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A novel method to develop an automobile assembly line system

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The assembly line is an important component of the automobile production process. The function of the assembly line is to produce different models of vehicles with minimum work in the process. For better performance, activities on the assembly line should be performed to minimise the process steps and achieve other objectives. This study develops a new dynamic sequencing method to improve activities on the assembly line and also an automated sequence-control system. Three methods, namely the Multi-Objectives Model, the Genetic Algorithm System and the Simulation Model, are integrated to enhance the efficiency of the assembly line by controlling the processing time within the workstations. The results show that the method was able to improve the working time performance and also increase throughputs.

Key words: Processing time, assembly line, mathematical method, genetic algorithm system, simulation model.

INTRODUCTION

Body Shop (BS), Paint Shop (PS), Assembly Shop (AS) and Test Shop (TS) and other sub-assemblies, also called stations, have the function of feeding the main assembly. The production of automobiles in the AS is a typical example of the mixed-model production system (Wonjoon and Hyunoh, 1997). Figure 1 shows the assembly system of the automobile production system. In the figure, all the assembly plants have their own stations (namely S_1, S_2….S_n). The sub-assembly stations are also shown in the figure.

In the automobile industry system, one of the areas under consideration is the Assembly Line Balancing Problem (ALBP) which distributes the total workload among manufacturing stages (Adham, 2012; Ali and Razman, 2011; Toshio et al., 1996). There were many researchers who studied the issues related to the ALBP and the Production Line System (PLS) in order to obtain the best solution (Razam and Ali, 2012; Minh and Soemon, 2008; Williams, 2007).

The Hybrid Model (HM), combining the Multi-Objectives Model (MOM), the Genetic Algorithm System (GAS) and the Simulation Model (SM), is presented in this study. It is a new technique and one of the most powerful methods to obtain the best balance of the cycle. Many real-world

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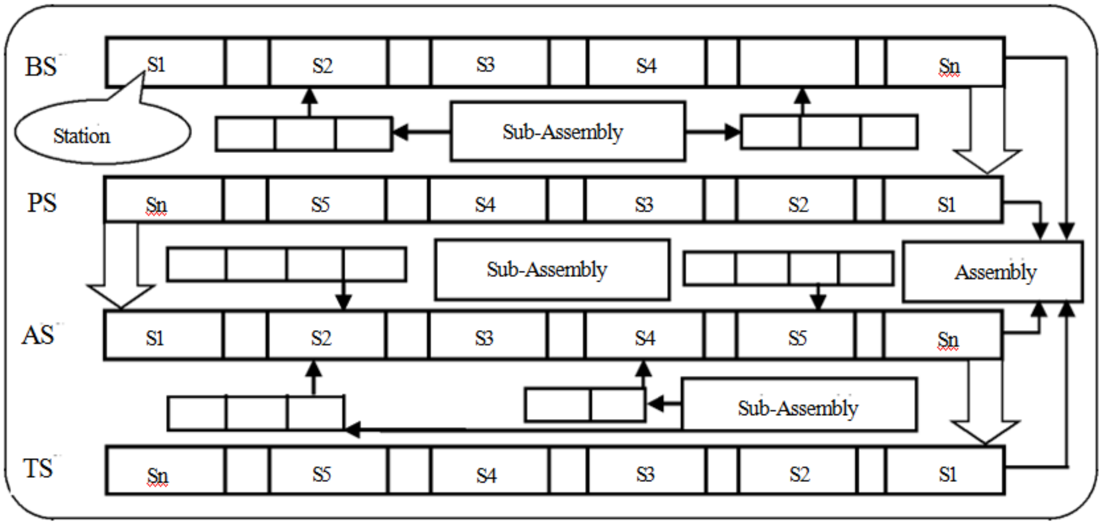

Figure 1. Assembly line system (ALS).

problems require an optimal solution that could be obtained by adopting the HM approach. The HM developed in this study is able to assist managers to have an optimal cycle time (CT), balancing the ALS and managing the production plan to know the capacity of the assembly line after solving the ALBP (Ali and Razman, 2012; Amir and Farhad, 2006; Anand et al., 2012).

