Assembly line balancing the comparison of COMSOAL and MSNSH technique in Motorcycle manufacturing company

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Abstract. Today's highly competitive market influencesthe manufacturing industry to improve their production systemsto become the optimal system in the shortest cycle time as possible. One of most common problems in manufacturing systemsis the assembly line balancing problem. The assembly line balancing problem involves task assignments to workstations with optimum line efficiency. The line balancing technique, namely "COMSOAL", is an abbreviation of "Computer Method for Sequencing Operations for Assembly Lines". Arcus initially developed the COMSOAL technique in 1966[1],and it has been mainly applied to solve assembly line balancing problems [6]. The most common purposes of COMSOAL are to minimise idle time, optimise production line efficiency, and minimise the number of workstations. Therefore, this project will implement COMSOAL to balance an assembly line in the motorcycle industry. The new solution by COMSOAL will be used to compare with the previous solution that was developed by Multi-Started Neighborhood Search Heuristic (MSNSH), which will result in five aspects including cycle time, total idle time, line efficiency, average daily productivity rate, and the workload balance. The journal name "Optimising and simulating the assembly line balancing problem in a motorcycle manufacturing company: a case study" will be used as the case study for this project[5].

Introduction

Due to significant factors such as the rapid change of technology, global competitions have influenced the change of product characteristics. In modern society, the common characteristics of products that customers desire are high level of product variety and small batch size. This has resulted in the need for short life cycle time of manufacturing systems[16], the requirement of technological equipment, and the need fordesign or redesign in manufacturing systems in order to respond to customers' needs [13, 10]. In terms of developing production systems, in the early twentieth century, Henry Ford initially introduced the first assembly line in history called the"transfer line", through which the products transferred through different workstations where workers were assigned tasks[11].

Assembly line system can categorised into three model types[4]. The first model is a single model line, in which only one product ismanufactured in production and all work pieces are identical. Secondly, a mixed-model line is when several products are produced in the same production. In the second type,there is an assembly line balancing problem associated with a sequencing issue regarding the sequence of assembling the model unit, due to the possibility of the huge difference in process times between the products[8]. Thirdly, a multi-model line also produces various products, but in a sequence of batches with intermediate setup operation, which means multi-production line allows only a group of products to be manufactured at any time. The different production linesare presented in the following figure, where the different geometric shapes symbolise the different products.

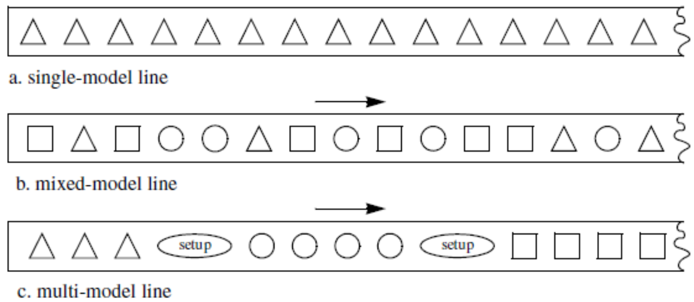

Figure 1: Assembly line for single and multiple products

The characteristic of assembly lines is a serial manufacturing system, which has been used in mass production with the quality or in made-to-order commodities that usually produce low quantity[4, 15]. In assembly line balancing, the majority of studies are associated with modeling and solving the simple assembly line balancing problem (SALBP). The characteristic of SALBP can be typically specified as the following rule [2]:

1. The overall input parameters are understood with certainty
2. No activity can be brokendown into two or more
3. Activity must be operated in sequence according to technological precedence constraint
4. All activity must be executed

Considering the above rules, it can be stated as “the assembly line balancing problem”. The assembly line balancing problem (ALBP) involves the assigning of tasks to the sequence of work stations in orderto minimise idle time, while the precedence relationship is not violated by result and the total processing time in each station is not longerthan cycle time. Then, the SALBP must have the above rules and the following rules are true:

5. All workstations are equipped equally (such as machines or staff) and manned to execute every activity.
6. The operation time of all activities are independent from the station where they are operated and any following activity.
7. None of all activity is fixed to any station.
8. The total production line is serial with no feeder or parallel subassembly lines.
9. The assembly line is assumed to be designed uniquely for single products.

