Jurnal Teknologi, 37(A) Dis. 2002: 73–87

WORK IMPROVEMENT AT A CAR MANUFACTURING COMPANY

MUHAMAD ZAMERI MAT SAMAN & LAW CHEAK YING

Abstract. Productivity has been identified as an important role in any organization, especially for manufacturing sectors to gain more profit that leads to prosperity [1]. This paper reports a work improvement project in a car manufacturing company. It involves problem identification at the metal finish line and proposing recommendation to improve the current situation more efficiently. Based on the observation and data online work-in-progress (WIP) has been identified as a major problem and this is caused by the insufficient movements due to material handlings and unbalanced workload.

Method improvement technique is used to determine the best method of carrying out a task in order to eliminate the unnecessary movements. Then, line-balancing technique is used to minimize the idle time at every station or the percentage of line balance loss (LBL). In order to verify the results that were obtained from the generated line-balancing alternative, *Witness* simulation package is used to obtain the output. One effective alternative is chosen based on the results obtained from the simulation and cost justification. Then, a proper planning is suggested to maximize the resource utilization at the metal finish line.

Simulation results showed that productivity increases roughly three times higher than the current situation. However, the results were obtained based on several assumptions that had been made during carry out this project.

Key words: On-line Work-In-Progress (WIP), Off-line Work-In-Progress (WIP), method improvement, line balancing, simulation, cost justification, resource planning and allocation

Abstrak. Produktiviti merupakan sesuatu yang amat penting bagi sesebuah organisasi, terutamanya bagi sektor pembuatan ke arah meningkatkan keuntungan untuk memajukan syarikat. Kertas kerja ini melaporkan satu kajian kes bagi pembaikan kerja di sebuah syarikat pengeluaran kereta. Kajian kes ini terbahagi kepada dua bahagian iaitu mengenalpasti masalah di lini pemasangan utama dan mencadangkan pembaikan ke arah meningkatkan kecekapan sistem yang sedia ada. Berdasarkan kepada pemerhatian dan juga data yang dipungut, kerja tergendala di lini pengeluaran adalah merupakan masalah utama. Ia disebabkan oleh sistem pengangkutan bahan yang kurang cekap dan pembahagian kerja yang tidak seimbang.

Teknik pembaikan kerja digunakan untuk mencari penyelesaian yang terbaik bagi mengatasi masalah di atas. Kemudian, kaedah keseimbangan lini digunakan untuk meminimumkan masa melahu pada setiap stesen kerja. Untuk mengesahkan keputusan daripada alternatif-alternatif yang dicadangkan, simulasi dengan menggunakan perisisan *Witness* telah digunakan. Satu alternatif terbaik dipilih berdasarkan kepada keputusan daripada simulasi dan juga justifikasi kos. Akhir sekali, perancangan sumber dijalankan ke arah memenuhi permintaan dan juga memaksimumkan penggunaan sumber.

Daripada keputusan simulasi bagi sistem yang dicadangkan, menunjukkan bahawa produktiviti meningkat sebanyak tiga kali ganda berbanding dengan sistem yang sediada. Walaubagaimanapun, keputusan ini adalah berdasarkan kepada beberapa andaian yang dibuat semasa projek dijalankan.

* Department of Manufacturing & Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor. E-mail: zameri@fkm.utm.my

Kata kunci: Kerja dalam proses (tergendala) di lini pengeluaran, Kerja dalam proses (tergendala) di luar lini pengeluaran, pembaikan kaedah, keseimbangan lini, simulasi, justifikasi kos, perancangan sumber

1.0 INTRODUCTION

Effort to increase the productivity is an important factor for any organization, especially for the manufacturing industries. Productivity may be defined as the ratio of output against input [2]. Utilization of inputs or resources may give the greatest scope for cost reduction. Efficiency is a tool to measure any industry organization's performance while productivity used to measure this efficiency [3,4].

In order to improve productivity, various techniques have been developed to tackle problems from different area such as work study, method improvement, quality improvement tools, line balancing technique and simulation approach.

