stock level. Thus,the demand rate may grow up or down with the on-hand stock level and inventory level dependent demand can be developed with an alogorithm to find optimal order quantity for reducing inventory cost (Chung, 2003)

Most of previous models assume the holding cost to be constant for the entire inventory cycle but in real condition, the storage time can be varied with time. Thus, the holding cost can be variable based on the storage time that used (Singh, et.al., (2010). Shao, et.al., (2000) considered a variable holding cost to determine the optimal target in order to maximize expected profits. In real situation, manufactures may hold goods that have been rejected by one customer and then to sell that goods to another customers in the same market at later date. Thus, the cost for holding the goods will increase until the good sold.

Alfares (2007) explored inventory model which the demand rate depends on the inventory level and the product avaibilitiy are greather than sales. Thus, the holding cost is variable and becomean increase function for longer storage periods. This paper presents representation of real situation in which the storage times can beclassified into a different range. There are two types of time-dependent holding cost which are retroactive and incremental. Retroactive means the unit of the holding cost rate of the last storage applied to all storage time otherwise incremental is the holding cost rate of each period, include the last period apllied only to unit stored in particular period and solved using numerical method.Those types are developed for determining the optimal order quantity and the optimal cycle time to minimizes total inventory cost (TIC).

The demand uncertainty will cause the difficulties in controlling the inventory. Sometimes the demand is greater than the inventory level. Therefore, shortages is occured (Hu and Liu, 2010). Xu and Sarker (2003) developed model in the effect of shortage cost in inventory system. The shortage have signifcant effect on the design of inventory system and are also given importance in somespecial cases to decide which option to be followed between reducing the production rate, cycle time, or combines options 1 and2 together to avoidbreaking the shelf-life constraint.

Chen and Lo (2006) considered allowable shortage in the optimal production length and time length when backorder is replenished for the imperfect production. The system of imperfect production with the product sold with freeminimal repair warranty is formulated as a cost minimmization model to find the optimal solutions.

Cheng,et.al.,(2007) extended Chen and Lo (2006) approach that allowsshortage for product life cycle in replenishment policies to determine the number of inventory replenishment, the inventory replenishment time points, and the beginning time points of shortage by minimizing the total cost of the inventory replenishment.Shamsi, et.al., (2010) presented a model by considering shortage cost for imperfect quality items and the result shows indicate the model is very sensitive to shortage cost. Therefore, if the existence of shortages are ignored, then the obtained results may differ considerably from the optimal outcome.

To overcome this problem, this research proposes a development of inventory model by combaining Alfares (2007)'s model to determine the optimal quantity and cycle time as decision variable to minimize inventory cost and Shamsi, et.al., (2010) by considering the shortage that consist of time dependent and time independent shortage cost.

2.2 Basic Theory

2.2.1 Inventory philosophy

Inventory is a stock of materials that used to facilitate in production process and to satisfy customer demand (Schroeder, 1994). The existence of inventory in company need to be regulated such as the process of fullfilling the customers need can be guaranteed and the incidence of the idle resources and time in waiting further processing can be removed, this is caused to be more efficient. According to Sumayang (2003), inventory is a material saving that consist of raw materials, work in process and finished product. Based on this definition, inventory can be summarized asmaterials (raw materials, work in process and finished roduct) that must be storedandmaintained in warehouse in order to always ready to fulfill the company need.

Basically, inventories simplifythe operationof acompany thatshouldbe donetoproducethegoodsandfurtherto consumers. In general, inventories exist because there is an imbalance between the supply of anitem at a location and its consumption or sale there. The imbalances are the consequenceof many technical, economic, social, and natural forces. Note that inventories are aconsequence and not a cause of some policy oraction. Hence inventories become adependent rather than an independent variable.According toAssauri(1993), as forreasonsinventory is needed by a companybecause:

1. There is timeneededto complete theproduction operationsto move productsfromoneprocess toanother process.
2. Toallowoneunittothe operatingschedulefreely, independently ofthe others.

Inventoryis oneof the mostactiveelementsinthe company's operations. Therefore,the availability ofsufficientinventorywillensure the sustainability ofthe company's operationsbecause of thetimebetweenone processestothe nextprocesscan beminimized

2.2.2 Type of Inventory cost

Inventory cost is one of the key factors in determining an inventory policy.The goal of inventory policy is to get the amount of raw materials at the right place, right time, with low cost (Tersine, 1994). Most models for planning inventory requirements consider costs of various types.According toTampubolon (2004) the cost caused bythe exixtence of inventory are ordering cost, holding cost, and shortage cost

2.2.3 Ordering Cost

Ordering costsarecosts associatedwithorderingproduct (material) fromthe supplier. Becausethe order is madethenthe materialsthat were ordered are deliveredto theinspectionat the warehouse. The costforthisis constantand the costdoes not dependon the sizeoramount ofgoods ordered (Tersine, 1994). In this case, theordering costisincluded inall costs relatedtoan orderof goods, includingadministrative costs,placement oforder purchasing, revenue cost, inspection cost, and doing the processing necessary to complete the transaction

2.2.4 Holding Cost

Holding cost is those required cost because of theinventorythat includesallcosts incurredby the company asa result oftheinventory. Those costsare related tothe average levelinventorythat is always therein thewarehouse, so theamount ofthis cost arevaries, dependingonthe average amount ofinventorycontainedin the warehouse. The costsincluded in the holding cost areallcosts incurredbecausethe goodsare stored includingcapital costs, insurance cost, storage cost, shrinkage, obsolescence, deterioration, and transportation.

Capital cost reflects the stack of goods in storage. Therefore, costs for having inventory must be calculated in the cost of inventory systems.Insurance coverage requirements are dependent on the amount to be replaced if property is destroyed. The material (goods) need a place to store that product, thus a company will spend the cost for storage cost. If the storage rented so it will be called rent cost, but if the company has its own storage, it called depreciation cost.Shrinkage is the decrease in inventory quantities over time from loss or theft and usually measured from the based on percentage of loss quantities. Obsolescence is the risk that an item will lose value because of shifts in styles or consumer preferences and obsolescencecosts are usually measured by the decreasing amount of the sale value of the goods.Deterioration means a change in properties due to age or environmental degradation.

Many of the models developed based on that assumption that will be used for calculating inventory holding costs and the goal is to minimize the average annual operating costs. In line with that assumption is the practice of establishing the holding cost of inventory items as a percentage of their dollar value (Tersine, 1994).

2.2.5 Shortage Cost

Shortage costs are those costswhichare causedbecause inventories are smaller than theamount required, such aslossesoradditionalcostsare requiredbecause ofa customerdemandor orderof goodswhile thematerials (goods) requiredare notavailable.

Inthis situation, the companies willhavetwo possible options that are the demandwill be canceledcompletelyor goods that are stillless will befilledlater. Basically,the companywill not choose the first operation thatthedemandwill be canceledcompletely, because it willeliminate thecustomers symphatyandwill affect thecompany'simage. Second option, the goodsarestillless and will befulfilled atnextproduction cycle. Thus, there are two types of stock out (shortage) thatare:

1. LostSalesCost,the costscaused byinventoryshortages, thus customers tocancel theorder. The costis balanced with thebenefitsorprofits to beobtainedfromthe sale ofthese products.

2. Back OrderCost,occurswhen consumersare stillwillingtowaituntilthe orderfilled, so inthis casethe saleis not lostbut justdelayed.These costsrepresent costsspentto processthe orders, andadditionaltransportationcostsifthe orderdoes notseem tobedistributedthroughnormaldistribution

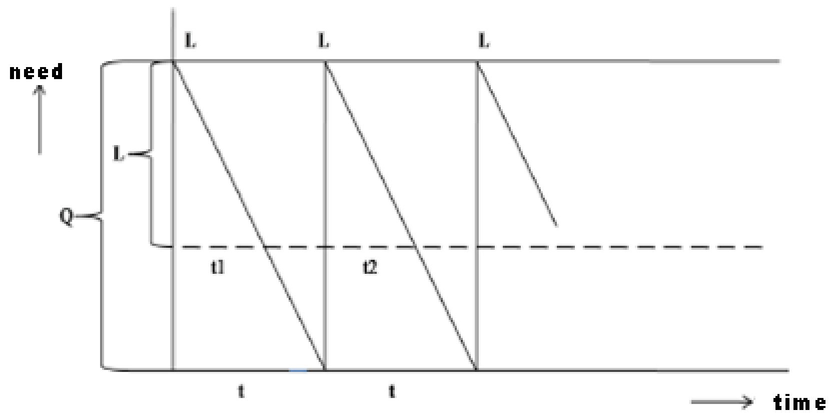


Figure 2.1 Condition of Lost Cost (Rangkuti, 2000)

According Schroeder (1994) inventory shortagecostscan be measuredfrom:

1. The quantitythat cannot befulfilled

Usuallymeasured bylostprofitsbecause the manufacturer cannot meet the demandorfromlossesdue to interruption ofthe production process. This condition istermedasa penaltycost

2. Fulfillment time

The duration ofan emptywarehousemeans theduration ofthe production processis stopped orduration ofa company may not profitable, so thatthe idletimecan bedefined asthe missing money. The cost offulfillment timeis measuredbased onthe time requiredtofulfilla warehouse

3. Emergency cost

In order to consumers not being disappointed, it can be donewhichusuallycausedan emergencyprocurementcostgreater thanthe normalprocurement. Excesscostcompared tothe normalprocurementcan be used asa measure todeterminetheunitcostinventory shortagefor exampleRp/each time theshortage

2.2.6 Inventory Model

Inventory model willdepend on thetype ofmaterial, whetherthese materialsare independent or dependent. The Independent demand is influencedby market conditionswhere outside the control ofoperating functions, and therefore it independent to the operatingfunctions otherwise the dependentdemand relatedto the demandforothergoodsandare independentlydeterminedby the market (Schroeder,1994)

According toTersine(1994)inventory demandcan be dividedinto twokindsthat are: indpendent demandinventory, theinventoryamount is notinfluencedby anamount ofotherinventory and dependentdemandinventory, theinventoryamountis influencedby the amount ofothergoodsinventory.