SALBP can be divided into four main categories[3,4]:

1. SALBP-1, the first version of SALBP, has several different names such as line balancing problem, basic ALBP, single-model ALBP, or type-1 ALBP[2].It can be defined when rules one to nine are true, the cycle time is given, and the required number of workstations isminimised.
2. SALBP- 2 is the second version of SALBP, and the concept is similar to SALBP-1 asit can be defined when the above rules one to nine are true.However, the difference isthat the number of workstations isgiven and the maximum cycle time is minimised. SALBP-2 can also be known as type-2 ALBP [2].
3. SALB-F, the feasibility problem, involvesestablishingwhether a feasible line balance exists when the numbers of workstations and the cycle time are provided.
4. SALB-E presents the most general problem version, and the line efficiency is maximised when the numbers of workstations and the cycle time are minimised.

Table 1: Version of SALBP [4]

	Cycle time c	
	Given	Minimise
No. m of stations		
Given	SALBP-F	SALBP-2
Minimise	SALBP-1	SALBP-E

In system management, assembly line balancing problem is an essential activity when doing medium-term and long-term production planning.High capital investment is most likely required in order to install the assembly production system, then an installation of assembly line must be careful regarding thecost factor[4]. Therefore, it is essential that the system is balanced smoothly, so that it achieves optimum production efficiency. Moreover, when balancing a new system, rebalancing the existing production line has to be processed periodically. Because of the long-term effect of balancing decisions, the objectives, which are used to consider the strategic goals of the organisation, need to be chosen carefully. In view of economics, cost and profit-related objectives could be valuable. Therefore, determining the maximum assembly line is a significant task that every organisation should do since the production-designing phase and continued improvement during production is operating.This study aims to study heuristic techniques, namely COMSOAL [1], which is applied to balance complex assembly lines in motorcycle manufacturing company,whichwas a previous studythat appeared in an international journal of production research, namely “Optimizing and simulating the assembly line balancing problem in a motorcycle manufacturing company: case study” [5]. The solutions from previous line balancing method, Multi-started neighborhood search heuristic (MSNSH), and from COMSOAL will be compared in five aspects.

Mortorcycle manufacturing system

On account of the variation of demands, rapid changes, and shortened product life cycle, this creates difficulties for the motorcycle production industry [7].Motorcycle production is generally complex in the design and manufacturing phases [12]. Therefore, assembly production line is a typical application in motorcycle manufacturing to deal with difficulties. In this case study, some operations in producing motorcycles require the specific position of workers, which means there are two workers working on the left and right sides in each workstation, which is different from the typical assembly line. Therefore, the details of operation including the average processing time, standard deviation of individual tasks,and positions required in each operation are included in following table.

