International Journal of the Physical Sciences Vol. 6(30), pp. 6928 - 6933, 23 November, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.690
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Process queuing in the automobile manufacturing body shop: Using a multi-objective model

Ali A.J Adham* and Razman Bin Mat Tahar

Faculty of Technology Management, University Malaysia Pahang, Kuantan 26300, Pahang, Malaysia.

Accepted 3 August, 2011

The automobile industry is one of the most important industries in global economics. The automobile manufacturing industry consists of many shops and many stations. Each station has a number of operations, which depend on the number of welded pieces in those stations. One of these shops is the body shop. The problems that occur in the body shop concern queuing and the lead time between stations. This paper focus on optimize queuing processes and lead time in the body shop at the production line. A multi-objective model was applied to create a balance of equal finishing of all operations in all stations at the same time and to reduce the lead time in transferring the car structure between stations. The result showed that saving time and ensuring maximum production can increase profits in the automobile manufacturing industry.

Key word: Automobiles industry, assembly line, multi-objectives model, optimum design, queuing.

INTRODUCTION

The automobile industry, like most other industries, has long been dependent on economies of scale. Many companies have moved toward an economy of variety due to extremely short product life cycles and competition. However, automobile companies are facing tough challenges to improve vehicle quality and reduce product development time to serve customer demand (Gnoni and Lavagilio, 2003; Ezutah et al., 2011). Therefore, the changing business conditions of the 21st century has led to companies facing issues ranging from globalization, economic uncertainty to new technologies and increasing consumer demands. In the automobile industry, as manufacturers design and build vehicles globally (Ismail and Sharifi, 2006).

Wonjoon and Hyunoh (1997) automobile manufacturing normally consists of many lines: body shop (BS), paint shop, assembly shop (AS) and test shop (TS). In addition there are several sub-lines that feed parts to these lines. The production of automobiles in the BS is a typical example of mixed-model production. Different models typically require different amounts and choices of body works creating an uneven flow of work along the line and variations in the workload of the individual workstations in the BS. Hence, for efficient utilization of the BS, it is very important to keep the production of models with 'heavy' options as smooth as possible (Zulnaidi, 2010).

This study presents the problems of the BS, which are queuing and the lead time between stations. Therefore, the concentration of this study will be on the BS. However, the same problem is present in other shops (AS). The main problem at the BS is that one station can finish all operations before another which causes problems in terms of waiting for all stations to finish an operation before the production line can continue. Hence, queuing is the first problem in the BS. On the other hand, there is a lead time to transfer the car structure from one station to another. However, the cooperation between all stations to finish the work in the same time should be available. Therefore, the processing time and the lead time are the targets, and they should be balanced in all stations to overcome the queuing problem.

A multi-objective model (MOM) creates an optimum solution to balance the time between the stations. The optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives. However, maximizing profit and minimizing the cost of a product, maximizing performance and minimizing the fuel

*Corresponding author. E-mail: aliadham12@yahoo.com. Tel: +60149053590.

consumption of a vehicle and (or) minimizing weight while maximizing the strength of a particular component are examples of multi-objective optimization problems. Finally, the outcome of the developed process is a reduction in processing time and the proposed model can be applied for all automobile manufacturing companies (Wonjoon and Hyunoh, 1997).

LITERATURE REVIEW

Queuing in all stations at the BS is the main problem in the automobile industry, as well as at the AS. Over the years, many researchers have written on this problem and they have also applied various methods in an attempt to solve it. Here, we highlighted some of the researchers who have looked at this area.

Joseph and Michael (2004) studied the BS and found that it is the most commonly used method for a mass production environment. There are many purposes to increase efficiency by maximizing the ratio between throughput and required costs. BS balancing has been the main design problem in the research literature of this field. In most cases, this problem relates to a single product assembled on the line, with the objective being to maximize the efficiency of the BS. This objective may be achieved by minimizing the lines' cycle time subject to a given number of stations, or by minimizing the number of stations subject to a required line cycle time (production rate).

Gamberini and Andrea (2006) proposed the AS rebalancing, a problem that nowadays frequently occurs in companies operating in competitive environments characterized by frequent changes in products features and sales volume. Such variable scenarios affect the AS balance involving stations' workload re-definition. Therefore, a multiple-objective heuristic procedure for solving the single-model stochastic AS re-balancing problem was proposed. However, two objectives taken into account are minimizing the unit total expected completion cost along with minimizing reassignment of tasks. An index called the "similarity factor" is introduced to measure the similarity between the task assignment in the initial and new line.