This study investigates the problems that arise at the metal finish line of a car manufacturing company (for one model only). This is done in order to improve the current situation through work improvement. Metal finish is the second process for this automobile manufacturer. Improvements had been recommended through this study to improve current situation by carrying out method improvement, line balancing, simulation using *Witness*, cost justification and also resources planning and allocation.

2.0 PROBLEM IDENTIFICATION

2.1 Background

Previously, the production capacity of a car manufacturing company is around 2000 unit/shift/month. However, due to the unexpected economy crisis, their production dropped approximately 80% from the previous market demand. The economy crisis also contributed to a high degree of demand fluctuations of production schedules.

Based on the past one-year data, work-in-progress (WIP) is the major problem among all of the observed problems as shown in Figure 1. Two types of WIP occurred in the current situation, these are on-line and off-line. The off-line WIP includes cars waiting for repairs and also those waiting to be sent to paint shop. Meanwhile, the on-line WIP is a queuing problem in the production line. However, this study will concentrate on the effort to reduce the on-line WIP only.

The causes that contribute to the on-line WIP were identified after conducting an investigation from the viewpoint of 4M (man, machine, material and method) as shown in Figure 2. However, from the brainstorming session, the most probably causes that contribute the on-line WIP are related to the method that used to carry out jobs at metal finish line. Basically, the two causes are,