The contribution of this study is to approach an integrated model (including the MOM and the GAS) to solve the queuing problem within the stations on the assembly line, with the SM to manage the capacity of the assembly line. Additionally, the integrated model can combine the unbalanced assembly line problem and the ratio of the production plan. As a result, the method will achieve the target by minimising unbalanced CT and maximising workload to achieve the production plan. This study focuses on the main problem of the production line which is balancing CT within the stations. The unbalancing problem occurs when not all stations are able to complete all tasks at the same time (Christian and Armin, 2009). As a result, it causes a congestion problem on the production line and the resources are underutilised. Figure 2 presents the ALBP which is unbalanced CT within the stations on the assembly line.

METHODOLOGY

Multi-objectives model (MOM)

The MOM is formulated to create a balanced time within stations through to obtaining optimal balance within the stations. There are two goals of the MOM: (1) to minimise the queuing time within the stations; (2) to minimise the idle time within the stations.

$$\text{Min } Q = \max \sum_{i=1}^{p} \sum_{i=1}^{sq} |QU_{ij}|\, X_{ij} \qquad (1)\ \ (1^{st}\text{ goal})$$

$$\text{Min } Id = \max \sum_{i=1}^{p} \sum_{j=1}^{sd} DT_{ij}\, X_{ij} \qquad (2)\ \ (2^{nd}\text{ goal})$$

Where: **Q:** total queuing time within the stations, **QU:** queuing between the stations, **Id:** total idle time within the stations, **DT:** idle time between the stations.

The MOM aids management to achieve either the optimum solution (Razman and Ali, 2011; Razman and Ali, 2010). Figure 3 shows the implementation of the MOM for the ALS. The MOM will reduce the queuing and the idle time to obtain the best balance, then the best solution for the PLS.

GAS

The GAS is formulated to create an advanced balance time within stations through shuffling of the tasks in order to obtain an optimum balance. The GAS will select the task that should be moved within stations according to the objectives (1) and (2). Figure 4 presents the model of moving tasks among the stations. In the figure, there are two categories of task movement: the first category is a movement (1) from station (1) towards the station (n) passing through all stations respectively. The second category is movement (2) from station (n) towards station (1) passing through all stations respectively. The aim is to find the best solution for these objects using the GAS. As seen, the solution should allow all points to be passed by choosing the closest path among them in one go. The task movement occurs after selection of the first task with a high CT from any station, which should be moved towards the next station which has a low CT and function as a final task. Otherwise, the GAS will select the final task with high CT from any station and move it towards the previous station with low CT and have it function as a first task. This formulation of GAS will be more realistic, that is, create an optimum balance of CT within stations.

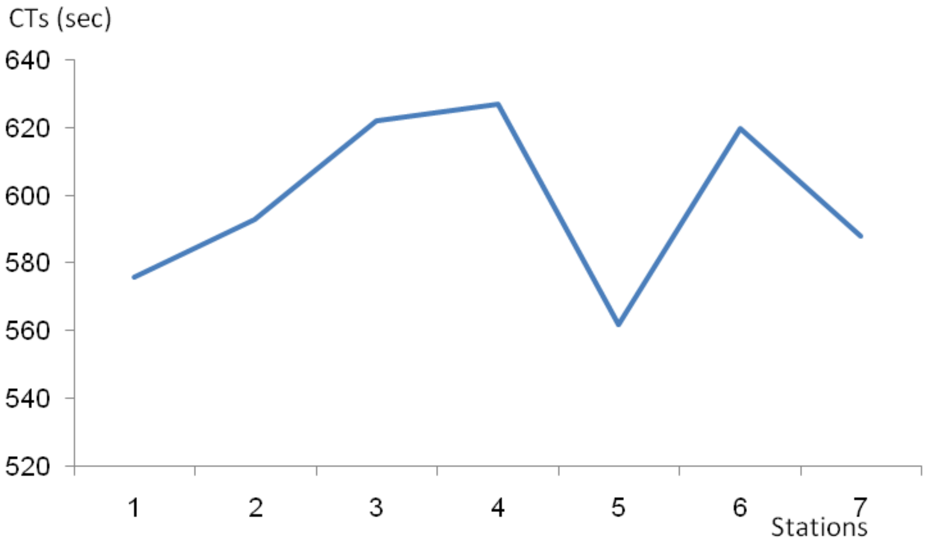

Figure 2. Unbalanced CTs.

