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Choosing the optimal balance for the production assembly lines at the Volvo car manufacturing plant in Babylon

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Abstract
Business organizations today are working hard to achieve competitive superiority over others through rapid access to local and international markets. What helps organizations do this is balancing assembly lines because of their effective role in reducing the time required to produce the product. From this standpoint, the main goal of this the study is to choose the optimal balancing for the production assembly lines at the Volvo Trucks factory in the Iraqi city of Babylon. To achieve this goal, data and information were collected from the factory records and analyzed using some heuristic algorithms (on-site weights, Comsoal, Moody and Yang). In light of the results of the analysis, it was found that the idle time decreased from 15 hours to less than 3 hours, and the number of stations has also decreased from 15 to 10 stations, and the efficiency rate has become 91% instead of 60%, which is the current efficiency rate of the factory, and other results. Thus, the problem of the study will be addressed and its importance will be taken advantage of, as was done. The study concluded with a set of conclusions and proposals related to the assembly process in the factory.

Keywords: Assembly lines, location weights algorithm, comsoal algorithm, moody and yang algorithm

Introduction

Balancing assembly lines is a vital part of production management strategies, as it aims to improve the balance and performance of production lines in industrial organizations. This process represents the core of efforts to control production flows and achieve effective distribution of resources in the context of manufacturing and assembly operations. Therefore, it must be Balancing assembly lines is an essential part of a production management strategy to achieve larger organizational goals.

Algorithms also play a vital role in improving the efficiency of assembly lines by introducing advanced methods and technologies to improve the planning and organization of production processes. Algorithms help in preparing effective production schedules that take into account many variables such as operating time, resource availability, and customer demand, in addition to improving the sequence of production. Processes and determining the optimal order for producing products, which allows reducing processing time and increasing the efficiency of the production line, as well as improving the balance between production stages, which reduces costs and delays, in addition to improving the use of resources such as labor and equipment as specified, and on the basis of the above, the current study consists of axes The first: includes the study methodology, the second contains the theoretical framework, while the third includes the field aspect, and the fourth also addresses conclusions and proposals.

The first axis: study methodology

First: The problem of the study: The problem of the study is represented by the challenges facing the Volvo Trucks Factory, one of the factories of the General Automotive Manufacturing Company in the Iraqi province of Babil, with a decrease in the efficiency of the assembly line as a result of the following reasons:

1. Increased production cycle time for assembling and manufacturing one truck, as the average production time reached 2.3 hours. This means that the factory produces 3 cars per day, and this number is small compared to the design capacity of the line.

2. There is a large amount of idle time in the factory, estimated at 15 hours, and this results either from bottlenecks in the line, a lack of workers at each station, a decrease in demand for the product, or a failure to distribute tasks in a balanced manner across all assembly stations.

In order to solve this problem, the following questions must be asked that will help us find effective solutions to this problem, which are: 1- What is the type of balance for the assembly line followed by the factory management? Can we reduce the number of stations by overlapping activities between them? How do we reduce idle time and bottlenecks in the factory? How do we achieve optimal assignment of tasks to workstations in order to maximize some efficiency criteria? The answer to these questions is done by adopting several algorithms and the proposed model.

Second: Objective of the study: The current study aims to choose the optimal balance for the assembly line through the following:

1. Diagnosing the obstacles that prevent choosing the optimal balance for the assembly line in factories.
2. Identifying the problems of high idle time in the product production cycle, which negatively affects the speed and accuracy of work completion.
3. Identifying problems of increasing or decreasing the workforce.
4. Addressing these obstacles based on the theoretical and practical sides of the study through the application of algorithms (weighted site weights algorithm, Moody and Yang algorithm - Comsoal algorithm).

Third: The importance of the study: Based on defining the problem and objectives of the study, its importance lies in the following:

1. Helping the factory management in identifying the most important scientific indicators related to assembly line balance, and its significant role in choosing the optimal balance.
2. Identifying the number of bottlenecks within the line, as well as identifying how to reduce idle time by increasing workers or reducing the number of stations.
3. Identify the most important algorithms that enable factory management to determine the optimal balance and time for production, which helps increase production, revenues and achieve profits.