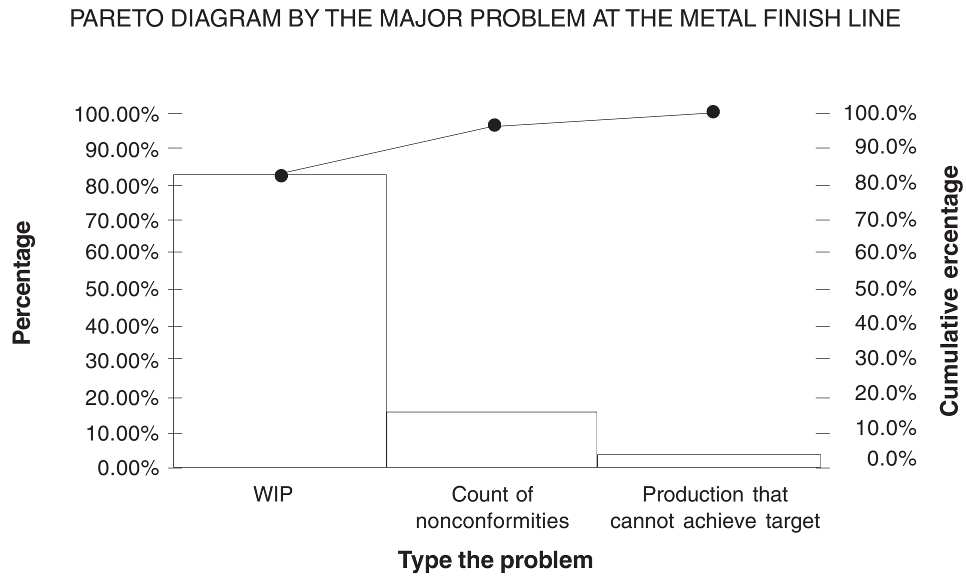

Figure 1 The three major problems identified at metal finish line

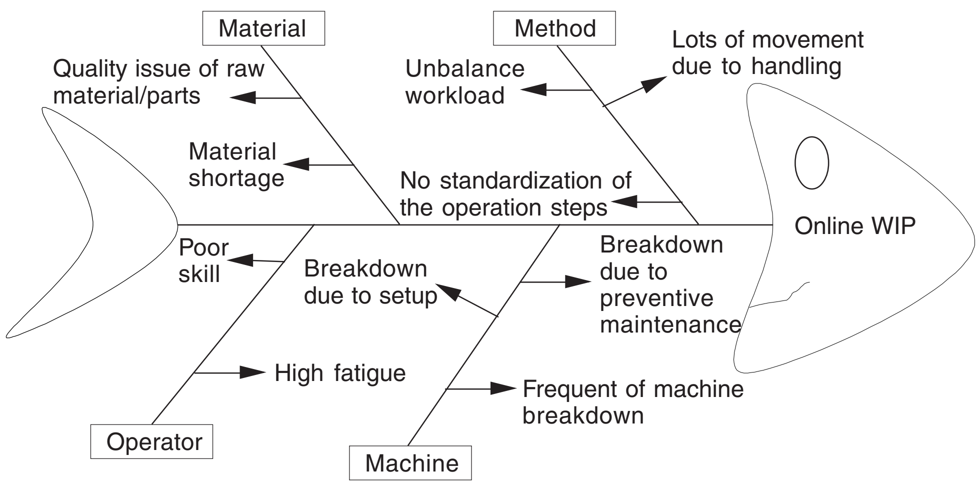

Figure 2 A couse and effect diagram of on-line WIP

(i) The operation performed in metal finish line involves a lot of movement around the working area in order to get the materials (parts) and equipment. This problem occurred due to the workplace arrangement and also material handling system.

(ii) The workload among station is not equal. Some of the station needs higher cycle time to perform several jobs. Some need more time due to repeated manual handling of heavy parts.

2.2 Metal Finish Line Process Flow

Each vehicle will passed through five major processes, which are body shop followed by metal finish, paint shop, assembly and car conditioning. The generic process flow of the welding process for the car white body at metal finish line is shown in Figure 3.

In metal finish line, critical area of the product is strengthened by using metal-inert-gas (MIG) weld. Doors, bonnets, trunk lid, fenders etc. are fitted to the body shell and then the whole car's white body is checked for panel irregularities. These are removed in the metal finish process.

There are 6 stations in the metal finish line. Stations 1 and 2 do spot welding. While station 3 is where MIG welding is done. Operators in station 4 grind and fix the small parts. After that, the car white body moved to station 5 for panel fixing. At this station, the doors, fenders and bonnet will be fixed to the car white body. Truck lid is fixed at station 6. The last two stations are for inspection and body repair, which are carried out off-line.

