COMPARATIVE STUDY BETWEEN MIXED MODEL ASSEMBLY LINE AND FLEXIBLE ASSEMBLY LINE BASED ON COST MINIMIZATION APPROACH

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LIST OF ABBREVIATION

Mixed Model Assembly Line	MMAL
Flexible Assembly Line	FAL
First in First out	FIFO
Last in First out	LIFO
Work in Progress	WIP
Just in Time	JIT
Cycle Time	CT
Line Status	ST
Parts Delivered	PD
Finished Goods	FG
Parts (P1,P2,P3 and P4)	P
N/Order	New Order
C/A	Cosnsumption for model A
Op/Stock	Opening Stock

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ABSTRACT

Mixed Model Assembly Line are widely used to produce different models as per customer's demands. sequencing problem is an important factor for an efficient use of Mixed Model Assembly Line. The Sequencing Problem is resolved in favor of minimzing the total cost and to keep uniform usage of each part.

In this research project cost model is presented. To get merits and demerits between Mixed Model Assembly Line and Flexible Assembly Line, a comparision is done concerning sequencing problem with cost saving and to keep continue usage of each part. Previously, researchers worked to minimize the utility time or setup time within Mixed Model Assembly Line. But in this research, different models are produced withing Mixed Model Assembly Line and without setup and then Mixed Model Assembly Line is compared with Flexible Assembly Line, where setup is required. Hence, this research is new and has its novelty. To measure the performance of Mixed Model Assembly Line and Flexible Assembly Line, different parameters i.e. different sequence patterns, constant and random demand, cycle time and setup time are used to check effect on total cost per unit is computed. This analysis yields a comprehensive result in favor of Mixed Model Assembly Line to save the cost. The outcome of this research suggests about best sequence pattern for Mixed Model Assmebly Line and Flexible Assembly Line, which gives continue consumption of each part and cost saving and reducing of cycle time, would provide higher production.

ABSTRAK

Barisan Penggabungan Model Campuran digunakan secara meluas untuk menghasilkan model-model yang berbeza mengikut kehendak pelanggan. Masalah yang berurutan adalah facktor penting untuk penggunaan Barisan Penggabungan Model Campuran secara efisien. Kami telah mengyelesaikan masalah yang berurutan lebih kepada mengurangkan jumlahan kos dan memastikan penggunaan sekata untuk setiap behagian.

Dalam projek penyelidikan ini, model kos adalah dipersembahkan. Untuk mendapatkan merit dandemerit antara baisan Penggabungan Model Campuran dan Barisan Penggabungan fleksibel, satu perbandingan telah dilakukan berkaitan masalah berurutan dengan penjimatan kos dan memastikan penggunnaan berterusan untuk setiap bahagian. Sebelum ini, penyelidik berusana untuk meminimumkan waktu pengunaan atau pemasangan Model Campuran tanpa penasangan dan seleps itu, barasan pengabulngan model penasangan dibandinganKan dengan Baisan Penggabungan Model Campuran dan Barisan penggabungan Fleksible, paramter paramter berbeza i.e. bentuk-bentuk urutan berbeza, pemalar dan permintaan rambang kos. Akhir sekali, segitiga antara jumlahan permintaan, jumlahan pengeluran dan jumlahan purata kos per unit adalah dikira. Analisis ini menghasilkan keputusan menyeluruh terutama bagi Barisan Penggabungan Model Campuran untuk mengurangkan kos. Hasil penyelidikan ini mencadangkan bentuk urutan terbaik yang.

CHAPTER 1

INTRODUCTION

1.0 Orientation

The problem of getting the best cost minimization results from limited resources that have occupied the attention of both production managers in industry and research workers in academia for many years. Numerous cost model and constant parts consumption model have been suggested over the years.

As far as the research in Mixed Model Assembly Line (MMAL) problems is consulted, there has been continued effort in this direction. Solving cost minimization problems is important not only because it has an immediate impact on the modern manufacturing industries but also because it represents solutions to a group of problems of the MMAL. Up-to-date developments in the study of MMAL reveal that an integrated approach to MMAL problems is now urgently needed. This research is aimed at extending previous research scheme for cost minimization and to keep continue consumption of each part in MMAL.

Now-a-days MMALs are widely used in manufacturing industries, because MMAL fulfills the diversified demand from small-high product. From production planning horizon fluctuation in scheduling is usual according to first in first out (FIFO) and last in first out (LIFO) to meet the market requirement. The produced items keep changing from model to model continuously on the line. In order to reduce the inventory cost, the number of model on the line is usually kept at a low level considering both customers satisfaction for different varieties and the corresponding demand.

