CHAPTER 2
LITERATURE REVIEW AND THEORITICAL BACKGROUND

This chapter explains the previous researches in decreasing demand problems and theoretical background of lot sizing technique those are being used in this research. This chapter is divided into three sub-discussions, which are the literature review based on minimizing total cost to avoid lost from not used item because of decreasing demand trend; and the theoretical backgrounds of some heuristic methods in Lot Sizing. Later in this chapter, the previous researches on minimizing total cost in decreasing demand problem are compared one to each other to show the research gap.

2.1. Decreasing Demand Problem

Benkherouf (1995) did a research for non-linear decreasing demand which was exponentially distributed using numerical example and his theory. His research used finite planning horizon with zero initial and final inventory. He decided the replenishment quantity to solve the problem. Next year, Benkherouf (1998) did another research with the same characteristic with the previous research, but he added Newton method to his research. The decision variable for his research was the lot size.

Chu and Chen (2002) solved an exponential decreasing demand problem using his theory and Newton method. His research used finite planning horizon with zero initial and final inventory. He decided the replenishment quantity. Those 3 authors solved a deterministic model.

Hill *et. al.* (1999) solved a poisson decresing demand problem using numerical example and dynamic programming. His research used finite planning horizon with zero initial and final inventory which inventory stock as the decision variable. Different with previous author, he solved stochastic model.

Ouyang *et. al.* (2005) solved an exponential decreasing demand problem and constructed EOQ model. They solved the problem by using numerical example and EOQ calculation, then decided the replenishment quantity.

Pujawan and Kingsman (2003) solved a lumpy demand problem using lot sizing techniques and decided which lot sizing technique was appropriate to lumpy demand problem.

Goyal and Giri (2003) solved a linear decreasing demand problem by using 5 different methods: Silver; CLUC; CTPP; YZR; and Numerical example. The characteristic of the problem were finite planning horizon with zero initial and final inventory. They decided the number of replenishment quantity.

Sicilia *et. al.* (2011) did a research of exponentially decreasing demand by using numerical example. Theirs research categorized as deterministic model.

Wee (1995) did a research in exponential – deterministic decreasing demand problem by using numerical example, Newton, and Hollier-Mark. The characteristic of the problem was finite planning horizon with zero initial and final inventory. He decided the lot size in his research.

Zhao *et al*. (2001) did a research in linear decreasing demand and construct an Eclectic model. He conducted Silver, CLUC, CTPP, YZR, and Ritchie's Cubic methods. Theirs research used finite planning horizon with zero initial and final inventory. They decided the replenishment quantity as the decision variable of the problem. It was similar from the previous research, but Yang *et al*. (2002) did a research with Parametric Model to determine the replenishment quantity.

Table 2.1. Gap Analysis

	Non-Linear Decreasing Demand Pattern	Model	Heuristics Calculation	Method(s)							Finite Planning Horizon	Zero Initial and Final Inventory	Decision Variable		
				Silver	CLUC	CTPP	YZR	Numerical Example	Newton	Else			Replenishment Quantity	Lot Size	Inventory Stock
Benkherouf (1995)	Exponential	Deterministic Model	√					√		Benkherouf	√	√	√		
Benkherouf (1998)	Exponential	Deterministic Model	√						√	Benkherouf	√	√		√	
Chu and Chen (2002)	Exponential	Deterministic Model	√					√	√	Chu - Chen	√	√	√		
Goyal and Giri (2003)			√	√	√	√		√			√	√	√		
Hill, Omar, and Smith (1999)	Poisson	Stochastic Model	√					√		Dynamic Programming	√	√			√
Ouyang, Wu, and Cheng (2005)	Exponential	EOQ	√					√		EOQ			√		
Pujawan and Kingsman (2003)	Normal	Stochastic Model	√					√		Lot Sizing Techniques	√		√	√	
Sicilia, San-Jose, Garcia-Laguna (2011)	Exponential		√					√							
Wee (1995)	Exponential	Deterministic Model	√					√	√	Hollier-Mark	√	√		√	

	Non-Linear Decreasing Demand Pattern	Model	Heuristics Calculation	Method(s)							Finite Planning Horizon	Zero Initial and Final Inventory	Decision Variable		
				Silver	CLUC	CTPP	YZR	Numerical Example	Newton	Else			Replenishment Quantity	Lot Size	Inventory Stock
Yang et al. (2004)	√	Parametric Eclectic Model	√	√	√	√	√				√	√	√		
Zhao et al. (2001)		Eclectic Model	√	√	√	√	√			Ritchie's Cubic	√	√	√		
Pratama (2015)	Exponential	Stochastic Model	√					√		Lot Sizing Techniques	√		√	√	

2.2. Gap Analysis and Research Contribution

After reviewing 12 papers on decreasing demand problem, these papers are classified based on 7 chriteria: demand pattern, research model, calculation, methods, finite planning horizon, zero initial and final inventory, and decision variables. As it can be seen in Table 2.1, no paper was found focusing on decreasing dependent demand problem using Lot Sizing techniques. There is one research from Pujawan and Kingsman (2003) about Lot Sizing techniques but only for lumpy demand problem. This is the research gap with previous papers on decreasing demand problem. This research contributes to the solution model in solving decreasing dependent problem using Lot Sizing Techniques.