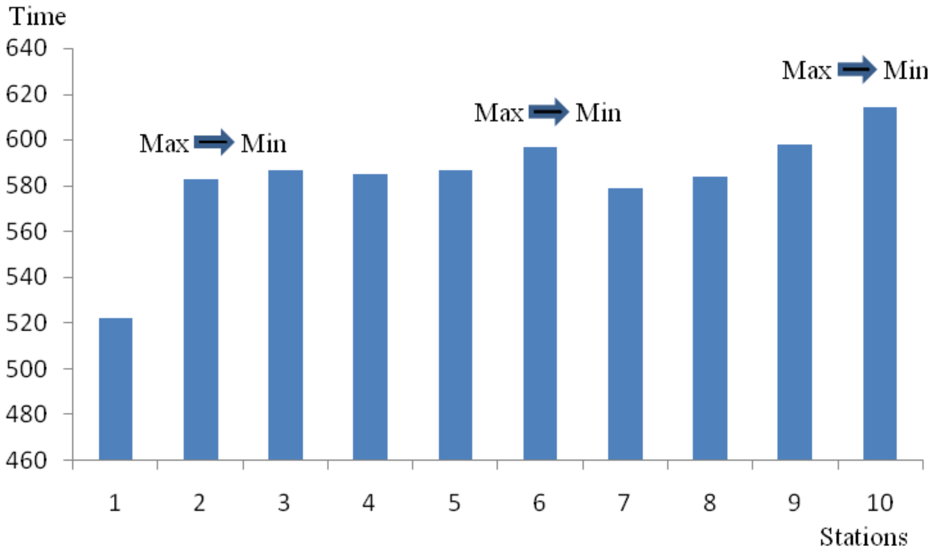

Figure 3. Unbalancing on the assembly line.

Genetic algorithm objectives

The GAS approach in this study aims to achieve two goals: rebalancing CT within the stations for each shop, through task movement; and also redistributing the jobs among the workers to obtain the optimum solution. The GAS obtains the optimum balance (optimum solution) of the ALS with two objectives which are:

(i) First goal: Moving the tasks among the stations.
(ii) Second goal: After applying the MOM, if the ALS still has queuing issues, the GAS will redistribute the jobs to the workers in order to achieve the optimum balance.

The formulas of the GAS are presented in Equations (3) and (4). These explain how the GAS achieves a time balance on the assembly line.

$$Goal1 = CTS_1 \approx CTS_2 \approx CTS_3 \approx CTS_4 \approx ,,,, \approx CTS_n$$ (3) (1st goal)

$$Goal2 = RJS_1 \approx RJS_2 \approx RJS_3 \approx RJS_4 \approx ,,,, \approx RJS_n$$ (4) (2nd goal)

Where: CTS_i =CT for each station, RJS_i = ratio of the jobs of each station.

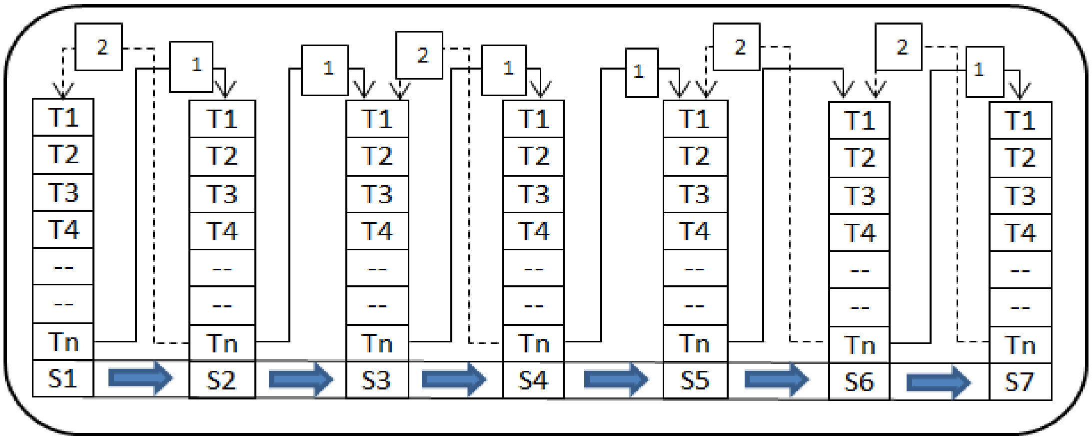

Figure 4. Task movement among the stations.