1.1 Research problem

Over the last decade, many researchers have been worked over the MMAL and they had been improved in MMAL problem by using different techniques. We studied various papers regarding to keep the constant parts consumption and to minimize the cost in MMAL. Mostly researchers discussed to keep the constant parts consumption along with sequencing problem (Ding and Tolani, 2003; Choi and Shinb, 2002 Zhu and Ding, 2000; Caridi and Sianesi, 2000; Lovgren and Racer, 2000; Xiaobo, *et al.,* 1999; Tamura *et al*., 1999; Celano *et al*., 2004;).

Cost saving is an important factor in the manufacturing industries. Many manufacturing facilities generate and update production sequences, which are plans that state when certain controllable activities (e.g. processing of jobs) should take place (Herrmann, 2003). So sequencing is a controllable activity and it could be directly related to production cost and good scheduling gives continue consumption of each part and ultimately provides better cycle to fulfill the demands, without backlogging and holding costs. In a manufacturing facility, the production sequencing is a dynamic technique for making decisions about which jobs should be done when. The production sequencing techniques includes the status of jobs, manufacturing resources (Equipment and production lines), inventory (on hand raw materials and work-in-process), tooling, and many other concerns (Herrmann, 2003). Previous researchers worked to resolve the sequencing problem in favor of cost saving, as to minimize the setup within MMAL (Hyun *et al*., 1998; Mansouri, 2005) and also Heike *et al.,* (2001) evaluated the effect of cycle time on inventory holding cost (Miyazaki, 1996). Other researchers worked to keep continue consumption of each part (Zhu and Ding, 2000; Caridi and Sianesi, 2000; Lovgren and Racer, 2000; Xiaobo, *et al.,* 1999; Tamura *et al*., 1999; Celano *et al*., 2004; Sarker and Pan, 1997). As the researchers worked on to minimize the setup cost within MMAL (Hyun *et al*., 1998; Mansouri 2005) or suggested different line for different model (Pesenti and Ukovich, 2003) and they gave an idea that several assembly line would induced for lesser setup cost and penalty cost. But demand is not remained same, there is flexibility from the customer side. Resulting some lines and labor remains idle and carrying cost is higher here. In the current research, the problem is also sequencing, but here proposed assembly line is assumed as single work station for MMAL (Xiaobo, *et al.,* 1999) and every model produce within a same setup. Then, MMAL compares with FAL in order to minimize the costs. So from the review of article, it is observed that there is a lack of model, which integrates the cost in MMAL and FAL. Therefore a cost model is introduced to compute the cost in MMAL with the sequencing problem.

In examining to minimize the cost in MMAL, it was experienced to minimize the setup is very critical. Generally it seems if sequence of the product is of same model then set up time would be minimized as well as set up cost will be minimized. Now-a-days marketing demand is diversified, that's why MMAL is adapted by every manufacturing industry. Resolving the sequencing problem would give reduced cost and constant consumption of each part. In reviewing the research works on the MMAL, the first impression was that the area had been over studies. However very shortly it was found that to great extent many works had been simply small variations of their predecessor's work. The area has not been completely understood and there still exists need for further research. The detail is in literature review (chapter 2) will give more information.

1.2 Research objectives

The main objective of this project is to present the cost model and compare the performance of MMAL and FAL with respect to cost saving. The costs are ordering cost of parts, holding cost of parts, Line setup cost, holding cost of finished goods, penalty cost for not deliver the finished goods and other objective is to keep the constant consumption of each part in assembly line.

1.3 Research contribution

This research is unique among all previous research and this research differentiate between MMAL and FAL. Because previous researchers worked on to minimize the setup within MMAL (Hyun *et al*., 1998; Mansouri 2005). So this research is unique and provides a difference between MMAL and FA. MMAL, where no setup is required while in FAL setup is required and mostly time is consumed in setup and induces for loss in output (Umble *et al.,* 2000) and MMAL can give more production than FAL. As many articles have been viewed for MMAL and FAL regarding sequencing problem. It is reviewed most work is published in considering the objective of keeping the constant usage of each parts as discussed in Research problem. But very little work has been done in the area of to minimize the different cost in MMAL. These aspects have been reviewed in the next chapter. It will be known that some researchers had worked to minimize the setup cost and minimize the costs of idle and utility times in MMAL (Sarker and Pan, 1997). On the behalf of all costs as discussed in the research objectives, a cost model is developed and implementation of the cost model would give more fruitful merits. An analyzing between different sequence pattern of same job orders and different cycle time and setup time of assembling the product would give the best sequence pattern and job order in order to minimize the cost.

1.4 Scope of the research

Scope of the research is based on comparing MMAL and FAL, to observe the following effects on total costs.

1- Effect of variable cycle time and setup time on total cost.

2- Effect of constant and random demand on total cost.

3- Sequencing the model in order to keep constant consumption of each part.