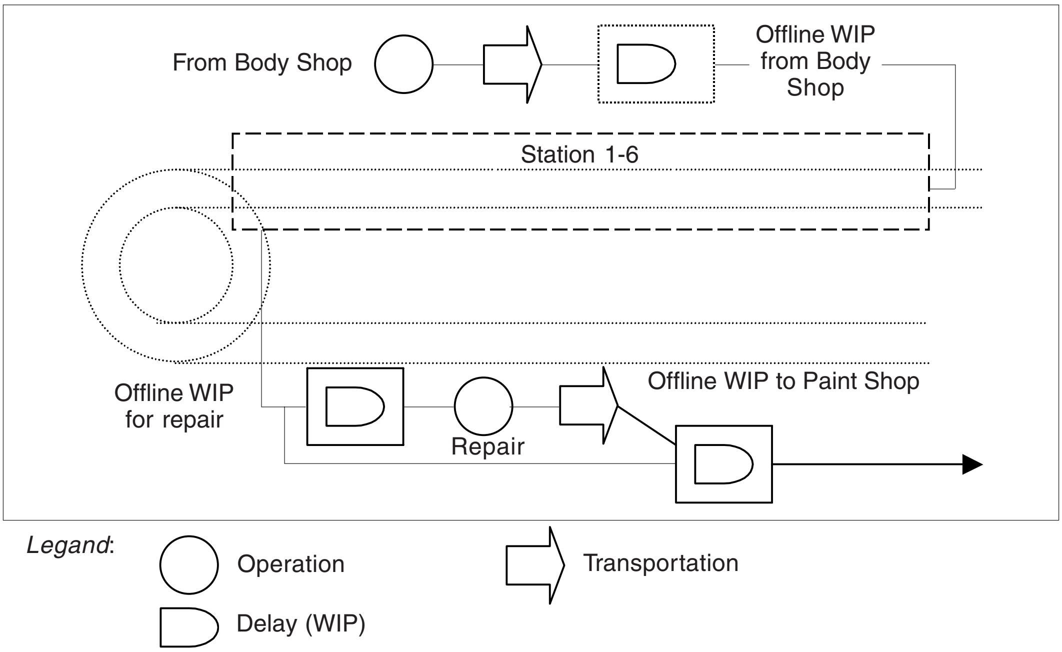

Figure 3 The process flow at the metal finish line

2.3 Findings

Work measurement has been used to gather all the information in order to justified the major problems. The work measurement data is analyzed to get a cycle time for each workstation. After that, line balancing technique and also analysis of workers' movement at the working area has been used in order to overcome the problem.

2.3.1 *Work Measurement*

The direct time study has been used to determine the cycle time for each workstation. Using a Westing House System of rating, the rating for operator can be judge as shown in Table 1 [5]. As a result, the calculated rating was 90%. But according to the foreman of metal finish line, the average rating for every station is around 75%. Therefore, the rating for the purpose of this project will be compromised between the Westing House System of rating and advise from foreman. The averageof both values, that is 82.5% will be used.

Table 1 Calculating the rating by using westing house system

Skill	C2	+0.03
Effort	E2	–0.08
Condition	E	–0.03
Consistency	E	–0.02
Total		–0.10

Meanwhile, allowances were based on the fatigue allowances suggested by International Labor Organization [5]. Before that, some assumptions had been made as follows,

(i) Atmospheric condition = normal
(ii) Noise = normal
(iii) Light = normal
(iv) The conveyor automatically moves the car white body

Table 2 shows how allowance is deduced. As a result, the calculated allowance was 15%. After rating and allowance had been considered, the cycle time for each workstation and also the total time for a car metal finish line processes as shown in Table 3.

Table 2 The calculated allowance

Personnel	5%
Basic fatigue	4%
Standing	2%
Abnormal position	2%
Tediousness	2%
Total	15%

Table 3 Summary of the work measurement analysis

Model: Honda Civik 4 Doors | **Observed by: Cylaw**
Line: Metal Finishing | **Observed Date: 12/01/99 – 13/01/99**

Description	Station	Opera-tor (s)	Reading (Minutes)									Rating %	Normal Times	Allowance %	Standard Times
			1	2	3	4	5	6	7	8	Average				
Spot Welding	1 2	2 2	7.96 7.06	8.62 8.12	8.49 7.92	8.70 8.36	8.18 6.95	7.84 8.48	8.41 8.08	10.10 8.06	8.54 7.88	82.5 82.5	7.05 6.50	15 15	8.10 7.47
Mig Welding	3	2	12.98	11.72	13.221	3.63	11.60	11.18	11.67	11.18	12.15	82.5	10.02	15	11.52
Fix Small Part (6 parts), Grinding & Flanges Knocking	4	2	10.73	10.23	11.06	10.39	11.75	10.32	11.18	10.74	10.80	82.5	8.91	15	10.25
Door, Fender & Bonnet	5	2	18.98	20.98	17.70	21.72	17.25	16.10	15.60	18.00	18.29	82.5	15.09	15	17.35
Truck Lid Alignment	6	1	5.65	6.33	5.55	6.87	4.85	5.13	5.23	5.43	5.63	82.5	4.64	15	5.34
														Total	60.16

Assumption:

1	Working Hour/shift (manual)	9 hr 23 minutes/day
2	Production Down Time	50 minutes/day
3	Material Down Time	–
4	Machine Down Time	30 minutes/day
5	Allowance	15%
6	Rating	75%
6	Production Hour (manual)	513 minutes
7	Number of Workers	15

8 The cycle time for every station is based on the time presented by one of the operator with the highest workload for that station.

2.3.2 *Analysis of Line Balancing*

The summary of the data analysis in the Figure 4, shows that the production line at the metal finish line is not balance. Therefore, the following steps are used to determine the balance loss ratio or line balancing loss (LBL).