Afshin (2005) introduced a multi-objective genetic algorithm approach searching for locally pare-to-optimal frontier of a mixed-model sequencing problem Just-In-Time (JIT) environment where simultaneous minimization of setups and production rates variation is desired.

Amir and Farhad (2006) investigated and developed a multi-objective model to optimally control the service rates of the manufacturing and the assembly operations in a dynamic multi-stage assembly system, in which the average lead time, the variance of the lead time and the total operating costs of the system per period are minimized and the probability that the manufacturing lead time does not exceed a certain threshold is maximized.

APPLICATION OF MULTI-OBJECTIVES IN AUTOMOBILE

Ali et al. (2009) presented the MOM used to optimally process the queuing and lead time of a multi-stage BS using an interactive method. The multi-stage BS is modelled as an open queuing network whose service stations represent manufacturing or body operations. It is assumed that the product order arrives according to a Poisson process. In each service station, there is either one or an infinite number of servers with exponentially distributed processing time in which the service rate (capacity) is controllable.

Amir and Farhad (2006) carried out a MOM approach applied to a JIT sequencing problem where variation of production rates and number of setups are to be optimized simultaneously. The implementation of optimization by algorithms will be present to process lead times in auto-motive manufacture. It can be solved by carrying out automobile plans to the BS to process queuing in product line.

However, the multi-objective optimum problem (MOOP) finds one and only one solution. In fact, this is an ideal case which predominantly finds a set of solutions. Therefore, for better understanding of the MOOP, a summary of some basic definitions is present in Equation 1. Without loss of generality, a MOM considered with (n) decision variables and (m) objectives (m > 1).

$$(Max\ or\ Min)\ y = f_i(x_j) = f_1(x_1), f_2(x_2), f_3(x_3), \ldots\ldots, f_m(x_n) \quad (1)$$

where $x_j \in R\^{}n, and\ f_i(x) \in R\^{}m$

The basic approach of MOM is to establish a specific numeric objective, formulate an objective function for each goal, and then seek a solution that minimizes the (weighted) sum of deviations of these equations from their respective goals.

Razman and Ali (2010) considered that the standard MOM formulation contains two or more objectives. Sometimes, the objectives take maximum or minimum value, or else, it may contain maximum and minimum values together. However, the MOM in this paper deals with the last pattern which contains the objective of maximum and minimum values. The following equation presents the standard multi-objectives equations:

$$(\ Max\ or\ Min\ )\ Z_i = \sum_{i=1}^{m} \sum_{j=1}^{n} \propto_j * f_i(x_j) \quad (2)$$

where $i = 1,2, \ldots\ldots, n \quad (nomber\ of\ variables)$,

$\propto_j > 0$ *parameter constant*

$j \geq 1,2, \ldots., m\ (number\ of\ objectives)$

The objective functions are to minimize the total operating costs of the system per period, the average lead time, the variance of the lead time and the probability that the manufacturing lead time does not

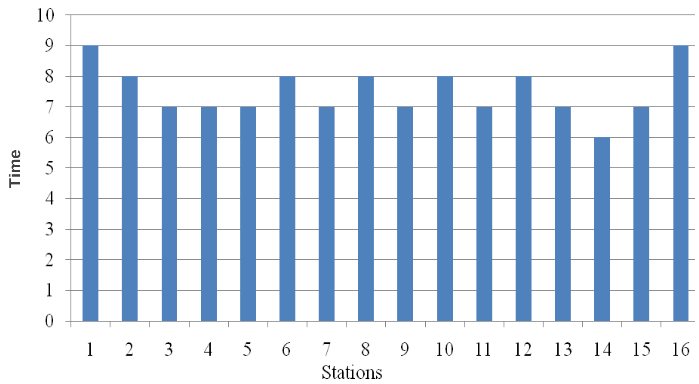

Figure 1. Time problem between stations.