1.5 Assumptions

Ding and Tolani (2000) presented an industrial example, where skid-steers loaders are manufactured. In this company, parts are delivered from local and foreign vendors. Some models can also expected shortages of parts. As engines are delivered from the foreign vendor, due to supply problem the models can not be scheduled until the engines are supplied from the supplier.

In the current research, to resolve the sequencing problem, an assumption of two models, four different types of parts are delivered from the local vendor on JIT basis is carried out. The aim of these assumptions is to show the flow of parts on assembly line and the role of local vendor in favor to supply the part on JIT basis.

1.6 Thesis organization

Figure 1.1 illustrates the thesis outline of this project. The research started with the research problem identification. Under this stage, the introduction to the research background and research problems as well as the research objectives are identified and highlighted. The next stage is the overview of the previous work. This stage consists of two major parts, they are the literature review and background theories review.

The purpose of the literature review is to explore the related works carried out by other researchers. The literature review in Chapter 2 focuses on the comparative studies on MMAL and FAL in order to resolve the sequencing problem regarding to minimize the total cost for MMAL and to keep continue consumption of each part.

The next stage of the research is the method selection, evaluation and testing to the proposed method. Chapter 3 “Methodology” describes the simulation study and parameters which are used to test the result for MMAL and flexible assembly line (FAL).

Chapter 4 shows the comprehensive results of compared MMAL and FAL, which are carried out to compare the results regarding to minimize the cost for MMAL and FAL. The purpose of the comparison is to check the effect of parameters i.e. sequence, cycle time, constant and random demand. Cost analysis gives the best sequence as compare to production and demand quantity for both lines. Merits goes to MMAL, because it gives multiple production and cost would be controlled and reduced after resolving the sequencing problem. We have been highlighted the best sequence pattern and its job order and other factors for reducing the costs. After the results, effects of all parameters are discussed in Chapter 5, in which each sequence pattern is shown with respect to production quantity, average total cost, productions and demand.

Finally, the research result ended with the chapter of conclusion and future works. This chapter concludes the thesis by summarizing the research contributions. The research problems are answered and future works are suggested.

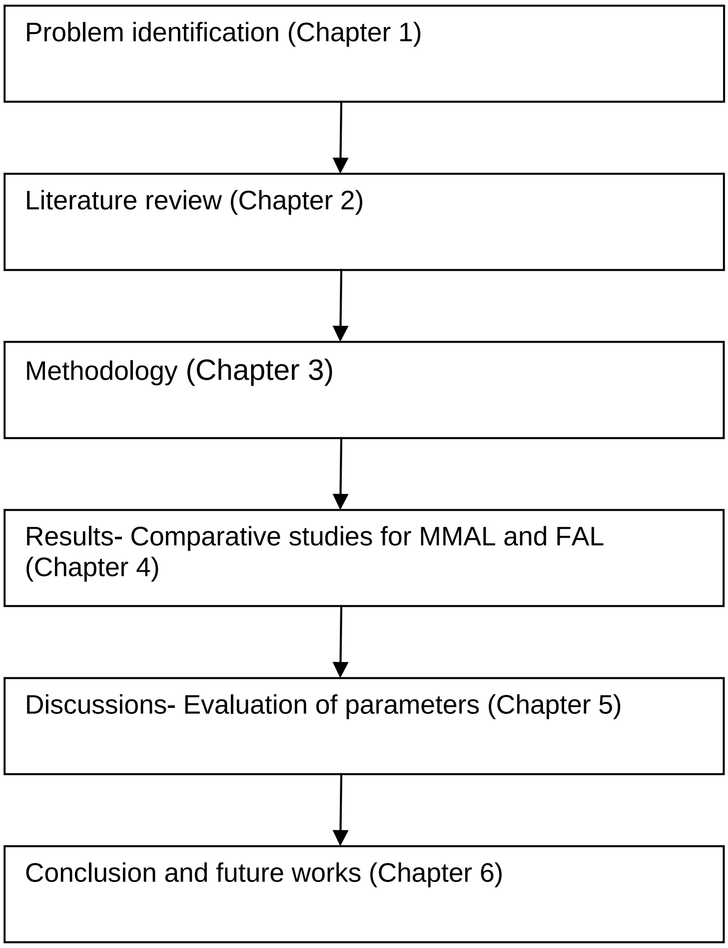

Figure 1.1: outline process chart for the thesis organization

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The central tasks of this chapter are, firstly, to review the research on MMAL and FAL problems, with the emphasis on the main approaches used to solve the problem of cost minimization, and secondly to draw the author's attention to the areas which still need attention. The effort is therefore devoted to the review of the recent development in the relevant areas, the identification of new research topics and the important concepts and procedures useful for incorporation into the current research scheme. In this chapter, common procedures in MMAL are summarized first. These are followed by the view on the recent development of cost minimization in MMAL and to keep constant parts consumption techniques.