Table 2: Operations in the motorcycle assembly line

No	Operation	Precedence	Position	Avg. Time(sec.)	Standard Deviation
1	Front chassis		B	10	4
2	Clutch-release yoke	1	B	22	11
3	Tipping device	2	R	35	11
4	Rear fastening	3	R	34	3
5	Snubber	4	R	37	9
6	Handlebars	2	L	76	22
7	Engine	2	B,L	82	9
8	Rear wheel shaft	5	L,R	9	4
9	Rear wheel	10	L,R	60	16
10	Rear brake installation	8	L,R	6	2
11	Front wheel shaft	2	L,R	6	4
12	Front wheel	11	L,R	67	12
13	Mileometer	6,11	L,R	32	15
14	Front brake	6,12	L,B,R	64	23
15	Rear chassis	5	B,R	135	34
16	Rear brake connection	9	R	32	9
17	Electrical installation	15	R	122	30
18	Crankcase oil	19	R	82	26
19	Engine connection	7,15	L	259	18
20	Left radiator grille	19	L	64	8
22	Electrical installation	7,13,14,17	L,B,R	194	29
23	Bolting oil tank	18	R	21	11
24	Radiator	17,19,22	L,R	24	10
25	Right radiator	24	R	43	16
27	License plate holder framework	29	L,R	18	6
28	Chain	9,7	L,R	182	35
29	License plate holder	15,17	L,R	75	23
30	Collector	19	L	5	15
31	Pinion cover	28	L	27	10
32	Left wire guidance	22	L	35	8
33	Right wire guidance	22	R	28	11
34	Front mudguard	22,32,33	L,R	4	19
35	Petrol tank flange	17,19,22, 30,37,38, 39,45	L,R	38	6
36	Petrol tank	35	L,R	14	2
37	Radiator antifreeze	24	R	41	8
38	Relief valve sleeve (right)	19,44	R	20	8
39	Oil fill	23	R	20	8
40	Brake pedal	1	R	37	6
41	Right rear cover	46	R	60	12
42	Right rear indicator	29	R	59	28
43	Right front cover	36	R	56	12
44	Exhaust pipe	19,20,30	L	45	11
45	Muffler	44	L	41	9
46	Rear mudguard	29	L	31	8
47	Left rear cover	30,36,38,45,46	L	73	25
48	Connection mudguard-licenseplate	29,46	L,B,R	50	18
49	Left rear indicator	29	L	25	9
50	Left front cover	36,45	L	47	12
51	Head lamp holder	22,19,32, 33	L,B,R	125	53
52	Seat	41,43,46,47,50	L	57	28
53	Carburetor connection	1,6	L	192	47
54	Oil filters sleeve	15,7	L,R	30	9
55	Clutch wire connection	57	L,R	23	8
56	Petrol plug vent	36	L,R	11	2
57	Clutch wire	6,7	L,R	52	7

The procedure of COMSOAL technique

To implement the COMSOAL approach, essential information needs to be prepared, including standard operation time inall activitiesand precedence relationships of activities as show in Table 2.Cycle time is also needed, which is estimated by this formula:

$$\frac{Total operation time}{numbers of workstation}$$

Therefore, this section will demonstrate how to assign tasks by using the COMSOAL technique systematically. The COMSOAL method can be briefly described according toseven steps [6]:

1. The first step is creating the table, which presents all activities lists in order, considering by precedence relationships.
2. Secondly, selecting the available activities from the table that has no predecessor task, in other words all predecessor tasks of considering activity need to be finished.
3. Creating the available activities list.
4. Choosing activities from the available lists to the workstation until the total processing time of all activities in the workstation is nearly or equal to the given cycle time.
5. The next step is recreating the new available activity list.
6. Repeating steps 2-5 until all activities are assigned into workstations.
7. The final step is keeping the possible solution and then repeating steps 1-5 to find the alternative solution, until the best solutionis obtained.

Following the COMSOAL techniqueprocedure, the possible solutions of all workstations are kept in order to consider the best scenario of all workstations, which provide the minimum cycle time as well as idle time. The best scenarios of all workstations have then been selected and summarisedin detail inTable 3. The results from the COMSOAL technique are compared to results from the MSNSH technique in five aspects as mentionedearlier, which are presented as the following figures and tables.

Table 3: The result from COMSOAL technique

Workstation	Task Number	Task Name	Worker		
			Left	Both	Right
1	1	Front chasis		10	
	2	Clutch-release yoke		22	
	11	Front wheel shaft	6		
	6	Handlebars	76		
	7	Engine	82		
	53	Carburetor connection	192		
	3	Tipping device			35
	4	Rear fastening			34
	5	Snubber			37
	15	Rear chassis			135
	12	Front wheel			67
	13	Mileometer			32
	8	Rear wheel shaft			9
	10	Rear brake installation			6
			356	32	355
	station total time (sec)			388	
2	14	Front brake	64		
	19	Engine connection	259		
	20	Left radiator grille	64		
	17	Electrical installation			122
	22	Electrical installation			194
	29	License plate holder			75
			387	0	391
	station total time (sec)			391	

Table 3: The result from COMSOAL technique (cont.)