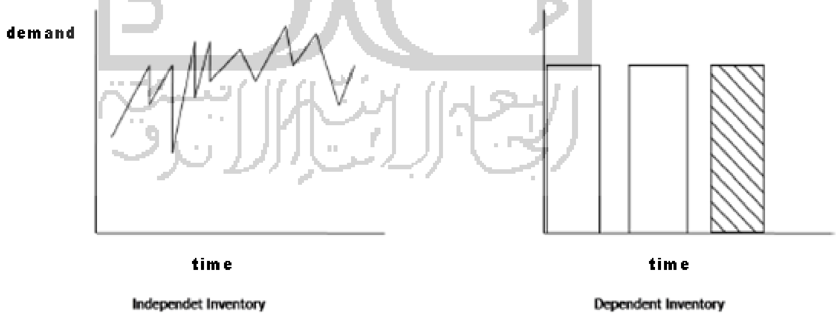


Figure 2.2Independent Inventory and Dependent inventory (Sumayang,2003)

Independent demand and dependent demand showpatterns ofdemand thatare verydifferent.

a. In theindependentdemandinventory system, theappropriate modelisthe addition ofinventoryto the amount usedorreplacement. At the time, inventoryis reduced, this conditionstimulateto immediatelymakereservationsin exchangeforinventorythat has beenused.

b. In adependentdemandinventory system, when theinventoryis reduced, theorder cannot be done. Orderingwillbe donewhen there isdemand for goodsfrom thefurtherprocess steps

2.2.7 Mathematical Model

Mathematicalmodelingisa process comprises three phases as follows (Pamuntjak, et.al., 1990):

a. Formulation ofmathematicalmodels

b. ` Completionand/oranalysis ofmathematicalmodels

c. Interpretingthe resultstoreal situations

Here isthe process offormulation ofthe phenomenon/behavior ofthe real conditioninmathematicalform. Stepin modelling, real conditionproblemsare illustratedin the following diagram:

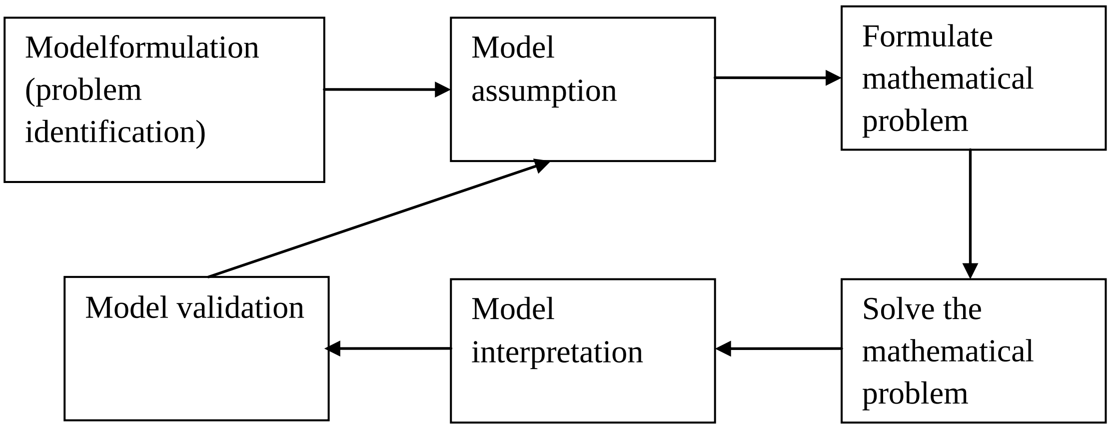


Figure2.3 Steps in modelling (Baiduri, 2002).

The nextmodeling stepscan be classifiedas follows:

1. Identify theProblem

2. MakingAssumptions

3. CompleteorInterpretativeModel

4. VerificationModel

In this study, the mathematical model used is a mathematical model formulatedbyAlfares (2007) and Shamsi, et.al. (2010), as described below:

1 Retroactive holding cost increase

In are retroactiveholdingcost, there are 3solutionalgorithmstodetermine theoptimalorderquantity(Q^*), cycletime(T^*), and TotalInventoryCost(TIC)

1a. Optimal order quantity (Q^*)

$$Q^* = \left[\frac{KD(1-\beta)(2-\beta)}{h_i}\right]^{(1/(1-\beta)} \tag{2.1}$$

1b. Cycle time (T)

$$T = \frac{Q^{1-\beta}}{D\ (1-\beta)} \tag{2.2}$$

1c. Total Inventory Cost (TIC)

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\ (1-\beta)Q}{D(2-\beta)T} \tag{2.3}$$

2. Incremental holding cost increase

InIncrementalholdingcost, an optimalsolutionalgorithmfor theoptimalorderquantity (Q*), quantityonhand (Q), and cycletime (T) based on theoptimumsolutionofTotalInventorycost (TIC)

2a. Optimal order quantity (Q*)

$$Q* = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\ Q}{(2-\beta)} + \sum_{i=1}^{e-1} (h_{i+1}-h_i)[Q^{1-\beta} -D\ (1-\beta)t_i]^{1/(1-\beta)} \tag{2.4}$$

$$-\sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)}\ x\ [Q^{1-\beta} -D\ (1-\beta)t_i]^{(2-\beta)/(1-\beta)} = 0$$

2b Total Inventory Cost (TIC)

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{(2-\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} \times [Q^{1-\beta}-D(2-\beta)t_i]^{(2-\beta)/(1-\beta)} \tag{2.6}$$

3. Planned Shortage Cost

In planned shortage models there can be both time-dependent and time-independent shortage costs

3a Time dependent shortage cost

$$TC_{\overline{B}} = C_s \ x \ \overline{B} \quad (2.7)$$

3b. Time Independent shortage cost

$$TC_B = NxC_b \ x \ B \quad (2.8)$$

2.2.8 Numericalmethod

Numerical method ore iterative method are scientific in the sense that represent systematic techniques for solving mathematical problems because the problem cannot be solved efficiently using analytical technique (Chapra and Canale,1990). There are many numerical methods for solving the minimization problem. Some of the numerical methods for finding roots of equation or solving differential equations require the user to specify initial guesses or starting point. These numerical methods process from an initial guess $x_{0,}$ determine a direction in which to search for a better approximation to a solution, construct a sequence of points x_1,.... x_i and terminate when x_i is sufficiently close to a solution.

The general Quasi-Newton iteration for approximating a solution of F(x*)= 0 for F : $IR^n IR^n$ is the iteration

$$X_{i+1}=x_k-\alpha i A_i^{-1} F(x_i) \quad (2.9)$$

Where x_i represents the *i* the approximation to the solution, the matrix A_i is viewed as an approximation to $F(x_i)$ and αi called the step length parameter. The coice of αi is refers to as step-length control, and we often call the iteration damped if 0< αi

≤ 1, and refer to $p_i = -A_i^{-1}F(x_i)$ as he search direction. The success of these iterative methods depend on the coices of A_i and αi

Numerical method can be classified into open method and close method, its an iteration method based on the number of previous iterates that the method uses at each iteration. For example, if at the *i* step, the iteration depend on precisely n of the previous iterates $x_{k-n},..., x_{k-1}$, this is called the method an n-point method. An n-point method requires n previous iteration (Kelly,1995)

2.2.9 Secant method

The secant method is one of the most popular methods for root finding. Standard text books in numerical analysis state that the secant method super linear that used to show the speed of convergence fo root-finding.

The secant method is a variation of the Newton-Raphson method due to Newtonself (Kelly,1995). This method requires two initial guesses, but unlike the bisection method, the two initial guesses do not need to bracket the root of the equation.

The secant method is an open method and may or may not converge. However, when secant method converges, it will typically converge faster than the bisection method.

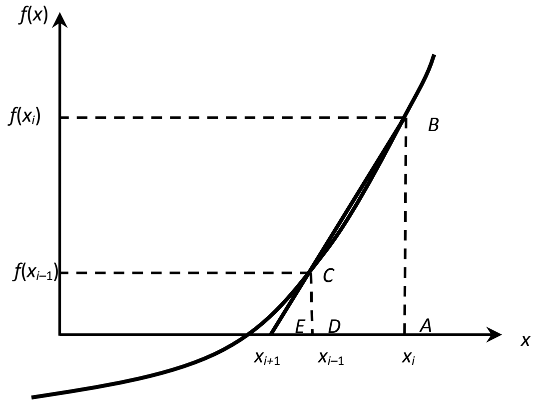


Figure 2.5 Geometrical representation of the secant method.

The secant method can also be derived from geometry, as shown in Figure 2.4. Taking two initial guesses, x_{i-1} and x_i, one draws a straight line between $f(x_i)$ and $f(x_{i-1})$ passing through the x-axis at x_{i+1}. ABE and DCE are similar triangles.

Hence

$$\frac{AB}{AE} = \frac{DC}{DE}$$

$$\frac{f(x_i)}{x_i - x_{i+1}} = \frac{f(x_{i-1})}{x_{i-1} - x_{i+1}} \tag{2.10}$$

On rearranging, the secant method is given as

$$x_{i+1} = x_i - \frac{f(x_i)(x_i - x_{i-1})}{f(x_i) - f(x_{i-1})} \tag{2.11}$$

To calculte the absolute relative approximate error $|\in_a|$

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100 \tag{2.12}$$

Advantages of secant method:

1. It converges faster than a linear rate, so that it is more rapid to convergence than the bisection method.

2. It does not require the use of the derivative of thefunction, something that is not available in a numberof applications.

3. It requires only one function evaluation per iteration, as compared to Newton's method which requires two.

Disadvantages of secant method:

1. It may not converge.

2. There is no error bound guarantee for the computed iteration

3. It is likely to have difficulty if f (α) = 0. Thismeans the x-axis is tangent to the graph of y = f (x)at x = α.

4. Newton's method generalizes more easily to the new methods for solving simultaneous systems of nonlinearequations.

5. Convergence of the secantmethod is a little slower than Newton's method

2.2.10 Convergence

There are many criterion by which can evaluate an iterative procedure, for example the length of time taken to calculate a solution or the amount of computer storage space used in the computation. The convergence rate of a method is as important as a key measure of performance. Broyden (1970) stated that the rate of convergence of a method is as important as the fact thatconverges. There could exist a situation when fast convergence occurs so late that it proves to be less benefical than slower convergence.

The Secant method converges faster than a methodwith linear convergence, but slowlythan a method with quadratic convergence:

$$| X_{f+1}| < \varepsilon \text{ or } | \frac{X_{f+1-X_f}}{X_{f+1}} | < \delta \qquad (2.13)$$

Where c_f is a constant dependent on the derivative. And this calls kind of convergence super-linear

CHAPTER III

RESEARCH METHODHOLOGY

This chapter explains the research methodhology, andthe subchapter are as follows: Location and research object, model formulation and development, system characteristic,development inventory model, data collection and processing method, discussion and analysis, and the last is conclusion and recommendation.

3.1 Location and Research Object

This research was conducted in Yopan Ceramics located at kasongan, Bantul. This research focused on the development of inventory model with variable holding cost to accomodate planned shortage.

3.2 Model Formulation and Development

In this stage, there are two models that used for this research. First, the model from Alfares (2007), that designed to determine the optimal order quantity and cycle time. This model considers the holding cost assumed to be variable and the cost will increase the time spent in storage for longer term. There are two types algorithmmodels of the variable holding cost based on increasing function of the time spent in storage, namely retroactive increase and incremental increase. For each type, a simple algoritm that minimizes the total inventory cost (TIC) is developed for calculating optimal order quantity and associated cycle time.