In order to get merits and demerits from MMAL and FAL, we have been overviewed recent articles for FAL. From FAL point of view each models requires different setup, or different line produce different models (Pesenti and Ukovich, 2003).

2.1 A general view of an assembly line

An assembly line is classified into paced or unpaced. In paced line, operators has limited time to complete the job. While in upaced, there is no time limitaion to complete the job. Jobs are transported manually or mechanically, manullay jobs are moved from one station to another by hand. In this system starvation or blockage generally occurs.

In Starvation case, workers complete their work and wait for the next job from upstream station, but workers of upstream station can't deilver the unit, because they still working on it. Then workers of the downstream face the starvation and blockage occur, when operator has not finished his work but units are coming from upstream station. Starvation and blockage can be minimized, if there is some space to hold the units between the stations. But this is not the lasting solution. Conveyers are used in the manufacturing indsutries to move the units along the manual assembly line. In continuous transport system, conveyors moves continuously at constant velocity. In continuous transport, work units are fixed to the conveyor. In automobile plant, the product is heavy and large, so worker should be finished the work in a assigned time. While in case of small product, the unit can be removed from the conveyor and in this way there is not fixed timing to complete the work (Groover, 2001).

In case of asynchronous lines job movement at adjacent stations is not incorporated to each station. The operator starts the work, whenever job is available and then completed job leaves the station as long as the space is available for the job. So, there is a chance of starvation or blockage the line (Groover, 2001).

Another classification of assembly lines is by the mix of jobs processed on the line, single-model lines or mixed model lines. In single model line, the models are produced in batch-wise, while in mixed model lines, models are produced in multi-model way. For example, in automobile company, models are demanded from the customers as different colors and in different transmissions, i.e. automatic transmission or manual transmissions can be produced in mixed model line (Groover, 2001).

In automobile industries, generally units are moved by manually or by mechanized work. Manually units are transported by hand and on this way starvation or blockage occurs. Some time, it is happened that operator of one station completing his job faster than next station's operator. And this situation leads to blockage the line and to resolve this problem a buffer zone between stations is used (Groover, 2001). Line pacing is classified into rigid pacing, pacing with margin and no pacing, in rigid pacing workers are given a limited time to complete the assigned job, usually time is set according to cycle time of the line. In pacing with margin, maximum time range is longer than cycle time. In this type of pacing, workers have more time to complete the job (Groover, 2001).

2.2 Techniques used by researchers in solving MMAL and FAL

In a mixed model line it is necessary to decide on the sequence with which jobs will be released to the line. Because the jobs will not have identical time requirements, it is necessary to find sequences that do not overload the operators. In particular a job that requires somewhat more time to process at a work station should be followed by a shorter job so that the operator has time to catch up. For example, in automobile assembly, it would be usual to ensure that cars requiring air conditioning are spaced out in the sequence of job release because they require more work at some stations (Groover, 2001).

In FAL different product types are assembled simultaneously. It is a unidirectional flow system made up of a set of assembly stations in series and a loading/unloading (L/U) station, linked with an automated material handling system. The flexible assembly stations have a limited work space due to their physical design (Sawik, 2000a). The following techniques are used to resolve the sequencing problem for both MMAL and FAL.

2.3 Heuristic method

“Many industrial problems such as machine scheduling, vehicle dispatching and routing, and facility layout and location problems, can be formulated as linear programs, integer programs and other programs. Some brief descriptions of these heuristics are as follows” (Ariel and Golany, 1996).

2.3.1 Goal chasing method one & two

“Goal chasing method is used for controlling the assembly line. The sequence of introducing models to the MMAL is different due to the different goals or purposes of controlling the line. There are two goals, in goal one it is important to note that a product might have a longer operation time than the predetermined cycle time. This is due to the fact that the line balancing on the mixed-model line is made under the condition that the operation time of each process, which was weighted by each quantity of mixed models, should not exceed the cycle time. As a result, if products with relatively longer operation times are successively introduced into the line, the products will cause a delay in completing the product and may cause line stoppage. Although this first goal is also considered the second goal of the sequence schedule to keep a constant speed in consuming each part “(Monden, 1993).

2.3.2 Goal chasing 1-look-Ahead

“Goal chasing 1-look ahead is to update goal chasing (GC) to obtain an improved sequencing solution. This new method requires the extra step of tentatively trying every eligible product in each position of the sequence. This extra step is designed to reduce the effects of the greed designed to reduce the effects of the greed designed into the GC heuristic” (Lovgren and Racer, 2000).