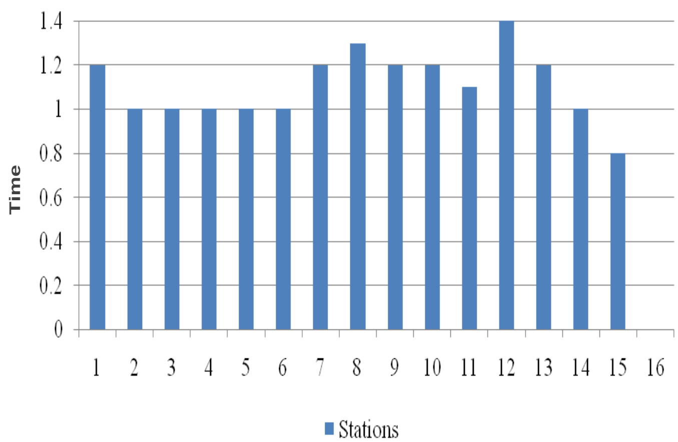

Figure 2. The lead time between stations.

exceed a certain threshold. Finally, the method is used to solve a discrete-time approximation of the original problem and also to investigate the trade-off between the accuracy (correctness) and the computational time of the proposed approximation technique.

The computer programmes are one of the most important tools used to solve the MOM in the automobile industry. This is due to an increase in the performance of computer systems which can perform so many mathematical operations in a second and have a memory capacity of hundreds of megabytes. These aids are urgently needed, in order to meet increased demand for automobile development, shorten development times and at the same time achieve higher product quality (Fritz, 1997).

PROBLEM STATEMENT

The BS continued to expand and diversify, but the best efforts to increase automobile capability were outpaced. The BS remains largely a manual activity, and workers remain critical. However, the past strategies for improving worker productivity resulted in lower job satisfaction and limited quality improvements. Moreover, increasing the job complexity added to workers' frustration (Toshio, 1996).

The BS time balancing problem (BSTBP) consists of the assignment of tasks to operate on the line engaged in such a way where the final item is produced with respect to a pre-specified production rate. In the literature, a wide variety of algorithm proposals to solve BSTBP are found. However, almost all proposals considered the BSTBP from a static standpoint as shown in Figure 1.

The lead time between stations needs a period to transfer the car structures which is different between the stations. Figure 2 shows the difference in time between the stations. Therefore, the two objectives of this study (the BSTBP and the lead time) are studied to process the problem of creating a balance and reducing the queuing time.

METHODOLOGY

Multi-objective model (MOM)

The MOM is proposed in this case study to solve the problems of the BS, in HICOM Company. The model includes two objectives (goals), as the stations in the BS contain many operations which need time for production. However, if the lead time can be minimized, this can lead to an increase in the products quantity in the operation process. Therefore, the first objective will reduce the process time in each station.

On the other hand, the production line loses time by moving the car structure from one station to another in the BS. Minimizing the lead time between stations leads to an increase in the productivity of the production line in the BS. Thus, lead time reduction is the second objective of this study. In the literature, some researchers did not pay attention to the lead time, because they thought it did not have a significant effect on the productivity of the production line. In fact, the losing of time between stations will affect the productivity if the number of stations is increased.

Objectives

1. Reduce the processing time in each station:

$$first\ Objective\ \ Min\ Z_1 = \sum_{i=1}^{n} Q_i \tag{3}$$

where

$Q = Queuing\ between\ stations\ to\ move\ body\ car$ and $i = \ number\ of\ stations$

2. Reduce the lead time of the production line in the BS:

$$second\ objective\ Min\ Z_3 = \sum_{i=1}^{n} (T_i - AOT_i) \tag{4}$$

where T is total time to move the structure car to the next station, and AOT is total time to finish all operation (s).

Table 1. Processing time operations at production line.