Fourth: Study Methodology: The study adopted the quantitative analytical method, which is the most appropriate method for this type of study.

Fifth: Study hypothesis: The study is based on one hypothesis: The use of the three discretionary algorithms contributes significantly to improving the assembly line balance and pushes the factory management to abandon the use of traditional methods of assembly line balancing.

Sixth: Indicators for measuring the assembly line balance: (Al-Mimari, 2022, 178) [5] (Al-Samman, 2005, 19) [3]:

1. **Production cycle tim**e = available time / production quantity
2. **Number of stations:** Standard time or task time / production cycle time
3. **Efficiency:** Standard time or task time / (production cycle time * number of stations)
4. **Idle time:** (Production cycle time * number of stations) - standard time or task time
5. **Delay ratio:** 1-Efficiency ratio
6. **Number of employees:** Number of employees required = total standard time/period * number of employees at each station.

Theoretical aspect: Balancing assembly lines

First: The concept of balancing assembly lines: Balancing assembly lines is defined as a production system directed towards the flow of the product processing process on a number of workstations arranged along the conveyor belt, where work pieces are transferred between successive workstations, and a certain number of tasks are usually carried out in Each workstation is according to a precedence order relationship (precedence graph) (Aguilar, *et al.* 2020 [2], 2), and (Adeppa, 2015, 295) [1] is seen as assigning a number of work items to different workstations to maximize balance efficiency or reduce The number of workstations or to accomplish any other objective function specified for a specific volume of output without violating the precedence relationship. (Bukchin & Raviv, 2018, [7] 2) explains that it is the process of producing and manufacturing the product through its passage through several workstations arranged sequentially, as each workstation is responsible for performing A specific set of tasks, then the production elements move across the line from one workstation to another according to their order and end up as final products. (Pereira & Álvarez, 2018, [14] 85) explains: It is a production system that is frequently used to produce large quantities of standard basic goods in the assembly line, where Unfinished products flow through successive workstations until they are finished and then the finished product leaves the line, showing (Mumani, *et al.*, 2023, [13] 2) It is a continuous process that needs monitoring and adjustments to ensure that the production line remains balanced and efficient, and this applies to a wide range of industries and products, including the production of electronics, cars, and clothing industries. In light of this, we see that balancing assembly lines is a process of flow of parts. The product is distributed logically to a number of stations arranged according to precedence in order to provide a product that suits the customer's needs at the lowest possible cost, time and effort.

Second: Objectives of balancing assembly lines: The main objective of balancing an assembly line is to achieve the appropriate balance between the various stages of production to ensure that each production line is able to work efficiently without any major delays. The main objectives of balancing an assembly line include the following (Monden, 2011, Faraj and Hassan, 2020, 131) [12, 8]:

1. **Increase productivity:** Adjust the work flow so that line productivity is improved without wasting time.
2. **Reducing costs:** Improving the distribution of resources and organizing production processes effectively can contribute to reducing the cost of production.
3. **Improving product quality:** Ensuring equal distribution of the load reduces the chances of errors or

problems in product quality.
4. **Improving working conditions:** modifying production processes to reduce pressure on workers and improve working conditions.
5. **Improving the timeliness of delivery**: Organizing production processes so that timely delivery of products is effectively achieved.
6. Eliminate bottlenecks and ensure smooth workflow.
7. Determine the optimal number of workstations and tasks at each station.