In Alfares model’s the shortage cost are not allowed. Thus, this research using Shamsi, et.al., (2010) model’s as second models that used to develop Alfares model’s to accomodate planned shortage.

The model used in this research considers two cost, they aretime independent shortage cost and time dependent shortage cost. To accomodate planned shortage must be considered about the administrative cost for determining time independent shotage cost and backorder cost for determining time dependent shortage cost.

3.3 System Characteristic

Thisresearch was conducted inCeramicCompany.In theproduction, the company purchaseda claymaterialfrom thesupplier. In this process, the companyasked to the supplierto processmaterialthat consists ofred soil, white soil, and sand in order to beprocessed to be clay. Then, the company made an orderbased on the needsand inventory onthe warehouse, after thatthe supplierwill sendto the company. Therefore,thecompanymust payto place an orderandthis activity iscalled theordercost.Once finished,thematerialwillbeinspectedandthenstoredinthewarehouses, thisprocesscausedstoragecost(holdingcost).

The company production activities are based on the make of order and stock. So, after theavailability ofmaterials, the company canexecutethe production processbased onorders from customersandmake somestockproductsforanticipateifthere isan additional purchase from othercustomers. In the processof production, sometimesthereisadefect product, sotheproductwillbereturnedtotheproductionfloortoberepaired(rework).

Based on theexperience ofprevious years, companiessometimeshave a shortageof materialsorproductswhenthe demand increases.Therefore,the customerusuallywillwaituntil the demandcan be fulfilled. Accordingly,the company getsadditionalcost to fulfill that demandswhich is usually calleda penaltycost (Shortage cost).

3.4 Inventory Model Development

3.4.1 Mathematical Notation

Q (t): the quantity on-hand at time t

D : constant (base) demand rate

n : number of distinct time periods with different holding cost rates

t : time from the start of the cycle at $t = 0$

t_i : end time of period *i* , where i=1, 2,..., n ,$t_0 = 0$, and $t_n = \infty$

k : ordering cost per order

h_i : holding cost of the item in period i

$h_{(t)}$: holding cost of the item at time *t* , $h_{(t)} = h_i$ if $t_{i-1} \leq t \leq t_i$

β : demand parameter indicating elasticity in relation to the inventory level

B : The number of backorders

$\overline{B}$: Average backorders

N : Number of order

P : Production rate, units per planning period, (units/year).

α : Proportion of defectives in production process in each cycle

E1 : Proportion of good items that incorrectly rejected in each cycle

E2 : Proportion of bad items that incorrectly accepted in each cycle

Cs : Annual backorder cost per unit short

Cb : Fixed administrativ backorder cost per unit stockout

3.4.2 Decision Variables

*Q** : optimal order quantity

*T** : cycle time

TIC : Total Inventory Cost

$TC_{\overline{B}}$: Totaltime dependent shortage cost

TC_B : Total time independent shortage cost

TC : Total Cost

3.4.3 Assumption and Limitations

1. The holding cost is varying as an increasing step function of time in storage.

2. Shortages are allowed

3. A single item is considered

4. Customer is still waiting if the demand cannot be fullfilled and will be backordered by company

5. Eror inspection happened in the production process

3.4.4 Inventory Model with Variable Holding Cost

This model developed by Alfares (2007), the objective is to minimize Total Inventory Cost (TIC) per unit time, which includes two components: The ordering cost, and the holding cost. Since one order is made per cycle, the ordering cost per unit time is simply *K* /*T*. The total holding cost per cycle is obtained by integrating the product of holding cost $h_{(t)}$ and inventory level $q_{(t)}$over the whole cycle.

$$TIC=\frac{K}{T}+\frac{1}{T}\int_0^T h(t)q(t)dt \tag{3.1}$$

Since the demand rate is equal to the rate of inventory level decrease, it can describe inventory level q by the following differential equation:

$$\frac{dq(t)}{dt} = -D\,[q(t)]^{\beta}, \quad D>0,\ 0\leq t\leq T,\ 0<\beta<1 \tag{3.2}$$

The on-hand inventory level at time t, $q_{(t)}$, can be evaluated by solving (3):

$q^{1-\beta} dq = - Ddt$

By integrating both sides

$\int_0^T q^{1-\beta}\, dq = \int_0^T -D\, dt$, *where* $0 \leq t \leq T$

$\frac{q^{1-\beta}}{(1-\beta)} = -Dt,$

$q^{1-\beta}(t) = D(1-\beta)t + q^{1-\beta}(0)$

However

$q^{1-\beta}(0) = Q^{1-\beta}$

Thus,

$q^{1-\beta}(t) = -D(1-\beta)t + Q^{1-\beta},$

$q(t) = [-D(1-\beta)t + Q^{1-\beta}]^{(1-\beta)}$ (3.3)

The period T can be evaluated by substituting the inventory function $q_{(t)}$ at T:

$-q^{1-\beta}(T) = -D(1-\beta)T + Q^{1-\beta}]^{1/(1-\beta)} = 0$

Hence,

$T = \frac{Q^{1-\beta}}{D(1-\beta)}$ (3.4)

Or

$$Q = [D\,(1\text{-}\beta)T]^{1/(1\text{-}\beta)} \tag{3.5}$$

3.3.5 Optimization

A. Case I : Retroactive Holding Cost Increase

As stated earlier, the holding cost is assumed to be an increasing step function of storage time, i.e. $h_1<h_2<...<h_n$. In Case 1, a uniform holding cost that depends on the length of storage is used. Specially, the holding cost of the last storage period is applied retroactively to all previous periods. Thus, if the cycle end s in period *e*, ($t_{e-1}\leq T\leq T_e$), then the holding cost rate $h_e$is applied to all periods 1, 2,...,*e* . In this case, the TIC per uni t time can be expressed as

$$TIC=\frac{K}{T}+\frac{1}{T}\int_0^T h(t)q(t)dt, \quad t_{i-1}\leq T\leq t_e \tag{3.6}$$

Substituting the value of $q_{(t)}$ from (4)

$$TIC = \frac{K}{T}+\frac{1}{T}\int_0^T \text{-}D\,(1\text{-}\,\beta)t+Q^{1\text{-}\beta}]^{1/(1\text{-}\beta)}\,dtT,$$

$$= \frac{K}{T}\text{-}\frac{h_1}{D(2\text{-}\beta)T}[\text{-}D\,(1\text{-}\,\beta)+\,Q^{1\text{-}\beta}]^{(2\text{-}\beta/(1\text{-}\beta)}$$

Thus,

$$TIC = \frac{K}{T}+\frac{h_1}{D(2\text{-}\beta)T}\times[[Q^{1\text{-}\beta}]^{(2\text{-}\beta/(1\text{-}\beta)}\text{-}[\text{-}D\,\left(1\text{-}\,\beta\right)T+Q^{1\text{-}\beta}]^{(2\text{-}\beta/(1\text{-}\beta)}]$$

Substituting the value of *T* from (3.4)

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\,(1-\beta)Q}{D(2-\beta)T}, \quad t_{i-1} \le T \le t_i \tag{3.7}$$

Setting the derivative of *TIC* with respect to *Q* equal to zero and solving for *Q* , obtain:

$$Q^* = [\,\frac{KD(1-\beta)(2-\beta)}{h_1}\,]^{(1/(1-\beta)}\;,\; Q^* = t_{i-1} \le T \le t_i \tag{3.8}$$

B. Case II: Incremental Holding Cost Increase

According to this function (incremental), higher holding cost rates apply to storage in later periods. Thus, if the cycle ends in period e, ($t_{e-1} \le T \le T_e$), then the holding cost rate h_1 is applied to period 1, rate h_2 is applied to period 2, and so on, therefore rate h_e is applied only to period e from time t_{e-1}up to time T. For this case, first reset the value of $t_e$as ($t_e=T$),and then express the TIC per unit time as

$$TIC = \frac{K}{T} + \frac{h_1}{T}\int_0^{t_i} q(t)dt + \frac{h_2}{T}\int_{t_i}^{t_2} q(t)dt + \ldots + \frac{h_e}{T}\int_{t_{e-1}}^{t_e=T} q(t)dt \tag{3.9}$$

Substituting the value of $q_{(t)}$ from (4), obtain :

$$TIC = \frac{K}{T} + \sum_{i=1}^{e} \frac{h_i}{T}\int_{t_{i-1}}^{t_i} [-D\left(1-\beta\right)t + Q^{1-\beta}]^{\frac{1}{1-\beta}}\; dt,$$

$$= \frac{K}{T} + \sum_{i=1}^{e} \frac{-h_i}{D(2-\beta)T}[-D\left(1-\beta\right)t + Q^{1-\beta}]^{(2-\beta)/(1-\beta)}$$

Substituting the value of *T* from (3.4), rearranging and simplifying terms gives:

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{(2-\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} \times [Q^{1-\beta} - D(2-\beta)t_i]^{(2-\beta)/(1-\beta)} \tag{3.10}$$

To find the optimal order size Q^*, we set the derivative of TIC with respect to Q equal to zero. After simplification, then obtained:

$$\frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i Q}{(2-\beta)} + \sum_{i=1}^{e-1} (h_{i+1}-h_i)[Q^{1-\beta} - D(1-\beta)t_i]^{1/(1-\beta)} - \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} x \quad (3.11)$$

$$[Q^{1-\beta} - D(1-\beta)t_i]^{(2-\beta)/(1-\beta)} = 0$$

3.3.7 Solution Alogorithm Variable Holding Cost

A. Case I : Retroactive Holding Cost Increase

1. Start with the lowest holding cost h_1 , use (3.8) todetermine $Q$and (3.4) to determine T for each$i$until Q is realizable (i.e. $t_{i-1} \le T \le t_i$). Call thesevalues $T_R$and Q_R .

$$Q^* = [\frac{KD(1-\beta)(2-\beta)}{h_1}]^{(1/(1-\beta)}$$

$$T = \frac{Q^{1-\beta}}{D(1-\beta)}$$

2. Use (3.5) to calculate all break -point values of $Q, t_1 \le t_i \le t_R$, each Q_i is obtained by substituting t_i into (3.5).

$$Q = [D(1-\beta)T]^{1/(1-\beta)}$$

3. Use (3.7) to calculate the TIC for Q_R and each Q_i and $TC_{\overline{B}}$

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{D(2-\beta)T} + \hat{\pi}\frac{B^2\ PL}{2Q\ (PL-D)}$$

4. Choose the value of Q that gives the lowest TIC

B Case II: Incremental Holding Cost Increase

1. Substitute h_1 into (3.8) to determine Q_{max} , and then substitute Q_{max} into (3.4) to determine T_{max}. If $T_{max} \leq 1$, stop; the solution (Q_{max}, T_{max}) is optimal.

$$Q^* = \left[\frac{KD(1-\beta)(2-\beta)}{h_1} \right]^{(1/(1-\beta)}$$

$$T = \frac{Q^{1-\beta}}{D\,(1-\beta)}$$

2. Substitute h_n into (3.8) to determine Q_{min} , and then substitute Q_{min} into (3.4) to determine T_{min} .

$$Q^* = \left[\frac{KD(1-\beta)(2-\beta)}{h_1} \right]^{(1/(1-\beta)}$$

$$T = \frac{Q^{1-\beta}}{D\,(1-\beta)}$$

3. Depending on the values of T_{min} and T_{max}, determine the possible periods that T may fall into (i.e., all feasible values of e).