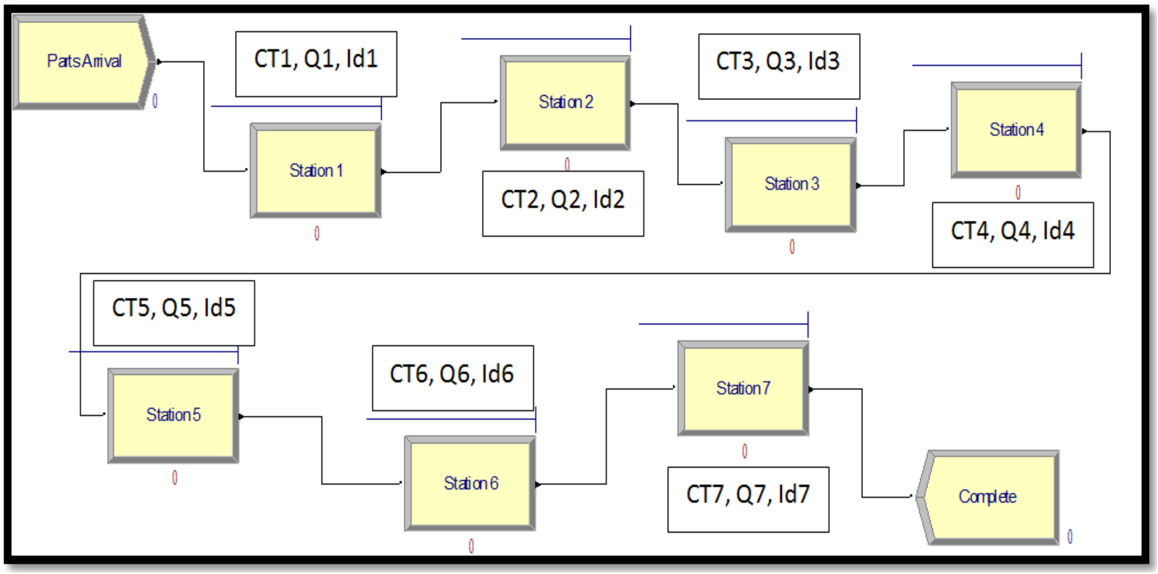

Figure 5. SM of ALS.

To achieve goal 1, the GAS should move the tasks among stations until it gets the best CT balance. This goal corresponds to the first and second objectives of MOM (1, 2), that is, to obtain the optimum balance.

Simulation model (SM)

Simulation is a technique with which a real-world problem can be mimicked and modelled with the aid of computers. The SM provides analysis and allows users to perform 'what-if' analysis where users can test different strategies or policies and observe how the model behaves before implementing it in the real world. Besides that, the simulation also serves as a training and educational tool (Holst and Bolmsjo, 2001).

In this study, the SM is developed using the ARENA simulation package. Figure 5 shows the SM of ALS. The chassis section in the ALS is modelled and inputs such as arrival time and processing time are incorporated into the model.

Hybrid model (HM)

HM flowchart

The HM, applied to solve both problems, which are queued and idle time, also manages a new plan depending on the available total working time to obtain the best balancing by applying the MOM. The SM will create new plans depending on the efficiency of the cycle time. Figure 6 shows the flowchart of the HM.