Third: Assembly line balancing requirements: The successful application of assembly line balancing is based on the following requirements:
1. **Precedence requirements:** Precedence requirements specify the operations that must be completed before other operations, and the operations that are performed simultaneously, and which must wait until a later time. This requires drawing a precedence chart to determine the sequence of completion of operations in the assembly line (Faraj and Hassan, 2020, 132) [8].
2. **Production cycle time:** The maximum time that a workpiece can spend at the workstation and is equal to the inverse of the production rate (Alhomaidhi, 2023, 3) [17].
3. **Number of stations:** The station is a part of the line in which a number of operations are carried out. Work at the station can be manual or automated, and the work done at the station is called loading the station (Alhomaidhi, 2023, 3) [17].
4. **Idle time:** It refers to the total amount of unused production time at all workstations, and is calculated by multiplying the number of actual workstations by the cycle time subtracting the work content (Faraj and Hassan, 2020, 132) [8].
5. **Efficiency:** It is the ratio between the total station time to the product of cycle time and the number of workstations, represented as a percentage, and this shows the relative efficiency of using the line (Legesse, *et al*, 2020, 95) [11], and production efficiency is defined as the proper use of resources to achieve the desired goal. By reducing costs, time and efforts, ensuring access to the highest number of products in exchange for a small number of inputs (Bilal and Rayes, 2023, 124) [15].
6. **The rate of delay or inefficiency:** It is the total unproductive surplus time at all work stations when assembling a single unit, and this results from an imbalance in the assembly line (Baghdad, 2022, 100) [6].

Fourth: The main types of assembly lines: There are many types of assembly line systems, and some common differences include classic, automated, intermittent, and simple manufacturing models. These assembly line systems are often used to manufacture different types of products (Adeppa, 2015, 295) [1]:
1. **Single model assembly line:** It is a type of assembly line in which assemblers work on the same product.
2. **Mixed model assembly line:** The practice of assembling several distinct models of a product on the same assembly line without changes and then sequencing those models in a way that facilitates demand for primary components. Mixed model sequences can be assembled on the same line, despite enormous efforts to make production systems more Versatile, but this usually requires very homogeneous production processes.
3. **Multi-model assembly lines:** It is a line that supports the production of multiple products, where multiple or individual components are run through a processing line that provides many final items or final products.

Fifth: Techniques used to determine the optimal choice for balancing assembly lines
1. **Weighted positional weights algorithm:** According to this algorithm, activities are arranged based on the time of each activity and the activities affiliated with that activity, and the activities are distributed to the stations in descending order from the highest activity that begins the ranking down to the lowest activity that received the minimum time, provided that the precedence or precedence relationships are not exceeded. Operations follow (Baghdad, 2022, 74) [6], and this algorithm works based on the following (Hassan and Ahmed, 2020, 132) [8]: 1- Drawing a precedence chart. 2- Determine the time required for each process from the beginning of the activities to their end. 3- Descending order of all activities. 4- Determine the highest activity in terms of time, then assign the work activity to the station. The process of allocating times continues on the condition that it does not exceed precedence, and the method is repeated for all activities.
2. **Moody and Yang's algorithm:** In 1965, the two scientists Moody and Yang presented a method or algorithm specialized in dealing with the problems of assembly lines in productive organizations. The content of this algorithm depends on the fluctuations in the time of the activity or task, considering its times to be independent, in addition to its role in reducing idle time through its distribution. On workstations by adopting the largest station time, and it is possible to move to another station before the previous station is saturated with what is equal to the cycle time or slightly less than it (Hassan and Ahmed, 2021, 153) [8].
3. **COMSOAL algorithm:** The COMSOAL algorithm generates many possible solutions randomly and then chooses the solution that contains the least number of workstations as the best solution. The list of total tasks distributed among the stations is kept, after which a subset of subtasks that are not preceded by activities is created. Others, as well as maintaining another subset of tasks that will be contained in the remaining cycle time available for the current workstation (Alhomaidhi, 2023, 12) [17], and the steps to implement this algorithm are according to the following steps (Hassan and Ahmed, 2020, 132) [8]: 1- Relying on A precedence chart to identify all major tasks and the tasks that follow them. 2- Create an A-list for each task on the assembly line, and collect the total tasks in this list in a precedence chart. 3- We create List B, and this list contains tasks that are not preceded by other tasks. 4- We prepare List C to determine the times of tasks that are not greater than the production cycle time, then we choose a random task from List C and assign it to the station.

