CHAPTER 2
LITERATURE REVIEW AND THEORITICAL BACKGROUND

This chapter presents some previous researches and theoretical background in automated material handling system, fleet sizing, and economic profitability. Simulation approach and time study which are very useful for this research are also explained in this chapter. Finally, this research contributions over some previous researches are being explained in the last section

2.1. Automated Material Handling System

Groover (2007) give a rough guide in selection of material handling equipment based on flow rate and distance moved and also based on layout types. Automated material handling system is suitable when flow rate high or/and distance moved low. Rough guide of material handling selection according to Groover (2007) can be seen in Figure 2.1.

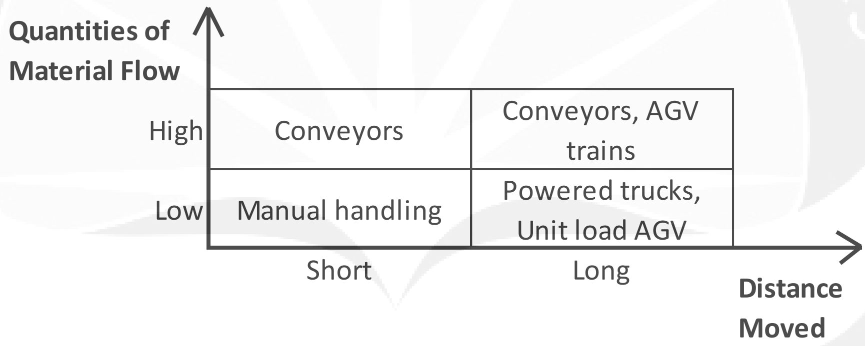

Figure 2.1. Material Handling Equipment Based on Flow Rate and Distance Moved (Groover, 2007)

Type of material handling based on layout type can be divided into three type, fixed-position, process, and product layout type. Fixed position usually related with large product size like airplane manufacturing which has low production rate. Material handling that suitable for fixed position layout type can be cranes or hoists. Another layout type is process layout type which has characteristic in product variability and low production rates. Material handling equipment that suitable for process layout is hand trucks or AGV which have high flexibility in their routing. Last layout types is product layout which has limited product variability and high production rate. Conveyor or powered truck is suitable for product layout type. Summary of material handling equipment based on layout types can be seen in Table 2.1.

Table 2.1. Material Handling Equipment Based on Layout Type (Groover, 2007)

Layout Type	Characteristics	Material Handling Equipment
Fixed position	Large product size, low production rate	Crane, hoists
Process	Variations in product and processing, low production rate	Hand truck, AGV
Product	Low product variety, high production rate	Conveyor, powered truck

One of the main features in automated material handling system is self-navigation and GPS-based navigation technology is widely used technology for outdoor usage but it is not suitable for indoor usage due to satellite signals are blocked (Grewal et al., 2007). For indoor usage, various sensors are introduced to replace GPS-based navigation, such as using camera and fiduciary markers as the track which is very easy to produce, manipulate, and maintain (Lee et al., 2013). One of the important parameter in selection on automated material handling is battery consumption (Ahmad et al., 2014) to make sure that automated material handling is not become an obstacle for production caused by high maintenance time.

Automated material handling systems is commonly used in manufacturing plants, warehouses, distribution center, and trans-shipment terminals (Rinkacs et al., 2014). The purpose of automated material handling is to connect two stations that cannot be combined due to area constraint and space availability to reduce headcounts in production floor.

2.2. Fleet Sizing

Fleet sizing is one of the important thing in designing automated material handling system. There are mainly five elements in fleet sizing research that become highlight of research, which are demand and supply point nature, amount of objective, amount of point, and approach used in the research. Demand point is time between of station require material to be processed and supply point is time between material coming and ready to be transported by material handling. In the beginning research, fleet sizing problems can be similar with queuing theory where fleet is treat as server in queuing theory (Parikh, 1977). Parikh (1977) gave adjustment in queuing model that has same behavior based on inter-arrival time. Situation on his research was automated material handling in flow shop with closed loop route and the objectives is to minimize waiting time of material. The research was continued by Papier and Thonemann (2008) to compared between queueing models and time-space models which is queuing models is more suitable for long term decision making, such as planning fleet sizes over the next years and time-space models is appropriate model to plan allocation for each fleet.

Too little fleet cannot satisfy the requirement, but too many fleet would be increase vehicle cost and traffic intensity (Chang et al., 2014). Chang et al. (2014) used simulation-based framework to find optimum fleet size under multi objective because one of the advantages of using simulation is user can treat some processes as a black box. Chang et al. (2014) use simulation due to complexity in automated material handling route. Another research found that analytical approach is found to be the best solution to determine minimum fleet size under time-window constraint (Vis et al., 2005)

Koo et al., (2004) done some research in fleet sizing for multiple pickup and delivery point with consideration of additional rules of nearest vehicle selection rule. Koo also shows the overall fleet sizing procedure which is shown in Figure 2.2.