4. For each feasible value of e , solve (3.11) numerically to determine the optimum value of Q. If Q corresponds to the correct period, it is considered realizable.

$$-\frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\,Q}{(2-\beta)} \sum_{i=1}^{e-1} (h_{i+1}-h_i)[Q^{1-\beta} - D\,(1-\beta)t_i]^{1/(1-\beta)} - \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)}$$

$$[Q^{1-\beta} - D\,(1-\beta)t_i]^{(2-\beta)/(1-\beta)} = 0$$

Using secant method to finding root of value of Q

$$Q_{n+1} = Q_n - \frac{f(Q_n)*(Q_n - Q_{n-1})}{f(Q_n) - f(Q_{n-1})}$$

5. Using (3.10) , calculate TIC for each Q_R and each $Q_i = Q_{(t_i)}$ and $TC_{\overline{B}}$

$$TIC = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{(2-\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} \times [Q^{1-\beta} - D(2-\beta)t_i]^{(2-\beta)/(1-\beta)} + \hat{\pi} \frac{B^2\ PL}{2Q\,(PL-D)}$$

6. Choose the value of Q that gives the lowestTIC

3.4.8 Planned Shortage Cost

This model developded by Shamsi, et.al., (2010)

During the normal production time, at rate R_1 which is equal to

$$R_1 = P\,[(1-\beta_1)(1-E_1) + \beta_1 E_2\,] - D \tag{3.12}$$

For simplification, let $L=(1-\beta)(1-E1)+\beta E2$, Thus we can write R

$$L_1 = PL-D$$

The required processing time for this quantity (the production time), t_p, is equal to Q_1/P, Includes $t_1$and t_2 respectively

$$t_1 = \frac{B}{R_1} \tag{3.13}$$

$$t_2 = t_p - t_1 \tag{3.14}$$

Cycle time, T, includes regular production time, rework process time and the idle time, i.e.,

$$T = t_{p+} t_{r+}\, t_d$$

t_d includes t_3 and t_4 where $t3=T\text{-}t_4\text{-}t_r\text{-}t_p$, $t_4=B/D$ and

$$T=\frac{Q}{D} \tag{3.15}$$

Shortage costs include the time dependent costs, the average backorder ($\bar{B}$), can be computed as

$$\bar{B}=\frac{B\,(t_1+t_4)}{2T} \tag{3.16}$$

Substituting eqs. (3.12) – (3.13) and (3.15) into Eq. (3.16), obtained

$$\bar{B}=\frac{B^2\;PL}{2Q\,(PL\text{-}D)} \tag{3.17}$$

3.4.9 Solution AlgorithmPlanned Shortage Cost

A. Time-dependent shortage costs

1 Determine average backorder ($\bar{B}$)

$$\bar{B}\;=\frac{B^2\;PL}{2Q\,(PL\text{-}D)}$$

2 Calculate total time dependent shortage cost ($TC_{\bar{B}}$)

$$TC_{\bar{B}}\;=C_s\;x\;\bar{B} \tag{3.18}$$

B Time independent shortage costs

1. Determine annual number of orders

$$N=\frac{D}{Q} \tag{3.19}$$

2 Calculate total cost backorders

$$TC_B = NxC_b \; x \, B \tag{3.20}$$

3.5 Collecting and Processing Data

Collecting and processing data are conducted to know the built which is mathematical modelling. The mathemathical modelling consist of retroactive holding increase algorithm, incremental holding increase algorithm, and planned shortage.

3.6 Discussion and Result Analysis

This step is conducted to analyze the data and discuss the result. It is supposed to know what the strength and weakness of this system. Therefore, this research could be used as references to company to policies that related to nventory

3.7 Conclusion and Suggestion

This last step is the answer of problem formulation for this research based on processing data and analysis. This section also comes with suggestions for improvements to the research.

3.8 Research Flow Diagram

The research steps are required to be organized properly in order to simplify the composing of research report. The following Figure 3.1 is the presentation of the research steps:

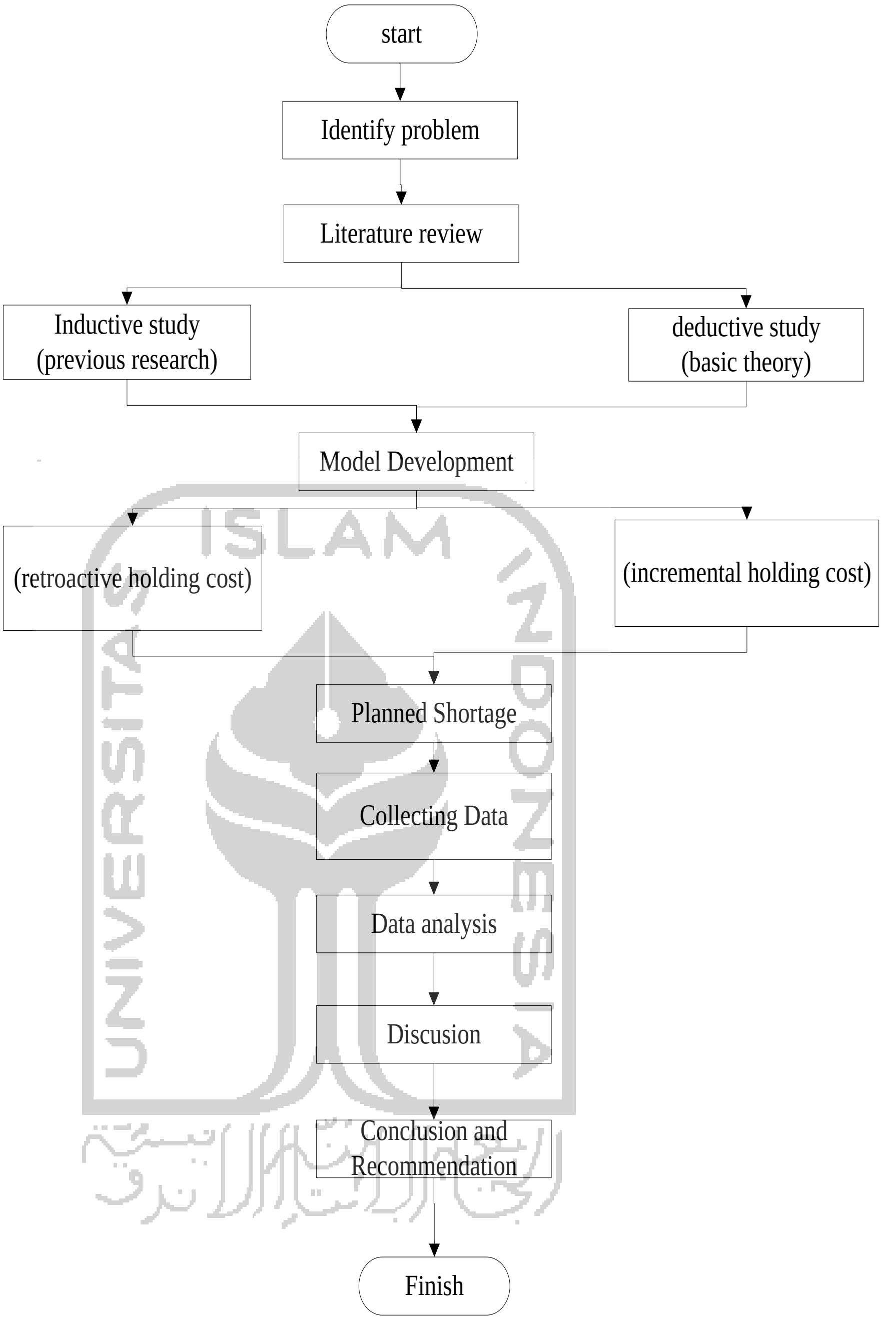


Figure 3.1 Research Framework

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 Data Collecting

The data collecting was conducted at Yopan ceramic, Kasongan Bantul. The product of yopan ceramic is spread ed out at java area such as Blitar, Surabaya, Jakarta and foreign country, such as Netherland, and U.S America.

4.1.1 Demand

Table 4.1 Actual demand

Periode	demand
October 2010	213
November 2010	209
December 2010	297
Januari 2011	213
Febuari 2011	314
Maret 2011	196
April 2011	294
Mei 2011	287
Juni 2011	217
Juli 2011	212
Agustus 2011	281
September 2011	292

4.1.2 Production rate

Table 4.2 Production rate

Periode	Production
October 2010	266
November 2010	275
December 2010	282
Januari 2011	269
Febuari 2011	295
Maret 2011	253
April 2011	283
Mei 2011	269
Juni 2011	283
Juli 2011	287
Agustus 2011	263
September 2011	275

4.1.3 Order Cost

a. Telephone time = 20 minutes

b. Telephone cost =Rp.400,-/minutes

c. Processing order = Rp. 250.000

d. Expedition cost = Rp. 50.0000

4.1.4 Holding Cost

a. Electricity cost = Rp. 100.000/month

b. Warehousing staff cost =Rp. 120.000/month

c. Warehousing staff = 2 staff

4.1.5 Shortage Cost

Thisshortage costcan bedivided by administrativ backorder cost and backorder cost. The administrative estimated Rp.500/unit order and backorder cost estimated Rp. 2500/unit

4.1.6 Defect item and Error Inspection (units)

A.defectiveitems inproduction

Defective itemsis causedthe imperfectburningprocesssothe product iscrackedorbroken

B.Error Inspection

Error Inspection is caused by incorrect inspection on products quality by the worker. So, several products could be incorrectly rejected or accepted. Item thatincorrectlyinspected is occurredwhen the item is moving tothe finishing process.

Reject items which are incorrectlyacceptedwill bereworked. While,good item that incorrectlyrejected will be stored. Since the second condition is rarely occurred in Yopan ceramics. This research assumes that the value of good item which incorrectly rejected is independently determined.