The third axis: The field aspect

First: The overall current reality of the factory: Table-1 shows that the Volvo Trucks manufacturing plant consists of 15 stations and produces 3 trucks per day, and that the idle time is estimated at 9 Hours, while the waiting time (bottlenecks) is only 1 hour, which indicates the high smoothness of the production line. We also learned that the available time is 8 hours a day, which makes the production cycle time estimated at 2:40, two hours and forty minutes to produce one car, and thus it will be efficient. The assembly line is 53%, and this is a small percentage. This is due to the increase in idle time due to the lack of demand for the product. The number of workers required was 38 instead of 54, and this matter will increase the idle time for the workers.

Table 1: Shows the current reality of the study sample factory

Station codes	stations	Task time	Previous task time	Idle time	Waiting period	Number employees available	rhyme	Number employees required
A	Al-Chassi station 1	2.3	0	0	0	4	0.0425	4
B	Al-Chassi station 2	2.3	2.3	0	0	6	0.0425	6
C	Pressing and fining station	1	2.3	1.3	0	3	0.0185	2
D	Excel station	1	2.3	1.3	0	5	0.0185	2
E	Electricity wiring station	1.3	2.3	1	0	2	0.024	2
F	Air terminal connecting valves and tanks	1	2.3	1.3	0	2	0.0185	1
G	Air duct wiring station	2	1	0	1	6	0.0371	5
H	Engine station and accessories	1	3	2	0	5	0.0185	2
I	Gambling station	1	1	0	0	6	0.0185	3
K	Dictation station	1	1	0	0	3	0.0185	2
L	Programming and operating station	1	1	0	0	2	0.0185	1
M	wheel alignment station	1	3	2	0	3	0.0185	2
N	Inspection and road inspection station	1	1	0	0	2	0.0185	1
O	Supplement station	2	2	0	0	3	0.0371	3
P	Final checking station	2	2	0	0	2	0.0371	2
Total	15	21		9	1	54		38

Second: The theoretical measurement of the current reality for each station in the factory, the study sample: The results in Table-2 show the indicators for measuring the theoretical efficiency of the assembly line, as these indicators show that the production quantity is 3 cars per day, the available time is 8 hours per day, and the average production cycle time is 2.3. An hour, or 2:18 hours and eighteen minutes to produce one car, which is better than the current cycle time estimated at 2:40 minutes shown in (the current reality of the factory), and the total time for work content (tasks) is 21 hours to produce 3 cars per day. Meaning that the average time spent on each station is 1:24 minutes, and the number of stations is 15, making the efficiency rate 60%, which is a low percentage. This is due to the increase in idle time by approximately 15 hours per day, and to address this matter, many algorithms were used.

Table 2: Theoretical measurement of assembly line efficiency in the Volvo Trucks factory

Stations	Production Vol	Available time	Cycle time	Task time	Number stations	Efficiency	Delay rate	Idle time
Al-Chassi station 1	4	8	2	2.3	15	0.70	0.3	9
Al-Chassi station 2	4	8	2	2.3	15	0.70	0.3	9
Pressing and fining station	4	8	2	1	15	0.70	0.3	9
Excel station	4	8	2	1	15	0.70	0.3	9
Electricity wiring station	4	8	2	1.3	15	0.70	0.3	9
Air terminal connecting valves and tanks	4	8	2	1	15	0.70	0.3	9
Air duct wiring station	4	8	2	2	15	0.70	0.3	9
Engine station and accessories	3	8	2.7	1	15	0.52	0.48	19.5
Gambling station	3	8	2.7	1	15	0.52	0.48	19.5
Dictation station	3	8	2.7	1	15	0.52	0.48	19.5
Programming and operating station	3	8	2.7	1	15	0.52	0.48	19.5
wheel alignment station	3	8	2.7	1	15	0.52	0.48	19.5
Inspection and road inspection station	3	8	2.7	1	15	0.52	0.48	19.5
Supplement station	3	8	2.7	2	15	0.52	0.48	19.5
Final checking station	3	8	2.7	2	15	0.52	0.48	19.5
Total	53	120	35	21	225	9.06	5.94	219
rate	3	8	2.3	1.4	16	0.60	0.40	15