To determine minimum fleet size, total vehicle travel time is divided by the length of available time of vehicle (Koo et al., 2004). Automated material handling design for closed loop flowshop already researched by Hall et al., (2001) and fleet sizing was based on minimum cycle time of processes that will not reduced anymore if one material handling was added.

Multi-objectives optimization for fleet sizing can become a major benefit in decision making. Sayarshad and Marler (2010) develop multI-objective optimization with two goals, minimize penalty cost for unmet demand and maximize profit from operations. Another research that three objectives on optimize fleet size and capacity, optimize both of quality and profit, and also the ability to satisfy constraint will become usefull in fleet size planning problem (Sayarshad et al., 2010).

2.3. Flow Shop and Queuing Model

Hard disk manufacturers can be classify as flow shop which has characteristic on limited product variability and high production rate. Buzacott & Shanthikumar (1993) breakdown flow shop into certain categories based on characteristic in flow shop. There are two categories based on operator policy in processing item, paced and unpaced lines. Paced lines is condition when cycle time of operator in every work center is fixed. Therefore, it is possible that operator not finish the task given. On the contrary, unpaced lines is condition when there is no limited cycle time of operator in doing their task.

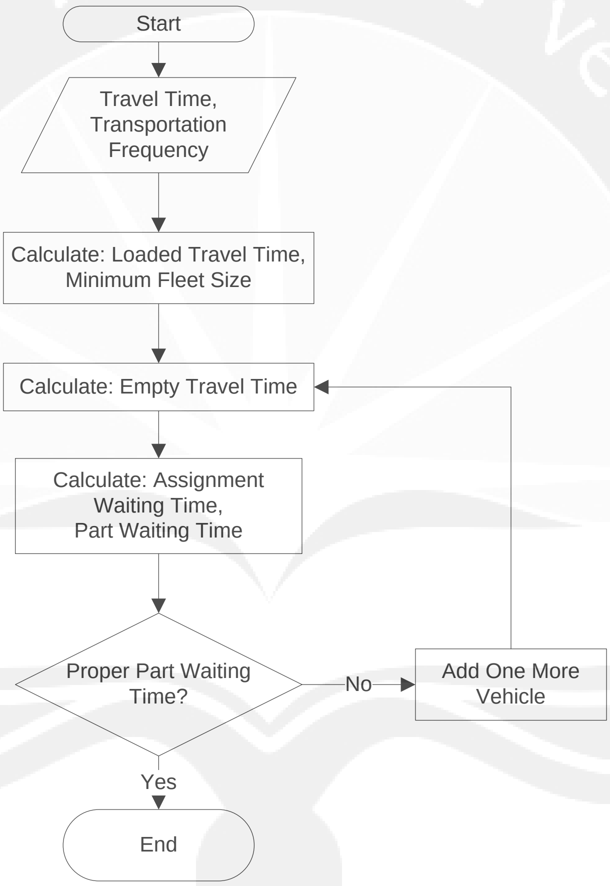

Figure 2.2. Overall Fleet Sizing Procedure (Koo et al., 2004)

Based on flow control from upstream process to downstream process, flow line can be classified as two categories, synchronous and asynchronous lines. Synchronous line or indexing line is the condition when transfer activity between process is coordinated. Asynchronous line is vice versa from synchronous line or there is no coordination in transfer activity. From research subject, which is hard drive manufacturer, it can be classified as asynchronous line due to no signal on transfer line. Therefore, it can be modelled by an open tandem queueing network. Buzacott and Shanthikumar (1993) also explained when inter-arrival time is poisson distribution and processing time in each server is exponential distribution, it can be solved using queuing model *M/M/c*. If inter-arrival time is not poisson distribution and/or processing time is not exponential distribution, it can be solved using queuing model *G/G/c*. Allen-Cunneen aproximation usually gives good approximation for *G/G/c* system, but unfortunately extensive testing by Tanner give conclusion that the result of approximation are within 10% of true values (Winston & Goldberg, 2004).

Taha (1997) explained about notation in queuing network with general notation *a/b/c:d/e/f* where a and b are respectively represent of arrival time and service time, c is represent number of server, d is represent queue discipline, e and f are respectively represent of maximum number in system and size of calling source which is infinite or finite. Notation to represent arrival and service time are:

a. *M* = Markovian (Poisson) arrival or service time which is equivalently with exponential inter-arrival time or service time
b. *D* = Constant (Deterministic) time
c. *Ek* = Erlang or gamma distribution of time
d. *GI* = General (generic) distribution of inter-arrival time
e. *G* = General (generic) distribution of service time

Taha (1997) also explained when queuing model arrival and departure time is not following Poisson distribution, the model will be very complex and it is advisable to use simulation approach.