Workstation	Task Number	Task Name	Worker Left	Worker Both	Worker Right
3	32	Left wire guidance	35		
	24	Radiator	24		
	46	Rear mudguard	31		
	30	Collector	5		
	44	Exhaust pipe	45		
	45	Muffler	41		
	48	Connection mudguard-licenseplate	50		
	51	Head lamp holder	125		
	54	Oil filters sleeve	30		
	18	Crankcase oil			82
	23	Bolting oil tank			21
	39	Oil fill			20
	38	Relief valve sleeve (right)			20
	37	Radiator antifreeze			41
	33	Right wire guidance			28
	41	Right rear cover			60
	9	Rear wheel			60
	42	Right rear indicator			59
			386	0	391
	station total time (sec)			391	
4	35	Petrol tank flange	38		
	36	Petrol tank	14		
	47	Left rear cover	73		
	50	Left front cover	47		
	34	Front mudguard	40		
	49	Left rear indicator	25		
	27	License plate holder framework	18		
	57	Clutch wire	52		
	31	Pinion cover	27		
	52	Seat	57		
	28	Chain			182
	56	Petrol plug vent			11
	43	Right front cover			56
	25	Right radiator			43
	16	Rear brake connection			32
	40	Brake pedal			37
	55	Clutch wire connection			23
			391	0	384
	station total time (sec)			391	

Result analysis

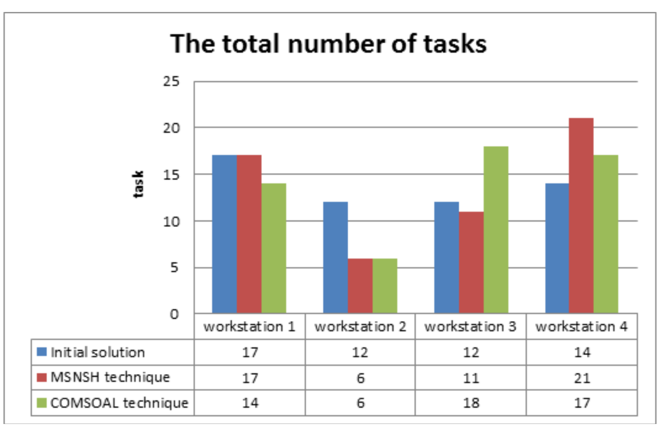

Figure 22: The total task numbers in each workstation of three systems

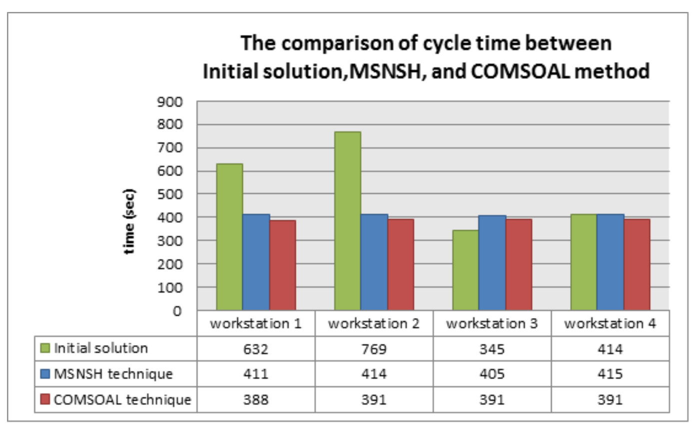

Figure 3: The comparison of cycle time between MSNSH and COMSOAL

Table 4: The idle time in each workstation of three systems

System	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Total**
Initial system					
Internal idle time	31	94	14	75	436
	30	52	57	31	
				52	
Idle time is caused by different cycle time	137	0	424	355	916
Total idle time					1352
MSNSH					
Internal idle time	0	0	4	3	21
				14	
Idle time is caused by different cycle time	4	1	10	0	15
Total idle time					36
COMSOAL					
Internal idle time	0	0	0	0	0
Idle time is caused by different cycle time	3	0	0	0	3
Total idle time					3