Based on the results of tables (1, 2), which show that the actual efficiency is 53% and the theoretical is 60%, while the practical cycle time is 2:40 minutes, and the idle time is estimated in practice to be 9 hours and in theory to be 15 hours, while the number of stations reached 15 stations. In order to reduce idle time, increase efficiency, reduce production cycle time, and reduce the number of stations for making one truck.

To address this problem, Table (3) shows the correct scientific method in estimating the number of stations, efficiency, and idle time, as the production cycle time was 2:18 minutes, the efficiency level was 92%, and the idle time was 2.9 hours. The number of stations also reached 10 stations instead of 15 stations through overlapping. Activities among themselves. The results of Table (3) are better than the results of the factory method referred to in Tables (1 and 2). The theoretical measurement of the assembly line was carried out according to the indicators referred to in the study methodology.

Table 3: Results of scientific indicators for balancing the assembly line in the factory

Stations codes	production quantity	available time	Cycle time	Standard time	Number stations	Efficiency	Delay rate	Idle time
A	4	8	2	21	10	1	0	0
B	4	8	2	21	10	1	0	0
C	4	8	2	21	10	1	0	0
D	4	8	2	21	10	1	0	0
E	4	8	2	21	10	1	0	0
F	4	8	2	21	10	1	0	0
G	4	8	2	21	10	1	0	0
H	3	8	2.7	21	10	0.77	0.23	6
I	3	8	2.7	21	10	0.77	0.23	6
K	3	8	2.7	21	10	0.77	0.23	6
L	3	8	2.7	21	10	0.77	0.23	6
M	3	8	2.7	21	10	0.77	0.23	6
N	3	8	2.7	21	10	0.77	0.23	6
O	3	8	2.7	21	10	0.77	0.23	6
P	3	8	2.7	21	10	0.77	0.23	6
total	53	120	35	21	10	0.92	0.08	2.8
rate	3	8	2.3					

In light of the results of Table (3), tasks must be distributed into subsequent tasks and previous tasks, with time allocated to each task, provided that it does not exceed the time of the production cycle and does not exceed the precedence chart. Table-4 shows the distribution of tasks and their times among the assembly stations.

Table 4: Work stations and their times

Stations	Tasks	Task time	Previous tasks
1	A	2.3	-
2	B	2.3	A
3	C	1	B
	D	1	B
4	E	1.3	D
	F	1	D, E
5	G	2	C
6	H	1	F, G
	I	1	H
7	K	1	H
	L	1	H
8	M	1	I, K, L
	N, O	1	M
9	O	2	N
10	P	2	O

Based on the results of Table (4) to draw a precedence chart to show the precedence relationship between assembly stations, as drawing a precedence chart is restricted to the time of the production cycle, which is estimated at 2.3 hours, meaning the combination is between stations whose time is equal to or less than the time of the production cycle, and Figure (1) Shows the precedence chart for assembly stations for all activities.