2.4. Simulation Approach

Winston & Goldberg (2004) defined simulation as a method or tool to depict the operation of a real world system as it evolves over time. System is a collection of entities that act and interact toward the accomplishment of some logical end (Schmidt & Taylor, 1970). Taha (1997) divided two type of simulation model, which are static and dynamic.

a. Static: Representation of a system at a particular point in time
b. Dynamic: Representation of system as it evolves over time

Taha (1997) also explained a simulation might be deterministic or stochastic based on existence on random variables. Winston & Goldberg (2004) gave framework on simulation study, which is shown in Figure 2.3. However, it is not mandatory to use the same framework caused by overlap between some of the stages.There are a lot of simulation software. Kelton et al. (2006) gave information needed such as features and capabilities in using ARENA Simulation software.

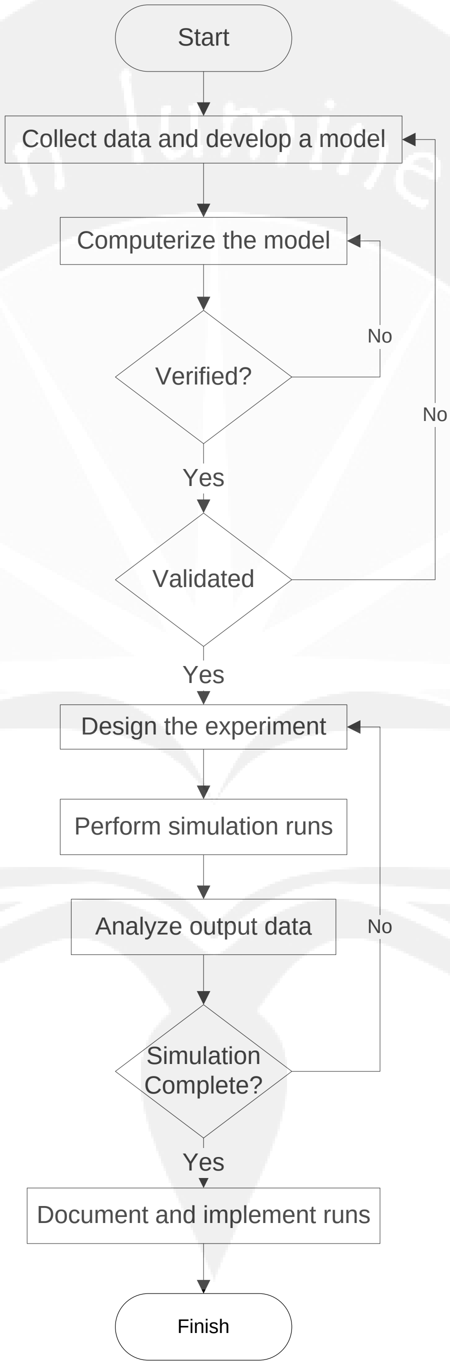

Figure 2.3. Process in Simulation Study (Winston & Goldberg, 2004)

Kelton et al. (2006) gave framework on analyzing simulation result based on time frame of simulation. There are two time frame of simulations, which are terminating and steady state. Problem occurred in terminating simulation when to determine number of replications. Approximation in determining number of replication can be seen in Equation 2.1.

$$n \cong z^2_{1-\alpha/2} \frac{s^2}{h^2} \tag{2.1}$$

Where:

n = Number of replications

z = Z-Value

α = Confidence interval

s = Sample standard deviation

h = Half-width

Another easier approximation but slightly different can be seen in Equation 2.2.

$$n \cong n_0 \frac{h_0^2}{h^2} \tag{2.2}$$

Where:

n_0 = Initial number of replications

h_0 = Initial half-width

The approximation formula on replication number needed can be defined as same as central limit theory, which is stated that it is fairly good enough if *n* is large (Kelton et al., 2006). Another stage to be considered in simulation is verification and validation stage. Kelton et al. (2006) gave definition on verification and validation. Verification stage in simulation software is to detect any error in model or ensure simulation behaves as intended. Validation is defined as activity to ensure that the simulation behaves the same as the real situation. There should be one or more parameter that can be compared between real situation and simulation model.

2.5. Statistical Analysis

In simulation approach, there are various scenario built to have optimum solution in the model. Replication and stochastic nature is involve in simulation approach.