Time of operations (s)	Station															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	21.6	19	18	17	18	18	18	19	17	20.4	21	17	18	17	17	21.6
2	21.6	19	18	17	18	18	18	19	17	20.4	21	17	18	17	17	21.6
3	18	18	17	17	17	19	15	20	18	19.2	18	19	15	20	19	16.8
4	18	18	17	17	17	19	15	20	18	19.2	18	19	15	20	19	16.8
5	14.4	17	18	14	18	17	18	17	18	14.4	16	16	19	19	16	20.4
6	14.4	17	18	14	18	17	18	17	18	14.4	16	16	19	19	16	20.4
7	18	16	17	17	17	20	18	19	15	18	19	20	18	22	20	21.6
8	18	16	17	17	18	19	18	17	18	18	19	18	18	20	20	18.6
9	16.8	18	18	17	19	19	18	22	20	16.8	20	17	17	18	21	19.2
10	16.8	18	18	17	20	19	19	22	19	16.8	20	17	17	18	21	19.2
11	14.4	19	17	16	19	22	17	19	19	16.8	20	17	17	18	21	19.2
12	14.4	19	17	16	19	22	17	19	17	14.4	16	17	19	16	17	20.4
13	16.2	18	20	17	18	19	16	21	17	15	16	16	16	19	19	21.6
14	16.2	18	20	17	18	20	16	21	17	15	16	16	16	19	19	21.4
15	16.8	17	17	16	18	20	17	22	17	16.8	17	21	17	20	17	20.4
16	15	17	17	16	17	19	17	22	16	15	17	21	15	20	18	20.4
17	15	16	17	17	17	18	16	15	15	15	16	18	15	-	19	20.4
18	18	16	17	16	18	18	20	18	16	18	18	18	19	-	19	20.4
19	18	17	22	17	18	19	19	18	20	18	18	19	20	-	20	21.6
20	16.8	17	22	17	17	19	17	17	17	16.8	17	19	19	-	20	21.6
21	18	18	-	17	-	18	-	18	-	20.4	18	18	18	-	-	22.8
22	16.2	18	-	18	-	17	-	16	-	16.2	-	-	-	-	-	22.8
23	16.2	18	-	-	-	15	-	-	-	16.2	-	17	-	-	-	20.4
24	16.8	15	-	-	-	-	-	-	-	19.2	-	-	-	-	-	20.4
25	18	15	-	-	-	-	-	-	-	-	-	-	-	-	-	22.8
26	15.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.8
27	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	473	434	362	364	359	431	347	418	349	410.4	377	393	365	302	375	535.6

Subject

The subject is the number of operations in each station:

$$\sum_{i=1}^{n} \quad \sum_{j=1}^{m} TO_{ij} \; S_i \; \leq C_1 \qquad (5)$$

Where is TOi_j time to achieve operation i at station i, and C_i is the total time to achieve all operation i in produce line.

RESULTS AND DISCUSSION

The production line in the BS contains 16 stations, where each station includes many operations. In this case study, the minimum operation is 16 tasks and the maximum operations are 28 tasks, the same time that one operation achieved to process one piece in body car, another way the one piece needs many operations in the wielding of the body car, the total pieces in BS for one type car (ISUZU) are 346 pieces, which are distributed differently on these stations. Therefore, these pieces need different times to process them. The total time is 6295 s to process these pieces to wielding them to body car. Table 1 shows the process time for each operation, total time in each station and number of operations in each station.

MATLAB software was deployed to solve this issue through the application of the proposed MOM. In this case study, the MOM included two objectives. Each objective had the sybarite one table, it is called Goal in the table (G), while Table 2 is for the first objective and Table 3 is for the second the objective. Table 2 presented the value of the objective in each station, the variable (x_i) is representing the saving time in each station, the column (Solution value) is representing the value of profit

Table 2. Result of the first objective (goal).

Chain	Objective	Decision variable	Solution value	Unit cost or profit	Total contribution
1	G1	X_1	0.81	1.00	0.81
2	G1	X_2	0	0.75	0
3	G1	X_3	0	0.50	0
4	G1	X_4	3.05	0.50	1.53
5	G1	X_5	1.48	0.50	0.74
6	G1	X_6	0	0.75	0
7	G1	X_7	1.24	0.50	0.62
8	G1	X_8	0	0.75	0
9	G1	X_9	0.53	0.50	0.26
10	G1	X_{10}	0.52	0.75	0.39
11	G1	X_{11}	1.33	0.50	0.66
12	G1	X_{12}	0	0.75	0
13	G1	X_{13}	0	0.50	0
14	G1	X_{14}	1.24	0.25	0.31
15	G1	X_{15}	0.79	0.50	0.39
16	G1	X_{16}	2.16	1.00	2.16
			Objective value (min)		7.87

Table 3. Result of the second objective (goal).

Chain	Objective	Decision variable	Solution value	Unit cost or profit	Total contribution
1	G2	X_1	0.81	0	0
2	G2	X_2	0	0	0
3	G2	X_3	0	0	0
4	G2	X_4	3.05	0	0
5	G2	X_5	1.48	1.00	1.48
6	G2	X_6	0	0	0
7	G2	X_7	1.24	1.00	1.24
8	G2	X_8	0	0	0
9	G2	X_9	0.53	1.00	0.53
10	G2	X_{10}	0.52	0	0
11	G2	X_{11}	1.33	1.00	1.33
12	G2	X_{12}	0	0	0
13	G2	X_{13}	0	1.00	0
14	G2	X_{14}	1.24	1.00	1.24
15	G2	X_{15}	0.79	0	0
16	G2	X_{16}	2.16	0	0
			Objective value (min)		5.81

in each station after applying the model, the column (Total contribution) is representing total profit in each station derived from multiplying column (Solution value) and (Unit cast profit).