Table 5: The average daily productivity of three systems

	Productivity (motorcycles)
Initial solution	37.45124
MSNSH technique	69.39759
COMSOAL technique	73.65729

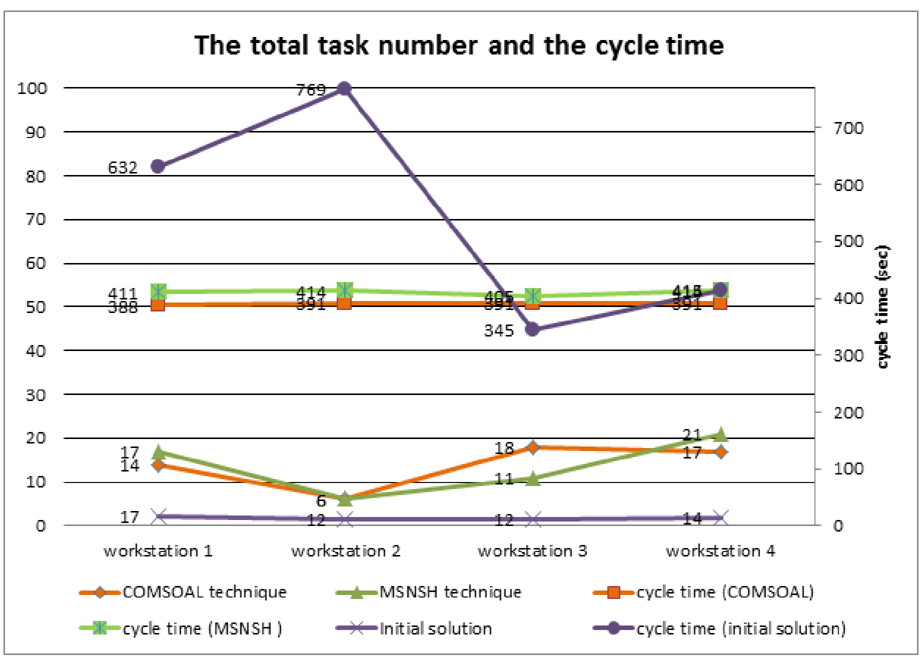

Figure 4: Line graph shows the relationship between the total task number and the cycle time in each workstation of three systems

The first indicator is the new cycle time in each workstation presented in Figure 2; the maximum cycle time by MSNSH is 415 sec or 6 minutes 55 sec, while the maximum cycle time by COMSOAL technique is 391 sec or 6 minutes 31 sec. The new schedule from COMSOAL is slightly better than the result from the MSNSH method by about 8.48% or 24 seconds. Moreover, in terms of the time difference between workstations,the COMSOAL solution also provides asmaller time difference compared to the previous method.

The second indicator, the total idle time, whichcan be determined by the summation of free time when

1. The operator needs to wait for the predecessor task to be completed, which can happen within the same workstation and between workstations; for example, an operator is waiting for task 4 to be completed to start working on task 5, or the operator in workstation 2 is waiting for a work piece from workstation 1.
2. The idle time, which occurs when an operator on the left side is waiting for anoperator on the right side to work together on task that requires the cooperation of both operators.
3. Lead-time of producing a motorcycle is equal to the maximum cycle time, then idle time can happen when the cycle time of a workstation is lower than the maximum cycle time.

According to the definition of idle time as above,Table 4 shows the detail of idle time in each category among workstations, and it can be seen that MSNSH algorithm can assist the operation to reduce idle time in the system by 97.33%, whereas the COMSOAL method contributes the greatest timesaving by an approximately 99.77% reduction, which gives better results than MSNSH technique by 2.4%.