2.3.3 The border swap algorithm

“This algorithm is based on leveling the usage of component parts over time while allowing any number of late items. The algorithm is designed to start with a sequence in which no items are produced late, and which probably has a relatively large deviation. The next sequence generated allows one item to be produced late while decreasing the overall deviation of component usage as much as possible. A series of sequence is produced until there is no improvement in the deviation. This final sequence is a heuristic solution for minimizing the deviation in component usage over time" (Lovgren and Racer, 2000).

2.3.4 The 2-optimal algorithm

"This algorithm begins with an existing sequence and swaps each feasible pair of items in the sequence, within due date restrictions, to try and reduce the total deviation of part usage from linearity" (Lovgren and Racer, 2000).

2.3.5 Integer programming

"The wide applicability of integer programming (IP), sometimes known as discrete programming as a method of modeling is not obvious. Most practical IP models restrict the integer variables to two values, 0 or 1. Such 0-1 variables are used to represent 'yes or no' decisions. Logical connections between such decisions can often be imposed using linear constraints" (Williams, 1999).

2.3.6 Linear programming

"For many practical problems this is a considerable limitation rules out the use of linear programming. Non-linear expressions can, however, sometimes be converted into a suitable linear form. The reason why linear programming models are given so much attention in comparison with non-linear programming models is that they are much easier to solve. Care should also be taken, however, to make sure a linear programming models is only fitted situations where it represents a valid models can be solved compared with non-linear ones" (Williams, 1999).

2.4 Artificial intelligence

"The techniques and theoretical results from the field of artificial intelligence (AI) offer a new exciting technology for solving problems in manufacturing today. Research and study in methods for the development of a machine that can improve its run operations. The development or capability of a machine that can proceed or perform functions that are normally concerned with such human intelligence as learning, adapting, reasoning, self-correction, automatic improvement. In a more restricted sense, the study of techniques for more effective use of digital computers by improved programming techniques" (IE Terminology, 2000).

2.4.1 Genetic algorithm

"A genetic algorithm (GA) is a search technique based on the biological process of natural selection and genetic inheritance, various version of the algorithm have been developed. These efforts have mainly aim at improving solution quality and reducing computation time. GAs has been used in a wide variety of applications, particularly in combinatorial optimization problems, such as traveling salesman problems and have obtained good results. GAs can search for many pareto optimal solutions in parallel by virtue of maintaining a population of solution. Parallelism is an intrinsic feature of GA approach. This characteristic makes GAs very promising for solving multiple objective optimization problems. The GA for multiple objective optimization problems is similar to a simple genetic algorithm in every way except its fitness evaluation and selection mechanisms"(Hyun *et al*., 1998).

2.4.2 Tabu search

"Engineering and technology have been continuously providing examples of difficult optimization problems. Tabu search (TS) is a heuristic that guides a local heuristic search strategy to explore the solution beyond local optimality. The local procedure is a search that uses an operation called move to define the neighborhood of any given solutions. The neighborhood of the solution is explored and the best solution is selected, even if it is worse than the current solution. This strategy allows the search to escape from local optima and explore a larger fraction of the search space" (Dengiz *et al.,* 2000).

2.4.3 Simulated Annealing

"The idea behind simulated annealing (SA) is to mimic the physical process of annealing. SA is an effective randomized heuristic. It is proposed as a combinational optimization method" (Dengiz *et al.,* 2000).

2.5 Mixed model assembly line

MMAL is capable of producing a variety of different product models simultaneously and continuously. Each worker of work-stations is skilled in a certain set of assembly work elements, but the stations are sufficiently flexible that they can perform their respective tasks on different models. Mixed model lines are usually used to complete the final assembly line of automobiles, small and large trucks, major and small appliances are the example of MMAL (Groover, 2001).

2.5.1 General assumptions for MMAL

In considering MMAL problems, the following assumptions are made by the authors to resolve the sequencing problem. Their works have been frequently cited and should therefore be representative of the common practice.

- Production planning gives the scheduling for the various demands (Ding and Tolani, 2003).

- Each task of the combined precedence is performed for at least one model and task duration is known and depends on the model type.
- The first station is never starved and the last station is never blocked.
- A work in the back buffer can proceed to the station of the main line only if another work comes into the front-buffer. Conversely, least one work is in the back buffer (Tamura *et al*., 1999).
- The amount of consumption of part for each unit time is independent of each other (Miyazaki, 1996).
- The parts manufacturing process can start with production of parts once the production order is issued. The capacity in producing parts (maximum out put rate) is sufficiently larger than the consumption rate of parts at the final assembly line (Miyazaki, 1996).
- When holding cost of parts is higher than this inventory cost of parts per unit time is an increasing function of total production costs (Miyazaki, 1996).