Table 4.3 Defect item and Error Inspection

Defect	Erorr inspection	
	rejected item (incorretly accepted)	Good item (incorretly rejected)
50 units	7 units	3 units

4.2 Data Processing

4.2.1 Total Demand in year (*D*)

Table 4.4 Total demand

Periods	**demand**
October 2010	213
November 2010	209
December 2010	297
Januari 2011	213
Febuari 2011	314
Maret 2011	196
April 2011	294
Mei 2011	287
Juni 2011	217
Juli 2011	212
Agustus 2011	281
September 2011	292
TOTAL	3025

So, the total demand in year 3025unit/year

4.2.2 Total Production rate in year(*P*)

Table 4.5 Total production rate

Periode	Production
October 2010	266
November 2010	275
December 2010	282
Januari 2011	269
Febuari 2011	295
Maret 2011	253
April 2011	283
Mei 2011	269
Juni 2011	283
Juli 2011	287
Agustus 2011	263
September 2011	275
TOTAL	3300

So, the total production ratein year 3300 unit/year

4.2.3 Total order cost per order (*k*)

Telephone time = 20 minutes

Telephone cost = Rp. 400, /minutes

Processing order = Rp. 250.000

Expedition cost = Rp. 50.0000

Total cost per order :

= (20*400) + 250000 + 50000

= 8000+250000+50.000

=Rp 308.000/order

4.2.4 Demand parameter elasticity in relation to inventory (*β*)

Total inventory in year = total production rate (*P*) – Total Demand (*D*)

=3300 - 3025

= 275 units

So, the demand parameter elascticity to inventory

$$\beta = \frac{\text{Inventory}}{\text{Demand}}$$

$$= \frac{275}{3025}$$

= 0,0909 ~ 0,1

So,the demand parameter elasticity to inventory is 0,1

4.2.5 Holding cost per unit per year (*h*)

1. Electricity cost

= Rp. 100.000/month x 12 month/year

= Rp. 1.200.000,-/year

2. Warehouse staff cost

= Rp. 120.000/month x 2 persons x 12

= Rp. 2.880.000,-/tahun

Total Holding cost in year = Rp. 1.200.000+ Rp. 2.880.000

= Rp. 4.080.000.-/year

So the total holding per unit per year :

$= \frac{\text{Total holding cost in year}}{\text{Prodution rate}}$

$= \frac{\text{Rp. 4.080.000}}{\text{3300 unit/year}}$ = Rp. 1236,364/unit/year

So the total holding costs per unit per year can be estimated Rp1200/units/year

Based on this research, the holding cost is an increasing of the time spent in storage($t_{e-1} \leq T \leq t_e$) so,

Table 4.6 Variable holding cost

Holding cost	Range time	Cycel time
h_1= 400	$0 \leq T \leq 0,2$	t_1=0,2
h_2= 800	$0,2 \leq T \leq 0,4$	t_2=0,4
h_3= 1200	$0,4 \leq T \leq \infty$	$t_3=\infty$

4.2.6. Proportion of defect and eror inspection (units)

1. Proportion of defect (α)

$$= \frac{\text{Total defect (units/year)}}{\text{Produstion rate}}$$

$$= \frac{\text{50 units/year}}{\text{3300 unit/year}}$$

= 0,015 units/year

2. Proportion of reject item (incorretly accepted) (E2)

$$= \frac{\text{Total reject item}}{\text{Produstion rate}}$$

$$= \frac{\text{7 units/year}}{\text{3300 unit/year}}$$

= 0,002 units/year

3. Proportion of Good item (incorretly rejected) (E1)

$$= \frac{\text{Total good item}}{\text{Produstion rate}}$$

$$= \frac{\text{3 units/year}}{\text{3300 unit/year}}$$

= 0,0009units/year

4.3 Retroactive Holding Cost Increase

In retroactive holding cost increase, a uniform holding cost depends on the length ofstorageused. Then, the holding cost of the last storage period is retroactively applied.Thus, if the cycle period ends in period $e(t_{e-1} \leq T \leq t_e)$, then the holding cost rate h_e is applied to all periods 1,2,..,e

The steps of retroactive holding cost increase calculation are :

Step1. Q and T value is determined from the lowest holding cost h_1 until Q value is realizable. Using equation (3.8) todetermine $Q$and use equation (3.4) to determine T

Iteration 1

h_1= Rp.400

$$Q^* = [\frac{KD(1-\beta)(2-\beta)}{h_1}]^{(1/(1-\beta)}$$

$$= [\frac{308.000*3025(1-0,1)(2-0,1)}{400}]^{(1/(1-0,1)}$$

= 2977,177 ~ 2978 units

$$T^* = \frac{Q^{1-\beta}}{D\ (1-\beta)}$$

$$= \frac{2978^{1-0,1}}{3025(1-0,1)}$$

$$= \frac{1338,2345}{2722,5}$$

= 0,491 years (unrealizable)

Iteration 2

h_2= Rp.800

$$Q* = [\frac{KD(1-\beta)(2-\beta)}{h_2}]^{(1/(1-\beta)}$$

$$= [\frac{308.000*3025(1-0,1)(2-0,1)}{800}]^{(1/(1-0,1)}$$

= 2067,088 ~ 2068 units

$$T* = \frac{Q^{1-\beta}}{D\ (1-\beta)}$$

$$= \frac{2068^{1-0,1}}{3025(1-0,1)}$$

= 0,35402~ 0,35 years (realizable)

Iteration 3

h_3= Rp.1200

$$Q = [\frac{KD(1-\beta)(2-\beta)}{h_i}]^{(1/(1-\beta)}$$

$$= [\frac{308000*3025(1-0,1)(2-0,1)}{1200}]^{(1/(1-0,1)}$$

= 1669,858 ~ 1670 units

$$T = \frac{Q^{1-\beta}}{D\ (1-\beta)}$$

$$= \frac{1670^{1-0,1}}{3025\ (1-0,1)}$$

= 0, 292 year (not realizable)

Step 2.Calculate all break-point values of Q using equation (3.5)

Iteration 1

Q_1 $= [D\ (1\text{-}\beta)T]^{1/(1\text{-}\beta)}$

$= [3025\ (1\text{-}0,1)0,2]^{1/(1\text{-}0,1)}$

= 1096,472 ~ 1097 units

Iteration 2

Q_2 $= [D\ (1\text{-}\beta)T]^{1/(1\text{-}\beta)}$

$= [3025\ (1\text{-}\ 0,1)0,4]^{1/(1-0,1)}$

= 2368,511 ~ 2369 units

Step 3. Calculate the total inventory cost (*TIC*) for $Q_R$and each Q_i using equation (3.7)

Iteration 1

TIC (2068) $= \frac{KD(1\text{-}\beta)}{Q^{1\text{-}\beta}} + \frac{h_i\ (1\text{-}\beta)Q}{(2\text{-}\beta)}$

$= \frac{308000*3025(1\text{-}0,1)}{2068^{1\text{-}0,1}} + \frac{800(1\text{-}0,1)2068}{(2\text{-}0,1)}$

= 870007,75 + 783663,15

= Rp.1.653.670,90/year

Iteration 2

$$TIC\ (1097) = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\ (1-\beta)Q}{(2-\beta)}$$

$$= \frac{308000*3025(1-0,1)}{1097^{1-0,1}} + \frac{400\ (1-0,1)1097}{(2-0,1)}$$

= 1539333,21 + 207852,63

=Rp.1.747.185,8/year

Iteration 3

$$TIC\ (2369) = \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i\ (1-\beta)Q}{(2-\beta)}$$

$$= \frac{308000*3025(1-0,1)}{2369^{1-0,1}} + \frac{800(1-0,1)2369}{(2-0,1)}$$

= 769856,9775 + 897726,3158

= Rp.1.667.583,293/year

Step 4. Choose the value of Q that gives the lowest TIC

Based the iteration above, the optimum solution obtained is Q = 2068 units, T = 0,35 years, and *TIC* =Rp. 1.653.670,90 /year

4.4 Incremental Holding Cost Increase

In Incremental holding increase, higher storage cost rates isapplied to storage in later periods. Thus, if the cycle ends in period $e(t_{e-1} \leq T \leq t_e)$, the holding cost rate h_1 is applied to period 1, rate h_2 is applied to period 2 then h_e is applied to period e

Step1. Determine Q_{max} using equation (3.8) and T_{max} use equation(3.4)

From previous calculation (retroactive holding increase),$Q_{max}$and T_{max} is obtained:Q_{max} = 2978 units and T_{max}= 0,491 years. Since $T_{max} > t_1$, the process is continued

Step 2. Determine Q_{min}using equation (3.8) and T_{min} use equation(3.4)

$$Q_{min} = \left[\frac{KD(1-\beta)(2-\beta)}{h_i}\right]^{(1/(1-\beta)}$$

$$= \left[\frac{308000*3025(1-0,1)(2-0,1)}{1200}\right]^{(1/(1-0,1)}$$

= 1669,858~ 1670 units

$$T_{min} = \frac{Q^{1-\beta}}{D\ (1-\beta)}$$

$$= \frac{1670^{1-0,1}}{3025\ (1-0,1)}$$

= 0, 292 years

Step 3. Determinine the possible periods of T, Depending on the values of T_{min} and T_{max}

Since T_{min} included period 2 and T_{max}included period 3. The total inventory cost to be calculated only for period 2 and 3

Step 4. Determine the optimum value of*Q*using equation (3.11) numerically for each feasible value of e

a) *e*=2, with *T* and *Q* range is 0, 292 $\leq T \leq$ 0,4 and 1670 $\leq Q \leq$ 2369

$$-\frac{KD(1-\beta)}{Q^{1-\beta}}+\frac{h_i Q}{(2-\beta)}+\sum_{i=1}^{e-1}(h_{i+1}-h_i)[Q^{1-\beta}-D\,(1-\beta)t_i]^{\frac{1}{1-\beta}}-\sum_{i=1}^{e-1}\frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)}\,x$$

$$[Q^{1-\beta}-D\,(1-\beta)t_i]^{\frac{2-\beta}{1-\beta}}=0$$

$$-\frac{308000*3025(1-0,1)}{Q^{1-0,1}}+\frac{400\,Q}{(2-0,1)}+\sum_{i=1}^{e-1}(800-400)[Q^{1-0,1}-3025\,(1-0,1)0,2]^{\frac{1}{1-0,1}}-$$

$$\sum_{i=1}^{e-1}\frac{(800-400)(1-0,1)}{Q^{1-0,1}(2-0,1)}x[Q^{1-0,1}-3025\,(1-0,1)0,2]^{\frac{2-0,1}{1-0,1}}=0$$

So the equation is

$$-\frac{838530000}{Q^{0,9}}+\frac{400\,Q}{1,9}+400[Q^{0,9}-544,5]^{\frac{1}{0,9}}-\frac{360}{1,9Q^{0,9}}\,x[Q^{0,9}-544,5]^{1,9/0,9}=0$$