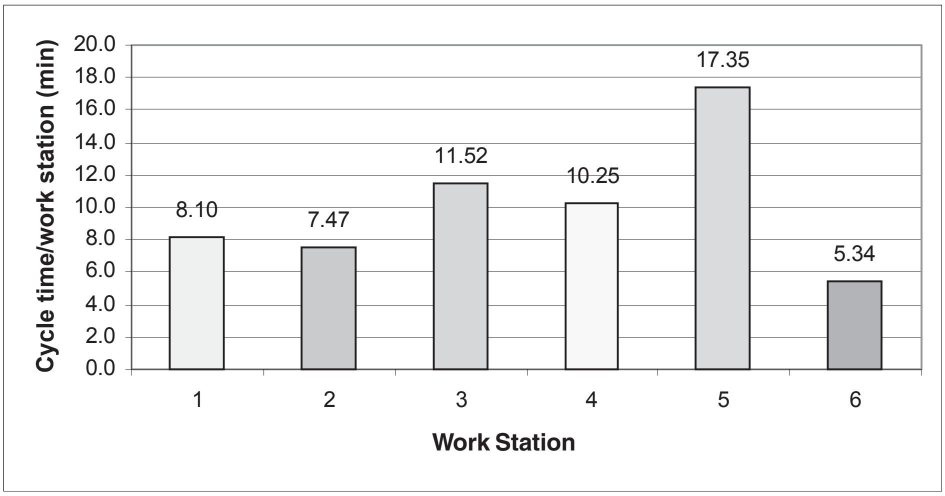

Figure 4 Cycle time for every workstation

$$T_{max} = 17.35\text{min}$$

$$\sum t_i = 60.16 \text{ min}$$

$$n = 6$$

$$\%\text{LBL} = \frac{nT_{max} - \sum t_i}{nT_{max}} \times 100\% \frac{6(17.35) - 60.16}{6(17.35)} \times 100\% = 42.21\%$$

Thus, 42.21% of the production time is idle due to the imbalance line. From Figure 4, the station 5 (door, fender and bonnet) currently controls the working speed in the metal finish line. It shows that on-line WIP will occur as station 5 is the main bottleneck station while cycle time for other stations also varies from one another. It is noted that the maximum cumulated WIP in between station 4 and 5 is only 3 cars. This is due to the space constraint. WIP will not be build up at other stations as there is no space provided for this purpose. However, because of the variation in the cycle time and no WIP space is given, these will cause to other stations to slow down or because idle while waiting for parts to arrive.

2.3.3 *Analysis of Workers' Movement*

In the metal finish line, most of the workers have to move over certain distance to get the equipments, materials or parts. Obviously, time and effort are wasted due to the non-productive movement. Therefore, a study had been carried out to cumulate the total distance of worker' movement.

For a purpose of studying their movement, a string diagram has been used to measure the path of workers, materials or equi pments [6]. To simplify the study, Euclidean distance is used to measure from the objects' mid-point to another. This study is based on the movement from the workstation to the bin, rack or shelves to get equipment or material. Table 4 had summarizes the cumulative movement, which had shown in string diagram.

Based on the unnecessary movement, the non value-added process time can be calculated. The percentages of the non value-added cycle time can be calculated by dividing the total time of movement with the total cycle time of each workstation. This percentage will show which station has the highest percentage of non value added time [7].

$$\text{Percentage of non value-added} = \frac{\text{Total time for movement}}{\text{Total cycle time for every workstation}}$$

Further analysis will be done on the most critical workstation and suggest improvement that should be carried out in order to eliminate the unnecessary movement and reduce the cycle time.