The total operation time at all stations is the first objective which is equal to 7.87 min. Therefore, just from the first objective of 7.87 min saving in operation, it indicates that even without any time saving in the lead time, the proposed model already brings some profits. However, the obtained results of the lead time (Table 3) provide further attraction.

Table 3 is in the same design as Table 2. It shows the results of the achievement of the second objective, that is, the process of the lead time between the stations in BS. The value of time saving in each station from the column (Solution value), as well as, the total saving time in each station as presented in last column (Total contribution) as shown in Table 3. To sum up the model, saved approximately 5.81 min between the lead time.

As a result, the total time saving from the results of both objectives equals 13.68 min (7.87 from first objective + 5.81 from second objective). And this is merely for every daily working time in total to produce the car brand (ISUZU). That is to say, after applying the model, the total time reduction is around 13.68 min in each working day. Therefore, suppose in each month, there are 20 days for working in a company, it means that by applying the proposed model, the company can save 273.6 min (20 days multiply 13.68 min/month), or 4.56 h. Let alone if the company has two or three cars to process in one month. However, to achieve the best result in making high balance in BS, we recommended that the manager of automobile manufacture should apply this method to achieve the operations among the stations.

Conclusion

This paper has contributed to developing efficient PL in automobile manufacturing to reduce the queuing among stations. It analyzed the problem of processing time and lead time inside the BS of automobile industry. Accordingly, MOM was developed to solve these problems. The result showed that the saved time during the processing of all operations in the production line was about 7.87 min per working day with each car produced. Meanwhile, the model reduced the lead time between the stations by about 5.81 min per working day. The total saving time from the results of both objectives was 13.68 min per working day. Therefore, the time reduction will save around 273.6 min in each month. Finally, applying MOM increases the productivity of the BS by 2 to 3 cars monthly. Which lead to an increase in the profit of the company by around 6.66% yearly. Therefore, the result is the best solution to PL in BS.

ACKNOWLEDGEMENTS

This paper was partially supported by the University Malaysia Pahang, under Grant No. GRS090336. The authors would like to thank the University and all staff in HICOM Company for their assistance and making the research a success. They also thank the anonymous referees whose insights improved the content of the manuscript.

REFERENCES

Afshin SM (2005). A multi-objective genetic algorithm for mixed-model sequencing on JIT assembly lines. Eur. J. Oper. Res., 167: 696-716.

Ali A, Razman BT, Liu Y (2009). Mathematical model of lead time control in multistage assembly system: Automotive Manufacturing. MUCED Conference, p. 113

Amir A, Farhad K (2006). A multi-objective lead time control problem in multistage assembly systems using an interactive method. Appl. Math. Comput., 176: 609–620.

Ezutah U, Olugu K, Yew W (2011). Fuzzy logic evaluation of reverse logistics performance in the automotive industry. Sci. Res. Essays, 6(7): 1639-1649.

Fritz J (1997). Prediction of manufacturing operations sequence using recurrent neural networks. Thesis Doctorial, Thesis doctorial. Ohio University, pp. 2-3.

Gnoni MG, Lavagilio R (2003). Production planning of a multi-site manufacturing system by hybrid modelling: A case study from the automotive. Biotechnolology, 85(03): 251-262.

Ismail HS, Sharifi H (2006). A balanced approach to building agile supply chains. Int. J. Phys. Distribution Logistics Manag., 26(6): 431-444.

Joseph B, Michael M (2004). Multi-objective design of team oriented assembly systems. Eur. J. Oper. Res. Biotechnol., 7(156): 326-352.

Razman BT, Ali AJ (2010). Develop and enhance the customer demand from automobiles by using multi-objectives model. ICBER International Conference, p. 30.

Gamberini R, Andrea G (2006). A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem. Int. J. Prod. Econ. Biotechnol., 2(13): 226–243.

Toshio S (1996). Development of the new human-conscious automobile Assembly Plan. Annals of the CIRP. Biotechnolology, 46(7): 608-605.

Wonjoon C, Hyunoh S (1997). A real-time sequence control system for the level production of the automobile assembly line. Comput. Eng. Biotechnol., 33(3): 769-772.

Zulnaidi Y (2010). Quality management as an effective strategy of cost Savings. Afr. J. Bus. Manag., 4(9): 1844-1855.