2.5.2 Production scheduling and parts consumption in MMAL

An automobile assembly plant is a classic example to understand the MMAL environment in which different type of model produced in the same line. An automobile assembly plant consists of the main line of the body, painting, assembly shops and several sub-lines feeding parts to the main line. Production schedule is dispatched to the body shop and the production on daily basis. Bodies are built by the welding robots in the body shop and stored in a buffer named white body storage (WBS) before being fed into the painting shop. Then body pass several bodies processed according to the daily production sequence which is scheduled from the planning department of the company. Bodies are built by the welding robots in the body shop and stored in a buffer named painted body storage (PBS) before being fed into the assembly shop. Also based on the production plan, purchase orders are issued to vendors. Vendors supply parts to the assembly plant accordingly. Parts supplied by vendors are stored in a warehouse near the assembly shop. In the automotive industry, diversification of customer needs brings increase in the number of parts consumed, which causes disturbances in the production and logistics processes, inducing complication of the management (Choi and Shin, 1997).

Choi and Shin (1997) developed a dynamic part-feeding system, which give a technique to estimates the part consumption amounts and also gives the idea to insert the model of the product into assembly line. In order of utilization of the parts with respect to models of the product, the dynamic feeding system produce better results than a static feeding system. Ding and Tolani (2003) worked to resolve the problem of production planning and they assumed that each model has a given range of production days within the planning horizon and constant parts consumption. The just in time (JIT) production concept suggests that a level, mixed model production schedule be repeated daily on an assembly line. Production schedule gives better flow of materials on the assembly line and also better delivery to meet the demands of various models. And they have studied the problems to scheduling the production quantities. The heuristic solutions of randomly generated problems were found to be reasonably close to the optimal solutions.

Leveling the workload is supported by JIT and lean production concept and this technique gives the production smoothing and as well as material flow, shorter manufacturing lead times and lower work in process. Caridi and Sianesi, (2000) presented the problem of multi-Agent system and this problem is solved according to theory of autonomous agent. The experimental result shows that autonomous agent technique has a good performance and has a great potential which will be surely exploited in the future through real application. In Toyota production system the workers are allowed to stop the conveyor whenever problem is occurred to complete the operations. Therefore, the conveyor stoppage, in sequencing problems becomes an essential decisive factor. On the behalf of above idea of Toyota production system, Xiaobo and Ohno, (2000) addressed the sequencing problem with three goals in their research paper that leveling the workload so as to maximize the operator's efficiency or minimize the conveyor stopping time with the consideration of workers walking time, to keep constant usage of every part and to keep constant feeding rate of every model as well. Recently, Mansouri (2005) presented a Multi-Objective Genetic Algorithm (MOGA) that approaches to a Just-in-Time (JIT) sequencing problem in MMAL, where simultaneous minimization of setups and production rates variation is desired. The developed MOGA uses three basic genetic operators as crossover, inversion and mutation. It also exploits non-dominated sorting idea along with a niche mechanism to obtain quality as well as direct locally Pareto-optimal solutions. Performance of the MOGA was compared against a Total Enumeration (TE) scheme in small problems. The results reveal that the proposed MOGA outperforms the benchmark algorithms in terms of the quality of the solutions.

Leu *et al.,* (1996) proposed genetic algorithm (GA) that is an improvement of Toyota's goal chasing algorithm and this GA leads to solve the MMAL sequencing problems in favor of parts consumption. Resulting, GA performance, in order of generating the sequences was found better from Toyota's Goal Chasing Algorithm. Auxiliary, Celano *et al.,* (1999) presented lean production approach and proposed the GA for the scheduling of a MMAL in order to achieve the goal of minimizing the line stop time and component usage smoothing as well. The result showed that the proposed model gives near-optimal solutions.

Tamura *et al.,* (1999) proposed a bypass sub line technique which reduces the cycle time of the model. Three different algorithms were suggested on the basis of goal chasing method, tabu search and dynamic programming. The objective of this research was continuous usage of each part and balancing the work loads. The Tabu search gives precise solution and goal chasing method has an advantage in a computation time. Korkmazel and Meral, (2001) worked on same objectives to resolve the production scheduling problem. But they proposed different technique, the extension of bicriteria problem on the basis of goal 1 and 2 of Toyota production system, which gave the better results than others.

Bukchin *et al.,* (2002) worked on to reduce the customer lead time to produce the different model. Make-to-order environment point of view, the assembly line environment is small numbers of work stations, a lack of mechanical conveyance, and highly skilled workers. A mathematical formulation was proposed which shows the difference between their model and others models. Zhu and Ding (2000) resolved the sequencing problem in order to reduce the variation in part usage and to smooth the production. In the same year, Lovgren and Racer (2000) designed to be an initial step in the process of production's goal of utilization of the component. The result shows that a slight decrease in on-time production leads to substantial gains in smoothing of component utilization. They also presented some insight into the behavior of the multi-objective sequencing problem. Such that Goal chasing 1, goal chasing 1–look –Ahead and Border swap is used to resolve the problem. The 2-Optimal method produced high quality solutions, but with large computation time. The greedy method quickly produced good solutions, but were less consistent. The Border swap method was nearly as effective as the 2-Optimal, in less computation time. The look-Ahead methods did not offer any significant improvement.