Therefore, statistical analysis is useful to prove the any significance difference between scenarios. There are various tools to prove any significance difference between samples, such as z-test or t-test if there are only two samples involve. The tools in statistical analysis to prove any significance difference between samples if there are more than two samples involve is Analysis of Variance (ANOVA) (Bluman, 2012). Bluman (2012) divide ANOVA become two, which are one-way and two-way based on number of factor influence in the model. ANOVA is based on hypothesis testing. Following hypothesis is used in ANOVA:

H_o: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_n$
H_1: At least one μ_n is different

Where:

μ_n= Means of sampe *n*

ANOVA Analysis can be done using MINITAB Software and the result will be in p-value (Montgomery & Runger, 2010). Montgomery & Runger (2010) also explained definition of p-value, which is the smallest level of significance that lead to null hypothesis rejection. Based on definition of p-value, null hypothesis is rejected if p-value is smaller or equal than level of significance.

2.6. Economic Profitability

Parameter which mainly used by top management in considering to accept or reject investment offered by each division is called economic profitability. Sullivan et al. (2006) explained several method to calculate economic profitability such as:

a. Present Worth (PW)
b. Future Worth (FW)
c. Annual Worth (AW)
d. Internal Rate of Return (IRR)
e. External Rate of Return (ERR)
f. Payback Period

However, there is no method that ideal for every case due to patterns of capital investment and cash flow is different for every case. In this project, company that become subject in this research decided to use payback period to analyze economic profitability of investment. Different with another method, time value of money is ignored and measure breakeven point of an investment in time unit.

Simple payback period is the smallest value of θ. The longer breakeven point, the greater risk of investment for a project. For project where all investment done in initial period, the equation can be seen in Equation 2.3.

$$\sum_{k=1}^{\theta}(Rk\text{-}Ek)\text{-}I\geq 0 \tag{2.3}$$

Where:

Rk = Revenue at *k* period

Ek = Expenses at *k* period

I = Investment

However, payback period is not considering time value of money which is interesting to consider. Another method that popular in decision making on economic profitability analysis is Internal Rate of Return (IRR). IRR is a method on investment calculation compared between present value of investment and earnings in the future. To calculate IRR, Microsoft Excel can be used with formula that can be seen in Equation 2.4.

=IRR(Values,[guess]) (2.4.)

Where:

Values = Cash flow in certain period

Guess = Optional value of approximation IRR value

2.7. Time Study

To determine operator required in operating I-Trolley, cycle time of operator in operating I-Trolley is an important data. Therefore time study is needed in this research. Niebel & Freivalds (2003) determine steps in time study including: selecting the operator, analyzing the job, breaking down into elements, recording elapsed elemental values, performance rating the operator, assigning allowances, and working up the results.

Barnes (1980) explained about two test that should be done to fullfill assumption of data validity: sufficiency test and uniformity test. Sufficiency test is to determine that sample size is enough based on data variation. Sample data can be said sufficient enough when *N'* smaller than sample size. The formula of *N'* can be seen in Equation 2.5.

$$N' = \left[\frac{k/s \sqrt{N \sum X_i^2 - (\sum X_i)^2}}{\sum X_i} \right]^2 \quad (2.5.)$$

Where:

k = Coefficient of confidence level

s = Precision level

N = Sample size

Xi = Standard time

Uniformity test is to make sure that all data is in control or lies between upper control limit and lower control limit. The formula of control limit can be seen in Equation 2.6.

$$CL = \bar{X} + 3\sigma x \quad (2.6.)$$

Where:

CL = Control limit

$\bar{X}$ = Grand mean

σx = Variance of Data

2.8. Research Contribution

All the research found is about determining fleet size with various scenario possible and finished by two possible approaches, simulation or analytical approaches. This research contribution is to determine optimum number of automated material handling in hard drive manufacturer based on the characteristics in the production floor. The characteristic that will be researched is system has one loading point and one unloading point or closed loop route, stochastic nature in demand and supply from internal production floor, and also multi-objectives which are minimizing WIP, minimizing fleet size, and maximize capacity of workstation. Therefore to solve this research, queuing theory is used as reference. Simulation used due to characteristic in inter-arrival time of material is not follows exponential distribution. The explanation of material inter-arrival time is explained in chapter 4. The summary of previous researches characteristic and research contribution can be seen in Table 2.2.

Table 2.2. Summary of Literature Review

Research	Demand		Supply		Objective		Point		Approach	
	Deterministic	Stochastic	Deterministic	Stochastic	Single	Multi	Single	Multiple	Analytical	Simulation
Parikh(1977)		X	X		X		X		X	
Papier and Thonemann (2008)		X	X		X		X		X	
Chang et al. (2014)		X	X			X		X		X
Vis et al.(2005)		X		X	X		X		X	
Koo et al. (2004)		X		X	X			X	X	
Hall et al.(2001)		X	X			X		X	X	
Sayarshad and Marler(2010)		X		X		X		X		X
Sayarshad et al.(2010)		X	X			X	X		X	
Proposed Research (2016)		**X**		**X**		**X**	**X**			**X**