Solve this equation by the secant method,using range limit *Q*=1670 and *Q*=2369 as initial values, So

Q_1 = 1670 units $f(Q_1)$ = - 545427

Q_2 = 2369 units $f(Q_2)$ = 63711,33275

Secant method :

$$Q_{n+1} = Q_n - \frac{f(Q_n)*(Q_n - Q_{n-1})}{f(Q_n) - f(Q_{n-1})}$$

Iteration 1

$$Q_{(3)} = Q_2 - \frac{f(Q_2)*(Q_2 - Q_1)}{f(Q_2) - f(Q_1)}$$

$$= 2369 - \frac{63711{,}33275*(2369-1670)}{63711{,}33275-(-545427)}$$

$$= 2295{,}889837 \text{ units}$$

Absolute relative approximate error $|\in_a|$ for itreration 1

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2369 - 1670}{2369}\right| \times 100$$

= 29,506 %

Iteration 2

$$Q_{(4)} = Q_3 - \frac{f(Q_3)*(Q_3 - Q_2)}{f(Q_3) - f(Q_2)}$$

$$= 2295{,}889837 - \frac{8450{,}587216*(2295{,}889837-2369)}{8450{,}587216-63711{,}33}$$

$$= 2284{,}70968 \text{ units}$$

Absolute relative approximate error $|\in_a|$ for itreration 2

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2295{,}88 - 2369}{2295{,}88}\right| \times 100$$

= 3,184 %

Iteration 3

$Q_{(5)} = Q_4 - \frac{f(Q_4)*(Q_4 - Q_3)}{f(Q_4) - f(Q_3)}$

$= 2284{,}70968 - \frac{(-129{,}455102)*(2284{,}70968-2295{,}889837)}{(-129{,}455102)-8450{,}587216}$

= 2284,878366 units

Absolute relative approximate error $|\in_a|$ for itreration 3

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2284{,}709 - 2295{,}88}{2284{,}709}\right| \times 100$$

= 0,489 %

Iteration 4

$Q_{(6)} = Q_5 - \frac{f(Q_5)*(Q_5 - Q_4)}{f(Q_5) - f(Q_4)}$

$$= 2284{,}878366 - \frac{0{,}264100873*(2284{,}878366-2284{,}70968)}{0{,}264100873-(-129{,}456)}$$

= 2284,878023 units

Absolute relative approximate error $|\in_a|$ for itreration 4

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2284{,}878 - 2284{,}709}{2284{,}878}\right| \times 100$$

= 0,00738 %

Iteration 5

$$Q_{(7)} = Q_6 - \frac{f(Q_6)*(Q_6-Q_5)}{f(Q_6)-f(Q_5)}$$

$$= 2284{,}878023 - \frac{8{,}2578\ 10^{-6}*(2284{,}878023-2284{,}878366)}{8{,}2578\ 10^{-6}-0{,}264100873}$$

= 2284,878023 units

Absolute relative approximate error $|\in_a|$ for itreration 5

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2284{,}8783 - 2284{,}8780}{2284{,}878}\right| \times 100$$

= 0,00002 %

Value Q already convergence, so Q = 2285 units (realizable, since e = 2 means 1097$\leq Q \leq$ 2369, thus Q_R = 2285)

b)e=3, with T and Q range is $0{,}4 \leq T \leq 0{,}491$and $2369 \leq Q \leq 2978$

$$-\frac{308000*3025(1\text{-}0{,}1)}{Q^{1-0{,}1}}+\frac{400\,Q}{(2\text{-}0{,}1)}+(800\text{-}400)[Q^{1-0{,}1}\ \text{-}3025\ (1\text{-}\ 0{,}1)0{,}2]^{\frac{1}{1-0{,}1}}-\frac{(800-400)(1-0{,}1)}{Q^{1-0{,}1}(2-0{,}1)}[Q^{1-0{,}1}\ -$$

$$3025\ (1-\ 0{,}1)0{,}2]^{\frac{2-0{,}1}{1-0{,}1}}+(1200-800)[Q^{1-0{,}1}\ -$$

$$3025\ (1-\ 0{,}1)0{,}4]^{\frac{1}{1-0{,}1}}-\frac{(1200-800)(1-0{,}1)}{Q^{1-0{,}1}(2-0{,}1)}x[Q^{1-0{,}1}\ -3025\ (1-\ 0{,}1)0{,}24=$$

0

So the equation is

$$-\frac{838530000}{Q^{0,9}}+\frac{400\,Q}{1,9}+400[Q^{0,9}\ \text{-}544{,}5]^{\frac{1}{0,9}}\text{-}\frac{360}{1{,}9Q^{0,9}}x[Q^{0,9}\ \text{-}544{,}5]^{\frac{1,9}{0,9}}+$$

$$400[Q^{0,9}\ \text{-}1089]^{\frac{1}{0,9}}\text{-}\frac{360}{1{,}9Q^{0,9}}\ x[Q^{0,9}\ \text{-}1089]^{1,9/0,9}=0$$

Solve this equation by the secant method,using range limit Q=2369 and Q=2978 as initial values, So

Q_1 =2369units$f(Q_1)$ = 63779,08683

Q_2 = 2978units$f(Q_2)$ = 647554,2756

Secant method :

$$Q_{n+1} = Q_n - \frac{f\,(Q_n)*(Q_n - Q_{n-1})}{f\,(Q_n) - f\,(Q_{n-1})}$$

Iteration 1

$$Q_{(3)} = Q_2 - \frac{f(Q_2)*(Q_2 - Q_1)}{f(Q_2) - f(Q_1)}$$

$$= 2978 - \frac{647554{,}2756*(2978-2369)}{647554{,}2756-63779{,}08683}$$

$$= 2302{,}465031 \text{units}$$

Absolute relative approximate error $|\in_a|$ for itreration 1

$$|\in_a| = \left|\frac{x_1 - x_0}{x_1}\right| \times 100$$

$$|\in_a| = \left|\frac{2978 - 2369}{2978}\right| \times 100$$

$$= 20{,}449\%$$

Based on calculation, iteration 2 is divergence, so Q = 2302 is not realizable\

Step 5. Calculate the total inventory cost (*TIC*)using equation (18) for each$Q_R$and each Q_i

Iteration 1

$$TIC(1097) = \frac{KD(1\text{-}\beta)}{Q^{1\text{-}\beta}} + \frac{h_i(1\text{-}\beta)Q}{(2\text{-}\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}\text{-}h_i)(1\text{-}\beta)}{Q^{1\text{-}\beta}(2\text{-}\beta)} \text{ x } [Q^{1\text{-}\beta}\text{-}D(2\text{-}\beta)t_i]^{(2\text{-}\beta)/(1\text{-}\beta)}$$

$$\frac{308000*3025(1\text{-}0{,}1)}{Q^{0{,}9}} + \frac{400(1\text{-}0{,}1)Q}{(2\text{-}0{,}1)} + \frac{(800\text{-}400)(1\text{-}0{,}1)}{Q^{1\text{-}0{,}1}(2\text{-}0{,}1)} \text{ x}$$

$$[Q^{1-0,1} - 3025\ (2-0,1)0,2]^{\frac{2-0,1}{1-0,1}}$$

$$= \frac{838530000}{Q^{0,9}} + \frac{360\ Q}{1,9} + \frac{360}{1,9Q^{0,9}} \text{ x } [Q^{0,9} - 544,5]^{1,9/0,9}$$

= 1539333,214 + 207852,6316+ 0,00087 x0,04738

= Rp.1.747.185,8

Iteration 2

TIC (2285) $= \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{(2-\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} \text{x}[Q^{1-\beta}-D(2-\beta)t_i]^{(2-\beta)/(1-\beta)}$

$$= \frac{308000*3025(1-0,1)}{Q^{0,9}} + \frac{400(1-0,1)Q}{(2-0,1)} + \frac{(800-400)(1-0,1)}{Q^{1-0,1}(2-0,1)}\ x$$

$$[Q^{1-0,1} - 3025\ (2-0,1)0,2]^{(2-0,1)/(1-0,1)}$$

$$= \frac{838530000}{Q^{0,9}} + \frac{360\ Q}{1,9} + \frac{360}{1,9Q^{0,9}} \text{ x } [Q^{0,9} - 544,5]^{1,9/0,9}$$

= 795281,7583 + 432947,3684 + 0,000449 x 519717,79

= Rp.1.228.462.61

Iteration 3

TIC (2369) $= \frac{KD(1-\beta)}{Q^{1-\beta}} + \frac{h_i(1-\beta)Q}{(2-\beta)} + \sum_{i=1}^{e-1} \frac{(h_{i+1}-h_i)(1-\beta)}{Q^{1-\beta}(2-\beta)} \times[Q^{1-\beta}-D(2-\beta)t_i]^{(2-\beta)/(1-\beta)}$

$$= \frac{308000*3025(1-0,1)}{Q^{0,9}} + \frac{400(1-0,1)Q}{(2-0,1)} + \frac{(800-400)(1-0,1)}{Q^{1-0,1}(2-0,1)}\ \text{x}$$

$$[Q^{1-0,1} - 3025\ (2- 0,1)0,2]^{(2-0,1)/(1-0,1)}$$

$$= \frac{838530000}{Q^{0,9}} + \frac{360\ Q}{1,9} + \frac{360}{1,9Q^{0,9}} \text{ x } [Q^{0,9} - 544,5]^{1,9/0,9}$$

= 769856,9775 + 448863,1579 + 0,000435 x 597497,55

= Rp.1.218.979,98

Step 6. Choose the value of *Q* that gives the lowest *TIC*

Based the iteration above, the optimum solution obtained is *Q* = 2369, *T** = 0,4And *TIC* = Rp.1.218.979,98/year

The result of comparasion between retroactive and incremental holding cost increase shows that thetotal inventory cost of incremental holding cost less costly than retroactive holding cost.