Xiaobo *et al*., (1999) presented a modified goal chasing method (MGC). Toyota's goal of sequencing mixed models on an assembly line to keep the constant usage of every part used in the assembly line. "In all of Toyota's goal oriented studies a consideration which has not been explained explicitly in the literature is that all parts of a given product are assumed to be used at the epoch of just this unit into the assembly line with zero length". This result shows that it's a good approach for the JIT concept. Alternatively, if the units are fed into the assembly line with multiple workstations according to the optimal solution which comes from a single workstation with zero length, then the implementing for JIT at machining processes is driven by non- optimal sequence. MGC algorithm may not assure that it always generates an optimal or good suboptimal solution for the sequencing problem. Furthermore, Celano *et al*., (2004) analyzed heuristics for the solution of the sequencing problem of a MMAL and with the objective of smoothing of component of parts usage. The obtained results show that in the most cases the SA is outperforms the other heuristics.

2.5.3 Cost modeling in MMAL

Cost optimization for mixed model assembly system is concerned to parameters of model size, cycle time, job sequence and work station, an analyzing of these parameters gives the optimal solution of cost. Variable cycle time give the lesser holding cost of manufacturing. Linear and non-linear programs were developed in order to evaluate variable cycle and random cycle policy against the practice of holding cycle times constant for each model in order of cost saving. (Heike *et al.,* 2001).

Hyun *et al*., (1998) presented the paper regarding minimizing the total utility work, keeping a constant usage of parts and minimizing the total setup cost. A genetic algorithm is designed for finding near-pareto optimal solutions for the problem. A new genetic evaluation and selection mechanism called Pareto stratum-niche cubicle is proposed. The performance comparison of the proposed GA with three existing GAs is made for various test-bed problems in terms of solution quality and diversity. The results reveal that the proposed GA outperforms the existing genetic algorithms especially for problems that are large and involve great variation in setup cost. With the same objectives and using mechanism is the Pareto stratum-niche cubicle and the selection based on scalar function are compared with respect to the objective of minimizing variation in part-usage, minimizing total utility work and minimizing the setup cost. Results of evaluation indicate that the GA that uses the Pareto stratum-niche cubicle performs better than the GA with the other selection mechanisms (Ponnambalam *et al*., 2003).

Miyazaki (1996) compared inventory cost of parts between the pull system and the parts-oriented production system. The parts oriented system indicates the fewer inventory costs under the larger variation of parts demand, the larger production stages and the higher safety stock level. The merit of pull system increases as the variation of parts demand and the safety stock level decreases, respectively, which have been treated as management goals of Toyota Production System. The two main goals in Toyota Production System increase the advantage of the pull system in the light of inventory costs. On later year, Sarker and Pan (1997) worked to minimize the total cost of the utility time and idle time incurred due to different line parameters such that launch interval, station length, starting point of work, upstream walk and etc and operation sequences of the mixed models. The result indicates that the minimum total cost of utility and idle times in an open-station system are less than that in a closed-station system for given line length.

From the reviews of articles, different authors presented different cost models. As Heike *et al*. (2001) analyzed inventory holding cost which is effected by the cycle time. But the researcher did not highlight the penalty cost for not delivering the finished goods and also ordering cost of raw materials. In order to minimize the setup cost within MMAL, cost model also presented by various researchers (Hyun *et al*., 1998; Ponnambalam *et al.,* 2003). According to Toyota Production System, each type of model produces within one assembly line and average cycle time is considered for each model (Monden, 1993). In the current research, one assembly line is assumed to assemble the models within MMAL with zero length and no setup is required (Xiaobo *et al*., 1999). While in FAL, different setup is required for different models. And to observe the effect of cycle time on cost, the cycle time is varied for each model (Heike *et al*., 2001). The above researchers gave the idea of MMAL with setup cost. But the current research gives a unique idea with zero setup for MMAL.

2.6 Flexible assembly line

FAL is a unidirectional flow system made up of a set of assembly stations in series and a loading and unloading (L/U) station, linked with a automated material handling system. The flexible assembly stations (e.g., assembly robots or automated insertion machines) have a limited work space. The component feeding mechanism associated with each assembly task uses some of the finite work space. So, only a limited number of tasks can be assigned to a station. When component are all of relatively similar size one may assume that each task uses the same amount of the station work space. Under this assumption the limited work space of a station can be refined as its flexibility capacity which specifies the maximum number of tasks that can be assigned to the station (Sawik, 2000a).