Thirdly, line efficiency, which can be calculated by the following formula:

$$\text{Line efficiency}=\frac{\sum_{i=1}^{n} Ti}{n*c} * 100$$

Where, n = given number of station
C = lead time
T_i = lead time in i workstation

An implementation of MSNSH technique to rebalance production line can improve line efficiency up to 99.09%. Similar to the proposed method, that can also increase line efficiency by up to 99.80%. Therefore, the new task scheduling created by COMSOAL provides slightly higher line efficiency, approximately 0.71%.

The fourth indicator, the average daily productivity, can be determined by the following formula:

$$\frac{Total\ operation\ time\ per\ day\ (sec)}{C}$$

Where, C = lead time (sec)

MSNSH can increase the average daily productivity from 37 to 69 motorcycles, which means 86.48% of productivity improvement from the initial system. In comparison to the result from COMSOAL under the given conditions, COMSOAL can give the greater improvement in productivity rate than MSNSH, which makes the average productivity grow to 73.65 motorcycles per day or 97.29% of productivity improvement, higher than the MSNSH technique by 10.81% or 4 motorcycles.

For the last indicator, the workload balance, the total number of tasks in the workstation is used to indicate this area. Unfortunately, the results from COMSOAL and MSNSH technique are poor balance compared to the initial system. However, considering the balance of cycle time in each station together with the number of tasks, the result shows that there is no correlation between number of tasks and cycle time. Hence, COMSOAL and MSNSH techniques primarily focus on operation time rather than the total number of activities in a workstation, and the number of activities in all workstations is unequal, but the new cycle time in every workstation is balanced, which can be seen in Figure 5.

Conclusion

Overall, an assembly line can be defined as a serial manufacturing system which has been used in mass production with quality. Assembly production line has dominated themanufacturing industry, particularly automobile manufacturing companies. Motorcycle production line, which was used for this study, isalso characterised as assembly lines. There are four workstations in motorcycle manufacturing systems, in which each station has two operators working on the left and right position of an assembly line. The additional condition which makes this case study more complex than others, is about the restriction of tasks that sometimes require operators who work on the left or right position only to finish a product. Moreover, some tasks need both operators to cooperate. This difficulty has been successfully solved in previous studies using Multi-Started Neighborhood Search Heuristic (MSNSH) to balance the workload in each workstation. This study used another heuristic technique calledCOMSOAL to balance the line and make a comparison between the COMSOAL and MSNSHsolutions in five areas. As a result, the COMSOAL technique provides better results in areas of shorter cycle time, less idle time, higher line efficiency, and average daily productivity than the MSNSH method. However, both techniques cannot provide more balance of total task numbers among workstations compared to initial systems.

Future study

In terms of further improvement, there are two possible viewpoints that may be potential areas to develop greater solutions and may be interesting areas for futher study. These areas aredetermining operation time and the use of new line balancing technique.

1. Time and motion study

Time and motion study is a principle that uses various techniques such as work sampling or continuous observation, to be guidelines in terms of collecting data, operation time, and operator movement related to time in particular[17]. This approach has a potential to eliminate waste in operation, which leads to reduced production cycle time[9]. Hence, an implementation of time and motion study can be useful to gain reliable data. Moreover, it also assist learners to reduce process time by eliminating unnecessary movements in the process. Thus, time and motion study can be potential areas that may lead to the creation of better solutions.

2. Genetic algorithm in line balancing technique

Due to the broad range of applying genetic algorithm (GA) to determine effective solutions, the use of genetic algorithm has been increasingly applied in line balancing problems in the 21stcentury, and the result from this method tends to be optimal solutions, especially in the manufacturing industry[16]. According to Sabuncuoglu, Erel, and Tanyer [14],when applying GA to solve ALBP compared to results from severaltraditional heuristic methods, the new solution from GA was better among other techniques. Therefore, implementing GA technique solving ALBP, which has an additional restriction like this case study, can be a valuable topic for further research.

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