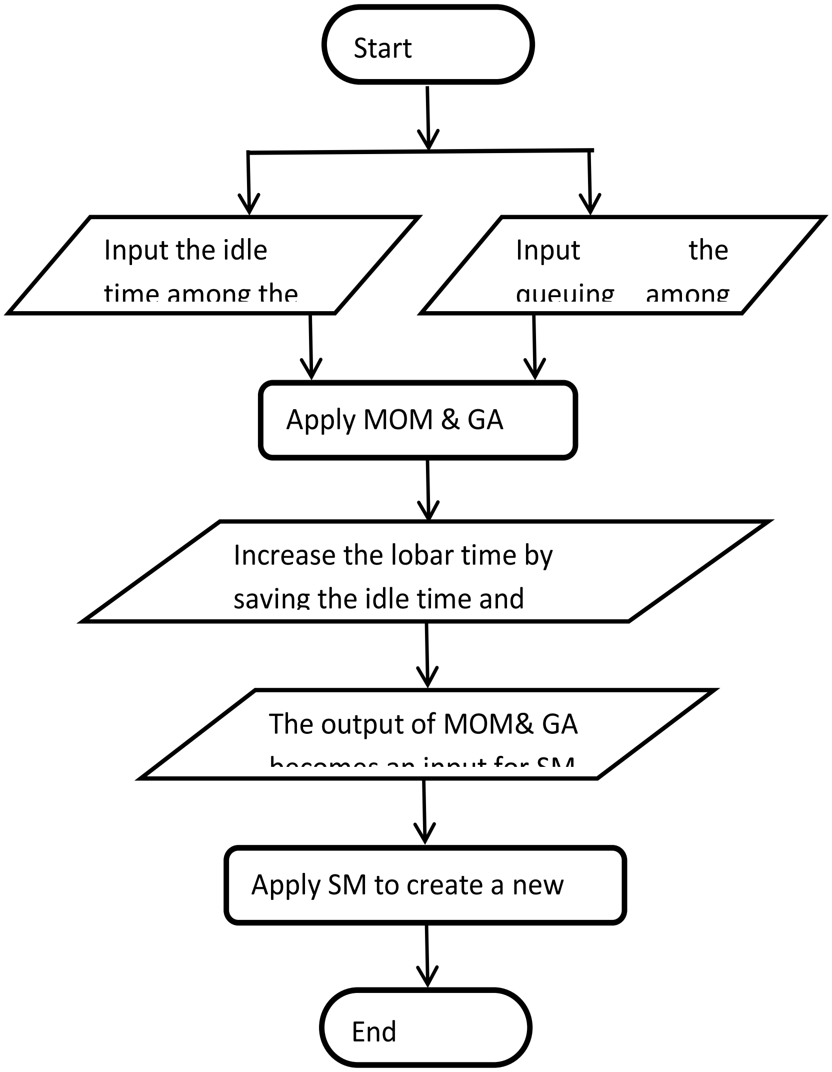

Figure 6. HM flowchart.

Procedure of HM

Computer software helps to optimise the ALS by applying the MOM and GAS. MATLAB software is used to solve the system issues to obtain the optimum balanced CT of the ALS. The procedure is as follows:

```
Procedure: solve the unbalanced CT of the assembly line.
Input data: CT, task number, number of workers for each station, queuing and idle time.
Output data: the optimum balancing of the ALS.
Begin
{
        Calculate the CT on the production line for each station
                While i < total number of stations
                        Balance process time tasks
                Move the tasks among the stations
        i=i+1
End
Print the optimum balance
} End
```

Once the optimum balancing of ALS is calculated using the MOM, a SM is developed. The SM is constructed to test the maximum number of cars that can be produced if the ALS CT is balanced in order to optimise the capacity of the production line.

MODEL RESULTS

Balancing problems of the ALS

CT is the time taken to complete all tasks at the stations of the shops. For a highly efficient ALS, the CT should be equal among the stations (Nai-Chieh and I-Ming, 2011).

Table 1. Variables of the chassis section.

Stations	CT seconds (L3)	No. tasks (L2)	Workers (L3)
1	576	122	2
2	593	116	2
3	622	130	1
4	627	125	2
5	562	118	1
6	620	127	1
7	588	120	1
Total	4,188	858	10

Table 2. Queuing and idle time at the CS.

No. station	CT before applying the model	CT after applying the model	Queuing before	Idle time before	Queuing after	Idle time after
CS_1	576	593	17	0	6	0
CS_2	593	599	29	0	0	0
CS_3	622	599	5	0	4	0
CS_4	627	603	0	65	0	1
CS_5	562	602	58	0	0	6
CS_6	620	596	0	32	0	0
CS_7	588	596	0	0	0	0
	4,188	4,188	109	97	10	7

Normally, it is a very challenging target to reach a balance of CT within the stations. An unbalanced CT is caused by the queuing problem on the assembly line. This study examined the chassis section which is one part of the assembly line.

Chassis section (CS)

The CS has seven stations. Its function is to assemble an engine, bellows, axle and other mechanical works. The total processing time in this section is 4,188 s. Table 1 describes the operational aspects of this data. It shows that station 1 has a processing time of 576 s with 122 tasks. Only two workers are involved at this station. Table 2 shows the queuing time and the idle time before and after applying the MOM. The queuing and the idle time before applying the model were 109 and 97 s, respectively. After applying the HM, the queuing and idle time become 10 and 7 s, respectively. As a result, the model reduced time arising from the queuing problem by around 99 s (1.65 min), and 90 s (1.5 min) due to idle time. The total time saved is 189 s (3.15 min) in preparation of only one car.