2.6.1 Setup Time and improvement

In an assembly line different model needs different setup to maintain the smooth production. When setup time is higher than output of the production would be lower. Thus setup time can be reduced, if one type model is produced and setup cost will be reduced as well. (Monden, 1993). Setup time might be lengthy, if it is not done properly and it is occurred when no standardization of setups, procedure is not observed properly, the operations of adjustment is high and etc. These problems can be improved through daily investigation and repeated questioning of setup conditions at the actual work place. Procedure for setup improvement, setup procedures can be improved by video taping, conduction time and motion studies of setup actions. And also setup procedures can be improved by improving operations, equipment improvement (Monden, 1993).

2.6.2 General assumptions for FAL

In this research a comparative cost analysis is carried out between FAL and MMAL. Numbers of articles are viewed for FAL; following assumptions are made by the authors to resolve the sequencing problem.

1- “Each assembly stage consists of parallel identical assembly stations, where each station is assigned the same types of component feeders and is capable of performing the same types of assembly tasks” (Sawik, 2004).

2- “Each assembly station has internal input and output buffer space of a finite capacity, which may result in blocking of a station” (Sawik, 2004).

3- “Each assembly station has a finite work space where limited number of component feeders can be placed” (Sawik, 2004).

4- Each station can perform at most one task at a time.

5- “Transportation times between processing stages, loading/unloading times of products and any change over times of assembly stations are negligible. For each assembly task of each product, the processing times at each assembly station capable of performing it are known ahead of time “(Sawik, 2004).

6- Each product has a constant demand rate and also a constant production rate and also setup time is required before beginning of production (Pesenti and Ukovich 2003).

7- In FAL, holding cost rate is constant and there may also be setup cost (Pesenti and Ukovich 2003)

2.6.3 Scheduling in FAL

The FAS consist of transportation link of different assembly stations, each station consist one or more identical parallel stations and has limited work space for component feeders and limited buffer storage of products waiting for processing or for transfer between the stations. So here chance of blockage of the models is very high. So, to resolve the this problem, Sawik (2000a) presented an exact approach by mixed integer programming to simultaneous or sequential loading and scheduling of a flexible assembly system (FAS). The propsed progmming gives the optimal solution of problem of loading and scheduling in a general with limited work capacity. It should be pointed out that the performance of the mixed integer programming models may depend on the FAS configuration (e.g. single Vs parallel assembly stations, single Vs multiple in-process buffers, etc.) and it can also be used for the performance evaluation of various heuristic algorithms constructed for the FAS loading and scheduling problem.

Later on Zhang *et al.,* (2004) investigated a scheduling model for optimal production sequencing in flexible manufacturing system. The objective is to find both a feasible assignment of operations to machines and schedule tasks in order to minimize the completion time for a single product or a batch of product. The assembly process is modeled using timed Petri nets (PN) task scheduling is solved with a dynamic programming algorithm, which calculated the total job completion time and obtain the optimal task sequence.

Balancing and scheduling are two most important short-term planning issues in FAL. Sawik (2002b) applied monolithic and the hierarchical approach for balancing and scheduling of a FAL. The FAL is made up of a set of assembly stations of various types in series, each with limited work space and is capable of simultaneously producing a mix of product types. He worked on goal of determining an assignment of assembly schedule for all products so as to complete the products in minimum time.

Jeong (1997) presented a paper in which evaluation and selection of assembly sequences are performed in the planning stage of assembly processes. Proposed paper dealt with the effect of selecting particular assembly sequences to the performance of flexible assembly systems (FAS). The study shows that the selection of efficient assembly sequences in FAS environment can be done by solving the generalized FAS scheduling problem.

2.6.4 Production lines and cost

Pesenti and Ukovich (2003) worked on scheduling for multiple production line. Multiple production line give minimization of the long-range production, setup, inventory, and shortage penalty costs. A heuristic method for this economic lot scheduling problem (ELSP) is introduced for resolving the scheduling problems.

Meyr (2002) addressed the simultaneous lotsizing and scheduling of several products on non-identical parallel production lines to reduce the setup times. The limited capacity of the production lines may be further reduced by sequence dependent setup times. The objective is to meet demand without backlogging, holding and production costs. The production lines offer at least partially the same service and thus can be used to alternatively. However, they do not have to be technically identical. Since commonly such lines are highly utilized, they represent potential bottlenecks. The problem is heuristically solved by combining the local search metastategies threshold accepting (TA) and simulated annealing (SA) respectively.

Saving cost always remains the problem in manufacturing industries. As Pesenti and Ukovich (2003) and Meyr (2002) proposed multiple production lines, here it can be criticized that multiple production lines can reduce, penalty cost and etc. But here setup cost is higher because different model produces with different setups and its