Using an example data from 5 items of suspension, this research presents the analytical approach of calculating the total cost from 5 different lot sizing techniques: Silver Meal 1 (SM1), Silver Meal 2 (SM2), Least Unit Cost (LUC), Part Period Balancing (PPB), and Incremental (ICR) on spreadsheet. Those techniques are adopted from Pujawan and Kingsman (2003) who try the same techniques to solve lumpy demand problem. The total cost from each techniques becomes the performance measure of this research. The lower the total cost, the better the lot sizing technique.

2.3. Lot Sizing Techniques

There are 5 lot sizing techniques will be used in this research. They have same characteristic in calculation in term of parameters. Ordering cost and holding cost are utilized to determine the number of order quantity. Explanation of those techniques are taken from a paper from Pujawan and Kingsman (2003).

2.3.1. Silver Meal 1 (SM1)

The objective of the Silver Meal 1 rule is to minimize the sum of ordering and holding cost per period. Based on that objective, the decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The calculation is presented in the equation below.

$$SM1 \rightarrow \min\left[\left(\frac{A+\sum_1^j(h\,.S_{ij})}{\sum_1^j n_j}\right)\right] \quad (2.1)$$

$A \quad = Ordering\ cost\ (\$)$

$h \quad = Holding\ cost\ (\$/unit/week)$

$S_{ij} \quad = Inventory\ on\ hand\ (unit/week)$

$n \quad = Number\ of\ Demand\ covered$

$i \quad = Item\ index\ (1,2,3,4,5)$

$j \quad = Week\ index\ (1,2,3, \ldots, 13)$

2.3.2. Silver Meal 2 (SM2)

The objective of the Silver Meal 2 rule is the same with Silver Meal 1, to minimize the sum of ordering and holding cost per period. But, in this method zero demands are excluded from calculating the periodic cost. The decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost.

2.3.3. Least Unit Cost (LUC)

The objective of the Least Unit Cost rule is to minimize cost per unit incurred in one order that covers some periods. The decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The calculation is presented in the equation below.

$$LUC \rightarrow \min\left[\left(\frac{A+\sum_1^j(h\,.S_{ij})}{\sum_1^i n_i}\right)\right] \quad (2.2)$$

$A \quad = Ordering\ cost\ (\$)$

$h \quad = Holding\ cost\ (\$/unit/week)$

$S_{ij} \quad = Inventory\ on\ hand\ (unit/week)$

$n \quad = Number\ of\ unit\ (unit)$

$i \quad = Item\ index\ (1,2,3,4,5)$

$j \quad = Week\ index\ (1,2,3, \ldots, 13)$

2.3.4. Part Period Balancing (PPB)

The principle of the Part Period Balancing rule is to minimize the difference between ordering and inventory holding cost. Based on that objective, the decision for the number of order quantity is taken from the order quantity that provides a minimum periodic cost. The calculation is presented in the equation below.

$$PPB \rightarrow \min\left|A - \sum_{1}^{j}(h \cdot S_{ij})\right| \quad (2.3)$$

$A \quad = Ordering\ cost\ (\$)$

$h \quad = Holding\ cost\ (\$/unit/week)$

$S_{ij} \quad = Inventory\ on\ hand\ (unit/week)$

$i \quad = Item\ index\ (1,2,3,4,5)$

$j \quad = Week\ index\ (1,2,3, \ldots, 13)$

2.3.5. Incremental

The principle of the Incremental rule is to make an order should cover the *n*th demand if the incremental inventory holding cost incurred by doing so is less than or equal to the ordering cost.

$$ICR \rightarrow \sum_{1}^{j}(h \cdot S_{ij}) \leq A \quad (2.4)$$

$A \quad = Ordering\ cost\ (\$)$

$h \quad = Holding\ cost\ (\$/unit/week)$

$S_{ij} \quad = Inventory\ on\ hand\ (unit/week)$

$i \quad = Item\ index\ (1,2,3,4,5)$

$j \quad = Week\ index\ (1,2,3, \ldots, 13)$