2.3.4 *Analysis of Finding*

Refering to Table 3, the line is clearly not balanced with the highest cycle time at 17.35 minutes against the lowest time at 5.34 minutes. Station 5 has the highest cycle time as the workload of both operators is heavy and involved lots of movement to get doors and bonnets. Station 3 also has a high cycle time caused by the unbalanced workload and non-ergonomic working situation. In this station, both operators have to weld the critical area that cannot reached by the spot welding gun, such as the floor and firewall of the white car body. Station 4 is the third highest cycle time because the operators have to fix 6 parts located at different location of the car white body.

As a conclusion, there are two factors that consumes to the unbalanced line at metal finish line.

(i) The workload between stations has not been equal. Therefore, a study has to carried out to eliminate unnecessary activities, combine wherever possible, rearrange the sequence of operation and also simplify the operation.

Table 4 The measured movement of operators in carrying out their job

Station	Description	Operator (s)	Distant (meters)		Total time of movement (min)	% of non value added cycle time
			Left	Right		
1	Spot Welding	2	17.8	14.5	1.02	11.71
2	Sport Welding	2	9.0	9.0	2.00	12.36
3	Mig Welding	2	4.13	1.03	0.34	3.26
4	Fix small part (6 parts), Grinding & Flanges knocking	2	54.54	18.88	2.69	22.56
5	Door, Fender & Bonnet	2	47.20	46.32	1.84	10.62
6	Truck Lid Allignment	1	18.60		0.67	10.86

Assumption:

1. The distance that has been measured for every single station is based on the total distance (back and forth) from work station to the bin, rack or tooling.
2. Every distance is calculated based on Euclidean distance, which measures at the mid-point. Movement performed around the car body is neglected.
3. The distance of every grasp movement made by the welder as shown in the process chart is estimated as 1.5 m.

(ii) The workplace arrangement is not suitable. In other word, the worker cannot easily grasp tools or parts that are needed to perform their jobs.

2.4 Recommendations

Several recommendations will be suggested in order to overcome the aforementioned problems at the metal finish line. First, method improvement will be suggested to design tooling jigs and material handling devices and rearrangement of the workplace layout. This will be followed by line balancing assuming that all of the suggested method improvement (exclude partially automated for the welding processes) can be adopted into the current situation. This is to minimize the bias in the line balancing alternative, as there are too much non value-added cycle time in the present situation.

As implementation of these suggestions is not part of this study, *Witness* simulation package will be used to simulate the generate and evaluate alternatives. In order to choose the optimum alternative, cost justification will be used. The alternative with the minimum operation costs will be chosen. Finally, resources planning and allocation will be conducted to maximize the utilization of the resources, as the current market demand is lower than the line capacity after improvement had been carried out.

3.0 METHOD IMPROVEMENT

In the existing situation, there are too much loading and unloading of equipment, repeated manual handling of heavy parts (doors, bonnet and trunk lid) and material travelling distances. Therefore, suggestions to improve the current situation include redesigning tooling the sand material handling devices and also rearrangement of the layout of metal finish line.

3.1 Station 4

It is suggested that a trolley and tooling jigs is designed for station 4 to eliminate the unnecessary movement in processing parts and tools in order to reduce the cycle time. The principle of motion economy should be emphasized and tools should be located within the maximum working area and as near to the worker as possible [8]. Tools and jigs should be used to hold the torque wrench and grinder.

3.2 Station 5

The manual door fitting process (exclude handling time) need roughly 55% of the total cycle time of station 5. This includes fifting of the front and rear door. The used of setting jigs is proposed to increase the effectiveness of door fixing process. The car door setting is placed with a setting jig to get a more effective fitting result.

3.3 Other Suggestions

(i) The implementation of partially automated welding process at metal finish line in order to reduce the cycle time and human error. Robot can also be programmed to carry a consistent numbers of optimum welding point to minimize the welding costs. However, manual welding gun cannot be fully replaced by the robot welder because certain points cannot be reached by robot arm especially those located at the inner side ot the product. Proper planning regarding implementation of automated robotic welder should also be carried out as it involves a substantial amount of investment and expertise. Manual-welding process should not be combined with automated welding process at the same station.