Figure 7 presents the CT station before and after applying the MOM and the GAS to the ALS. In the figure, L1 represents the working CT before applying the model; L2 represents the best balancing within stations after applying the model.

Simulation results

The current assembly line operates for 7.5 h per day and produces 28 cars daily. The SM is used to test the maximum number of cars that can be produced if the assembly line operates according to the optimum CT calculated using the MOM. Table 3 shows the number of cars that can be produced daily. The simulation results reveal that by adopting the new balanced CT, the ALS can produce an additional four cars daily, given that the maximum number of operating hours of the ALS is 7.5 h. Producing more than 32 cars will require additional working hours. This finding serves as a guideline on how many additional cars can be produced daily without exceeding the current capacity and maximum duration.

DISCUSSION

The new method combines the MOM and the GAS with the SM to solve the unbalancing and planning

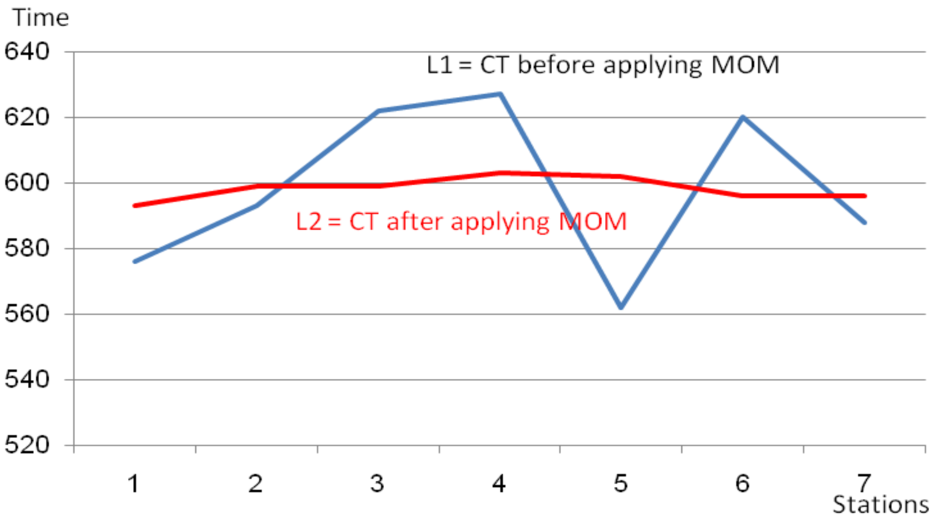

Figure 7. CTs before applying, after applying the MOM and the GAS.

Table 3. Number of cars produced and hours needed.

Number of cars produced	Hours
20	5.69
24	6.02
28	6.36
30	6.69
32	7.03
34	7.36
36	7.53
37	7.70

problems in the ALS. This method was applied to the chassis section of the ALS to obtain the optimum balance and plan. The MOM the GAS saved 189 s in the chassis section. The total queuing before applying the MOM and the GAS was 109 s (1.81 min); it became 10 s (0.16 min) after applying the MOM and GAS which saved 99 s (1.65 min) for preparation of one car. Also, the model reduced the idle time within the stations as well. It was 97 s (1.61 min) before applying the model and became 7 s (0.11 min) for preparation of one car. Therefore, the total time saved by using the MOM and the GAS is 189 s (3.15 min) for preparation of one car in respect to both issues of the queuing and the idle time. Besides minimising queuing and idle time, this study further enhanced the results by developing a SM to test the maximum number of cars that can be produced daily by the ALS if the balanced CTs are adopted. The results show that from the current number of 28 cars produced, the balanced ALS can produce a maximum of 32 cars daily. The new technique is beneficial to all workshops and sections of the production line as it increases the capacity of the production line in automobile manufacture.

Conclusion

The ALS is very important for the automobile industry. The unbalancing variations within stations are difficult problems which affect efficiency of the assembly line. This study proposed a new technique to solve the problems, such as queuing and idle time within stations. The HM combines the MOM, the GAS and the SM to obtain the optimum solution and plan. As a result, the new technique is very important for enhancement of the efficiency of the assembly line. Moreover, the HM reduces the unbalanced time within the stations and increases production by four cars per day.

Conflict of Interest

The authors have not declared any conflict of interest.

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