4.5 Planned Shortage

To planned shortage, consider the optimum backorder (*B**) based on optimal order size (*Q**) that already be calculated. To calculate optimum backorder using equation (3.18)

$$B^* = \frac{h\ Q^* - DC_b}{h + C_s}$$

$$= \frac{(1200 \text{ x } 2369) - (3025 \text{x } 500)}{1200+2500}$$

$$= \frac{2842800 - 1512500}{1200+2500}$$

= 359,540~ 360 units

In planned shortage models there can be both time-dependent and time-independent shortage costs

a. Time-dependentshortage costs

Step 1.Determine average backorder ($\bar{B}$)

(i) Calculate the normal production timeat rate R_1 usingequation (3.12)

R_1 = P [(1- α)(1-E$_1$)+αE$_2$]-D

=3300 [(1- 0,015)(1-0,002)+0,015*0,0009]-3025

=3244,044 -3025

= 219,0436 ~ 220units

(ii) Determine average backorder using equation (3.17).For simplification, let L= (1-β) (1-E1) +βE2,

$$\overline{B} = \frac{B^2\ PL}{2Q\ (PL\text{-}D)}$$

$$= \frac{360^2 \text{ x } 3244{,}044}{2(2369)\text{x } 220}$$

= 403,342~ 404 units

Step 2.Calculate total time dependent shortage cost ($TC\bar{B}$) using equation (3.18)

$TC\bar{B}$ = C_s x$\bar{B}$

=$2500\ x\ 404$

=Rp.1.010.000/year

b. Time independentshortage costs

Step 1 Determine annual number of orders using equation (3.19)

$N = \frac{D}{Q}$

$= \frac{3025}{2369}$

= 1,27691~1 orders

Step 2 Calculate total cost backorders using equation (3.20)

TC_B = N_oxC_b x B

=1 x 500 x 360

= Rp. 180.000

4.6 Total annual cost

$TC = TIC + (TC\bar{B} + TC_B)$

= Rp.1.218.979 + (Rp.1.010.000 + Rp. 180.000)

= Rp.1.218.979 + Rp.1.170.000

= Rp. 2.408.979

CHAPTER V

DISCUSSION

5.1 Model Analysis

Based on the processing data in chapter IV, there are some data that shows that the demand greather than production rate and this condition creates a shortage. In the figure 5.1, the shortage condition happen at CV. Yopan Ceramics on the December 2010, March 2011, April 2011, May 2011, August 2011, and September 2011.

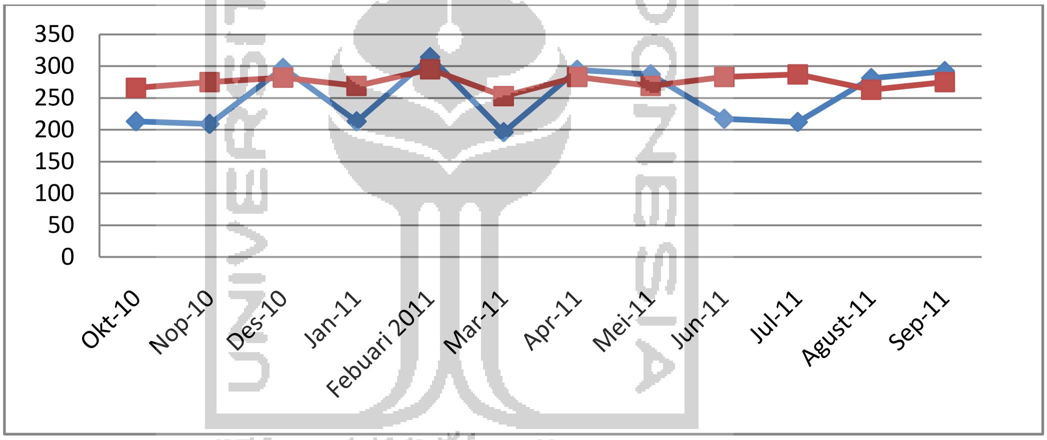


Figure 5.1 Production and Demand graph

As explanation in previous chapter, based on the real condition at CV, Yopan Ceramics related with has inventories in a storage. Therefore, to store the inventories need costs that called holding cost, and value of holding cost is variable based on time spent in storage. To solve that problem, this research using mathematichal way by Alfares model's to represent optimal solution in variable holding cost. Thereare two type ofvariable holding cost that are retroactive and incremental holding cost and also divided into 3 different periods, that are short term, medium term,and long term.Firstly, the final result of retroactive holding cost shows *Q**= 2068, *T**=0,35 and *TIC**= Rp.1.667.583,29.

Based on the function of incremental holding cost that the unit stored only used for particular periods, thus the result only calculated in period 2 and 3 using secant method that need two initial guess ($Q_1$and Q_2) to find the optimum value

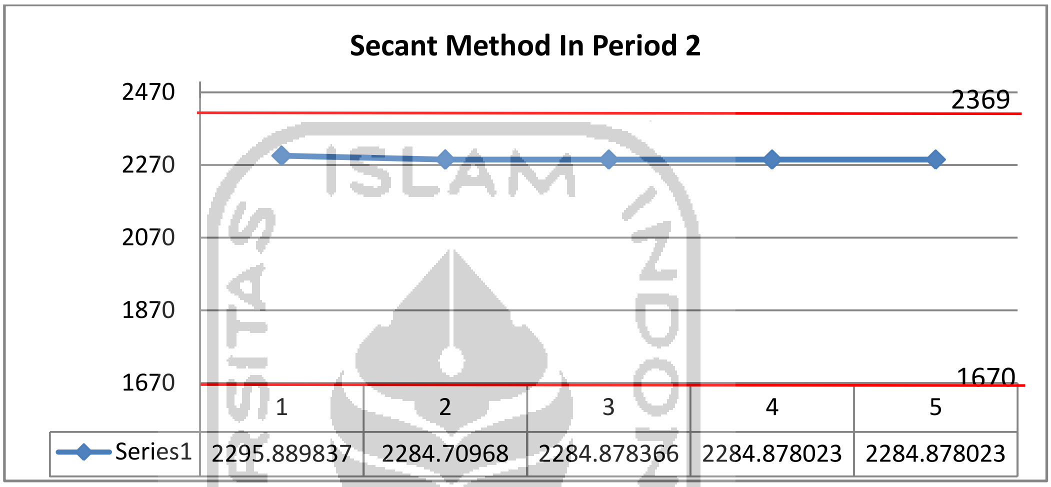


Figure 5.2 Convergence of Secant Method for period 2

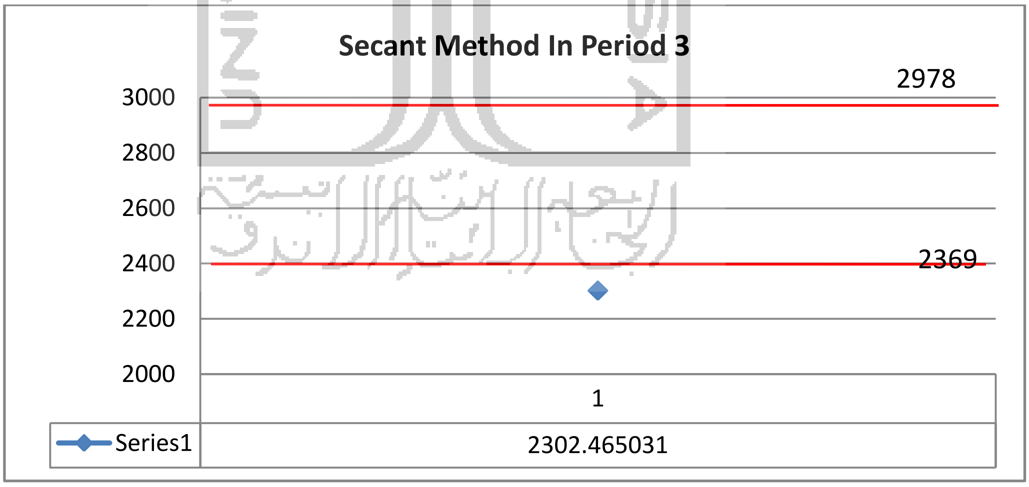


Figure 5.3divergence of Secant Method for period 3

The convergence graph above shows that period 2 is convergence at fifith iterations and also still in control of the range of period 2 but in period 3 the value is out of control. Thus, its indicate thatthe value of period 2is realizable and the result of incremental holding cost increase shows *Q**=2369, *T**=0,4 and*TIC**=Rp.1.218.979,98/years. Based on the result of TIC shows that the incremental holding cost lower than retroactive Therefore, incremental function in holding cost less costly and to be the best optimum solution than retroactive function.

To answer the real condition problem that the shortages can't be avoided because of uncertainties such as the demand greather than avaibility and material avaibility. Thus, company need to accomodate planned shortage to anticipate that conditions and the customer demand could be fulfilled quickly. Based on Shamsi ,et.al., model's, in planned shortage there can be both time that are time dependent that consider the backorder cost and time independent that related with administrative backorder cost. The result shows the B^*=360 units, $TC_{\bar{B}}$ =Rp.1.110.000, and TC_B=Rp.180.000

5.2 Sensitivity Analysis

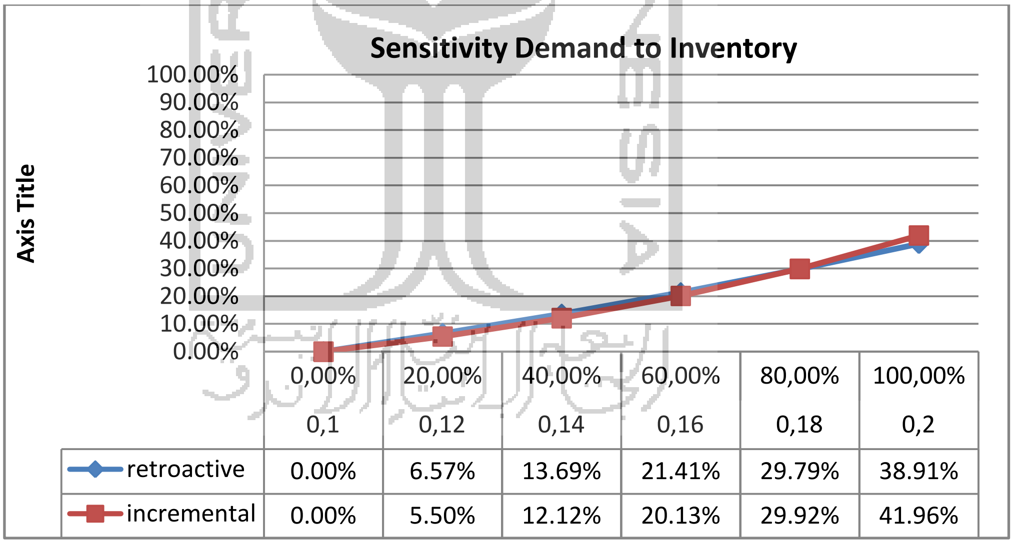
Sensitivity analysis is used to see how much the changes of Total Inventory Cost (TIC) by changing the parameter. The parameter that will be used is the demand elasticity to inventory (β), holding cost (h), and period time (t). The sensitivity analysis as follow;

5.2.1 Changes of Demand Elasticity to Inventory(β)

The sensitivity analysis for demand elasticity to inventory as follows;