(ii) Rearrange and standardize the layout of metal finish line to minimize the unnecessary movement due to poor workplace arrangement and to keep the line tidy and clean. This may be achieve by relocating all of the parts and tools close to the work station by using the material handling devices and jigs that has been suggested. Categorize and differentiate all elements in the line to prevent from unnecessary accidents such as workstation, on-line storage (part/material), accessories (equi pment, rack/trolley, stool), scrap part and rework workstation. Identify and fix the location for every category in the line and also use colorful tape to build the area for every category. Different color will represent different meaning.

(iii) Control the numbers of material in the line through top-up list (material handling approach). Parts are brought into the line according to daily production planning and the capacity of material handling device.

4.0 LINE BALANCING

Three manual line balancing method (Largest Candidate Rule, Kilbridge and Wester Method and Ranked Positional Weight) and four generated alternatives had been used to balance the current situation [9]. Two major assumptions that had been made,

(i) The aforementioned method improvement is adopted into the current situation (except automated welding processes) in order to eliminate all of the non-value added time and minimize the effect of the problems in the current situation.

(ii) The percentage of line balancing loss (%LBL) of 4 generated alternative differ from the 3 manual line balancing as there is an assumption that the priority requirements changed due to relocation of equipment (especially spot guns).

Table 5 shows the results for these line balancing methods in term of percentage of line balancing loss (%LBL). It shows that manual justification methods produce better result than manual line balancing methods. The line balancing loss is improved almost up to 50% by using manual justification. However, for the four generated alternatives, cost justification must be used to compare between them, as the conveyor speed is different.

Table 5 Comparison of the %LBL between manual line balancing methods with other alternatives

Method	**% LBL**	**Cycle Time**
Largest Candidate Rules (LCR)	15.18	6 minutes/ car
Killbridge & Wester (K&W)	15.75	6 minutes/ car
Ranked Positional Weight (RPW)	16.73	6 minutes/ car
Alternative 1	7.48	6 minutes/ car
Alternative 2	7.38	6 minutes/ car
Alternative 3	9.16	5 minutes/ car
Alternative 4	6.47	5 minutes/ car

5.0 SIMULATION AND COST JUSTIFICATION

Simulation is used to obtain the daily output that can be achieved for every alternative while cost justification is used as an indicator to choose the best alternative. The comparison between the actual outputs with the simulated current model is used to validate the simulation model.

Several assumptions that had been made in the simulation model and cost justification are,

(i) JIT system is applied to the whole process from body shop until car conditioning. Rework operations is neglected.

(ii) Warm up period had been defined as 120 minutes.

(iii) The cost for every equipment is as shown in Table 6.

Table 6 Equipment costs

Items	Cost
Spot gun	RM 7,000/ unit
MIG Welder	RM 1,500/ unit
Torque wrench	RM 800/ unit
Grinder	RM 800/ units
Trolley	RM 500/ unit
Tooling jigs	RM 300/ set
Door setting jigs	RM 800/ unit
Hammer	RM 100/ unit
Labor	RM 800/month-person

Table 7 shows the results from the simulation experiments and the cost justification. Alternatives 1 and 2 is almost equal as the daily output and total cost of both alternatives is the same. But, alternative 4 is better than alternative 3 as it has the same output level as alternative 3 but at a lower cost.

Alternatives 1 and 4 cannot be compared directly as they have different conveyor speed. However, as compared to alternative 1, alternative 4 has a lower %LBL and a 20% increase in output at 17% of initial investment increment. Thus alternative 4 is chosen as the best alternative and the following resources planning and allocation will be based on this alternative.

Table 7 Daily output and total costs of alternatives

Alternative	Normal Working Daily Output (unit)	Total Cost (RM)	%LBL
1	86	116,800.00	7.48
2	86	116,800.00	7.38
3	103	139,000.00	9.13
4	103	137,100.00	6.47

6.0 RESOURCES PLANNING AND ALLOCATION

Alternative 4 is capable of generating around 100 cars per normal working day in metal finish line and is suitable for high or heavy market demand. However, the market demand is soft at this moment due to economy crisis that is only ≤ 50 cars per day. Therefore, a proper planning as shown in Table 8 is suggested to allocate resources during soft demand period in order to produce the requirement output at the minimum costs.