In figure 5.4 shows the sensitivity of demand elasticity to inventory, then the effects *TIC*over the demand elasticity to inventory (β) are studied by changing the β values over the range from 0.00% to 100%. If the demand elasticity increase 20%, it will be increasing in *TIC* to 6,57% for retroactive holding cost, and 5,50% for incremental holding cost. If the demand elasticity increase 40%, it will be increasing in *TIC* to

13,69% for retroactive holding cost, and 12,12% for incremental holding cost. If the demand elasticity increase 60%, it will be increasing in *TIC* to 21,41% for retroactive holding cost, and 20,13% for incremental holding cost. If the demand elasticity increase 80%, it will be increasing in *TIC* to 29,79% for retroactive holding cost, and 29,92% for incremental holding cost. If the demand elasticity increase 100%, it will be increasing in *TIC* to 38,91% for retroactive holding cost, and 41,96% for incremental holding cost. It is observed that the total inventory cost are directly related with demand elasticity to inventory and its effect becomes increasing inventory cost if the value of demand elasticity to be increased. Based on the figure 5.4, can be analyzed that the total inventory cost using incremental model higher than using retroactive if the demand elasticity changed to 80%



	0,00%	20,00%	40,00%	60,00%	80,00%	100,00%
	0,1	0,12	0,14	0,16	0,18	0,2
retroactive	0.00%	6.57%	13.69%	21.41%	29.79%	38.91%
incremental	0.00%	5.50%	12.12%	20.13%	29.92%	41.96%

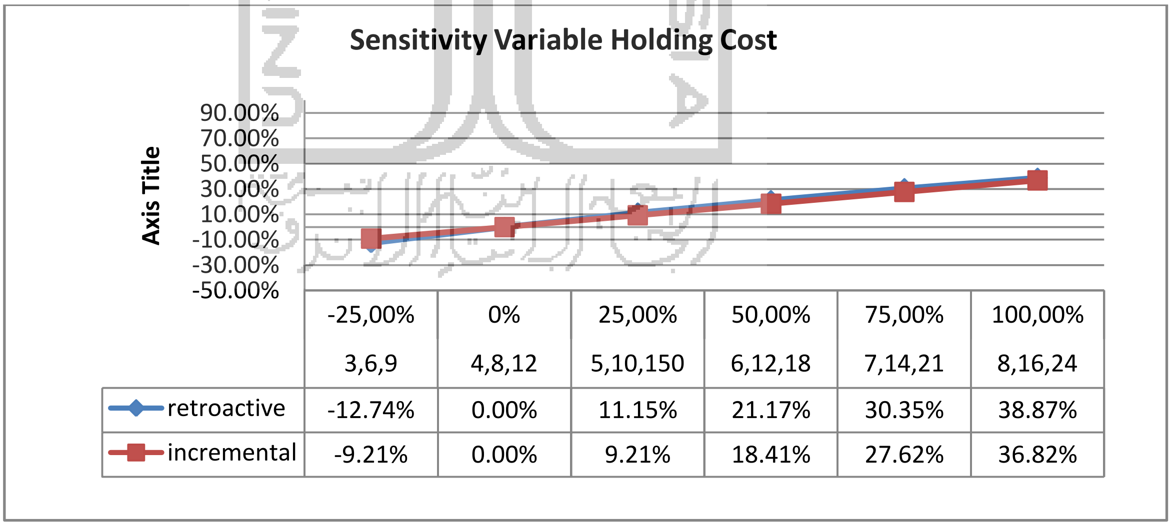
Figure 5.4 Changes of Demand elasticity to inventory

5.2.2 Changes ofVariable Holding Cost(*h*)

The sensitivity analysis for variableholding cost as follows;

In figure 5.4 shows the sensitivity of variableholding cost, then the effects *TIC*over the holding cost (*h*) are studied by changing the h values over the range from -25% to 100%. If the variable holding cost decrease 20%, it will be decreasing in *TIC* to

12,47% for retroactive holding cost, and 9,21% for incremental holding cost. If the variable holding cost increase 20%, it will be increasing in *TIC* to 11,15% for retroactive holding cost, and 9,21% for incremental holding cost. If the variable holding cost increase 50%, it will be increasing in *TIC* to 21,17% for retroactive holding cost, and 18,41% for incremental holding cost. If the variable holding cost increase 75%, it will be increasing in *TIC* to 30,35% for retroactive holding cost, and 27,62% for incremental holding cost. If the variable holding cost increase 100%, it will be increasing in *TIC* to 38,87% for retroactive holding cost, and 36,82 % for incremental holding cost. It is observed that the total inventory cost are directly related with variable holding cost and its effect becomes decreasing inventory cost if the value of variable holding cost to be decreased and otherwise. Based on the figure 5.5, can be analyzed if the total inventory cost using incremental modelstill less than using retroactive.



	-25,00% 3,6,9	0% 4,8,12	25,00% 5,10,150	50,00% 6,12,18	75,00% 7,14,21	100,00% 8,16,24
retroactive	-12.74%	0.00%	11.15%	21.17%	30.35%	38.87%
incremental	-9.21%	0.00%	9.21%	18.41%	27.62%	36.82%

Figure 5.5 Changes of Variable Holding Cost

5.2.2 Changes ofPeriod Time(*t*)

The sensitivity analysis for period time as follows;

In figure 5.4 shows the sensitivity of period time, then the effects *TIC*over the period time (*t*) are studied by changing the t values over the range from 0% to 50%. If the period timeincrease 25%, it will be decreasing in *TIC* to 9,40% for retroactive holding cost, and 9,53% for incremental holding cost. If the period time increase 50%, it will be increasing in *TIC* to 11,15% for retroactive holding cost, and 14,36 % for incremental holding cost. It is observed that the total inventory cost are directly related with period time and its effect becomes increasing inventory cost if the value of period time to be increased. Based on the figure 5.5, can be analyzed if the total inventory cost using retroactive model less than using incremental. Because of in the inventory cost of incremental influenced by period time. Thus, if the value of period time increased it also influence the inventory cost of incremental model to increasing.

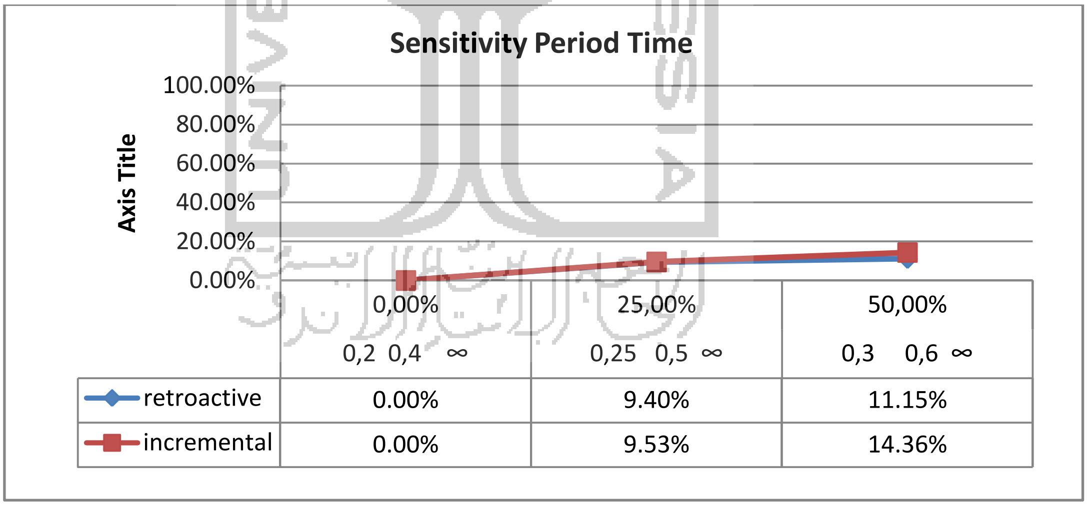


Figure 5.6 Changes of period time

CHAPTER VI

CONCLUSION AND SUGGESTION

6.1 Conclusion

From all of processes that have been done in this research, based on the problem questionscan be concluded that:

1. The result of retroactive holding cost is optimal order quantity =2068, optimal cycle time =0,35 and total inventory cost= Rp.1.667.583,29. The result of incremental holding cost is optimal order quantity =2369, optimal cycle time=0,4, and total inventory cost =Rp.1.218.979,98/years. Thus, incremental function in holding cost less costly and to be best optimum solution than retroactive function.
2. In planned shortage there can be both time that are time dependent that consider the backorder cost and time independent that cosider the administrative bakorder cost. The result shows the optimum backorder =360 units, time dependent shortage cost =Rp.1.110.000, and time independent shortage cost =Rp.180.000
3. Based on the sensitivity analysis, the variable holding cost has significant effect to inventory cost. If the variable holding cost increases50%, it will be increasing in TIC to 21,17% for retroactive holding cost, and 18,41 % for incremental holding cost.

6.2 Suggestion

Based on the result of the research and discussionthat have been done, can be concluded :

1. Inthisresearch, thevariablecostusing3differentperiodsrange,those areshort term, medium term, andlong term. Thus, the research withan additionalrange ofperiodsanddifferent periods of timewillgivedifferent results.
2. This research still using single item,so the research need to be continued with multi-items and also additional cost such as inspection cost, rework cost, and another cost that related in the production system

This thesis, I dedicate to my parents,

Thanks to my Dad and Mom for your prayer

sacrifice and advices.

MOTTO

"O you, who have believed, seek help through patience and prayer. Indeed, Allah is with the patient." (Al-Baqarah: 153)

"There is no problem that can not be solved as long as there commitment to resolve"

"Allah has educated me with the best of education."

(HR. by Ahmad)

PREFACE

بسم الله الرحمن الرحيم

Assalamualikum Wr.Wb

Alhamdulillahi robbil a'lamin. First of all, I would like to say thanks to Allah SWT that always give us bless and mercy for all mankind who had faith and worship to God. Because of His bless and mercy, I can finish my thesis with Title **INVENTORY MODEL BASED WITH VARIABLE HOLDING COST TO ACCOMODATE PLANNED SHORTAGE.** This Thesis is part of requirement to get bachelor's degree of Industrial Engineering Department at University Islam Indonesia.

I would also like to express my profound gratitude for the love, support, and faith to my parents, Nurjono, SH and Puji Rahayu. And I'm so thankful for the happiness brought by my sisters, Galuh Hayu Noormalisa, and my brother, Rizda Noor Ali Wicaksono and Swastika Noor Yudha Pratama

In this opportunity I would like to say special thanks and deepest respect to my supervisor Dr. Mirwan Ushada, S.TP, M.App.Life.Sc that always gives support, advice, guidance, and suggestion to me so that I can finish my thesis. Furthermore, my appreciation goes to CV. Yopan Ceramic for the cooperation as my research object.

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Wassalamualaikum Wr. Wb

Yogyakarta,February 30, 2012

Author

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