In order to come out with the resources planning and allocation for the soft demand, two major suggestions are,

(i) During soft demand, paint shop will only run once for every two days and only three ovens are used to minimize the production costs through reduction in electricity usage.

(ii) Both body shop and metal finish line will share the same group of workers when the demand is soft as most of them are high skilled and experienced workers that perform all of the job in both of this stations.

Table 8 Resources allocation during soft production period

Week		–1	Week 1					Week 2				
		Fri	Mon	Tues	Wed	Thus	Fri	Mon	Tues	Wed	Thus	Fri
Body Shop	M	–	–	–	–	–	–	–	–	–	–	–
	A	50	50	50	50	50	50	50	50	50	50	50
Metal Finish	M	50	50	50	50	50	50	50	50	50	50	
	A	–	–	–	–	–	–	–	–	–	–	–
Paint Shop (4 oven)	M&A		–	100	–	100	–	100	–	100	–	100

These operators will be allocated at the body shop in the afternoon section to build about 50 white car body to keep as offline WIP. These are to be sent to metal finish line the next morning. And, as paint shop will only switch on once every two days, it will serve 50 cars for the metal finish line's offline WIP and another 50 cars build at that particular day. This cyclic process is suggested to maximize the resources utilization during soft demand.

7.0 CONCLUSION

The objective of this project had been achieved, which is to improve the current method, to balance the Metal Finish Line in order to increase the productivity and to optimize the resources utilization in an efficient way.

The problem of online WIP is contributed by the unbalanced and poor layout arrangement. Therefore, three recommendations are presented in this project to improve the current situation. First, method improvement is recommended in order to reduce the non-value added cycle time or movement. Second, material handling device and jigs had been designed to help the operator to reduce unnecessary movement and help perform their work in a more efficient manner. Third, after assuming that all of the non-values add cycle time had been eliminated, effort to balance the line through manual line balancing and manual justification methods is made. Finally, *Witness* simulation package and cost justification method had been used to evaluate and choose an alternative capable of increasing the line capacity and also to optimize the resources utilization through better resources allocation.

From the results obtained, alternative 4 should be considered, as the productivity is increase roughly 3 times from the current line capacity. However, this result is only meaningful during high demand. This cannot be used for the current situation as the demand is soft due to economy crisis. Therefore, it is suggested that a proper planning regarding the allocation of the line resources should be conducted in order to maximize the utilization of these resources at a minimum operating cost. Attention should also be given to the assumptions that had been made in this study during the implementation of the recommendation outlined in this paper.

REFERENCES

[1] Philip, E. H. 1994. *Industrial Engineering and Management: A New Perspective*. USA: McGraw-Hill.
[2] International Labor Organization. 1986. *Introduction To Work Study*. India: Universal Publishing Corp.
[3] Lawrence, S.A. 1992. *Productivity Measurement and Productivity*. USA: Prentice Hall.
[4] Turner, W. C., Mize. J. H., Case, K. E. and Nazemetz, J. W. 1993. *Introduction To Industrial And Systems Engineering*. USA: Prentice Hall.
[5] Kanger, B. 1977. *Engineered Work Measurement*, 3rd ed., USA: Industrial Press.
[6] Tompkims, J.A. 1996. *Facilities Planning*, John Wiley & Sons, Canada.
[7] Gerald, N. 1957. *Work Simplification*. USA: McGraw-Hill Book Company.
[8] Marvin E. M. 1985. *Motion and Time Study*, 6th ed., . USA: Prentice Hall.

[9] The Association for Overseas Technical Scholarship. 1994. *Line-balancing Type Process Design*. Japan: Kansai Kenshu Center.

[10] Witness Training Manual. 1994. AT&T ISTEL Limited.