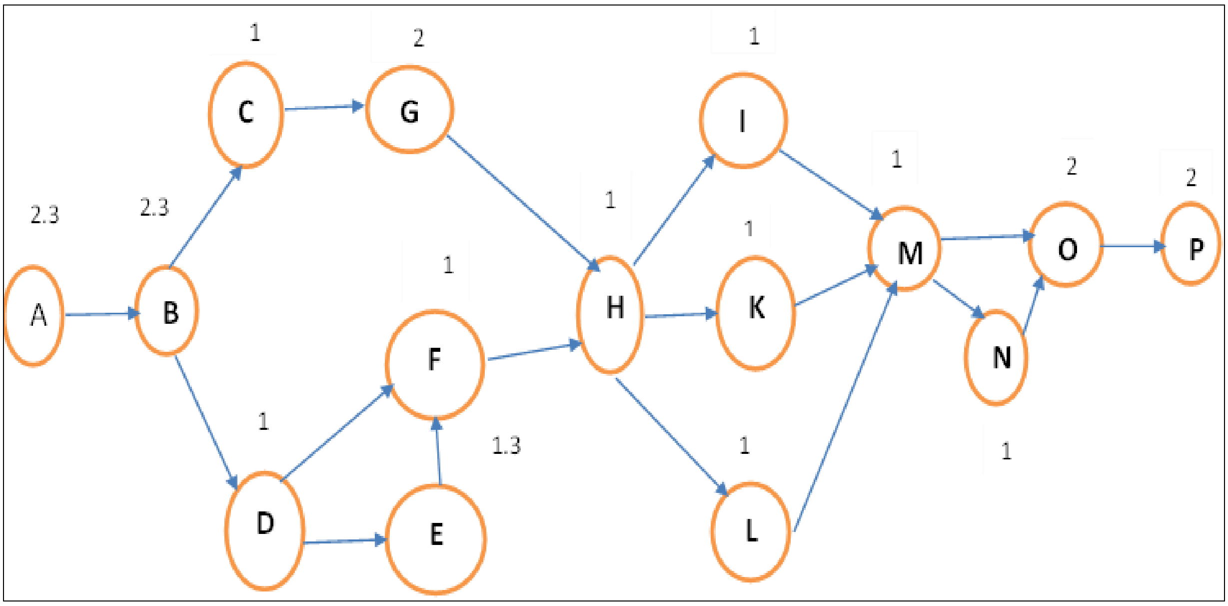

Fig 1: Precedence charts in the factory sample of the study

Third: Weighted positional weights algorithm: This algorithm indicates the relationships between the precedences of the assembly stations, as it is clear from matrix (1) that the relationships are between the precedences. If the sign is (-), this indicates a direct relationship between the precedences, but if the sign is (+). This shows that there is an indirect relationship, and the value of zero shows that there is no relationship. We would also like to point out that the value of the positional weight is the result of summing the values of the negative and positive precedences with the value of the activity. The positional weight of activity A is calculated by summing the values of the other activities and the symbols. With a sign - and + and excluding zero values, the site weight of A is 21 hours, and B is 19 hours after excluding activities with a value of zero, and so on for the rest of the activities.

Matrix 1: Weighted positional weights algorithm

Tasks	Task time	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Location weight
A	2.3	0	-	+	+	+	+	+	+	+	+	+	+	+	+	+	21
B	2.3		0	-	-	+	+	+	+	+	+	+	+	+	+	+	19
C	1			0	0	0	0	-	+	+	+	+	+	+	+	+	13
D	1				0	-	-	0	+	+	+	+	+	+	+	+	13.3
E	1.3					0	-	+	+	+	+	0	+	+	+	+	13.3
F	1						0	+	-	+	+	+	+	+	+	+	13
G	2							0	-	0	+	+	+	+	+	+	11
H	1								0	-	-	-	+	+	+	+	10
I	1									0	0	0	-	+	+	+	7
K	1										0	0	-	+	+	+	7
L	1											0	-	0	+	+	6
M	1												0	-	-	+	6
N	1													0	-	+	5
O	2														0	-	4
P	2															0	2

Depending on the results of the matrix of relationships between workstations, according to this algorithm, activities will be allocated or distributed to the workstations in the factory, where the distribution begins with the station that carries the highest site weight, provided that the production cycle time does not exceed 2.3 hours, followed by the lowest station, then the lowest until reaching The last station, and another station must be opened when the time of the current station is equal to or less than the time of the production cycle, as shown in Table (4). From this table it is clear that the idle time is 2.1 hour, This is an ideal time when adopting 10 stations. Grouping according to this algorithm.

Table 4: Distribution of work tasks to assembly stations according to the weighted location algorithm

Stations	Tasks	Task time	previous tasks	Location weight	Idle time
1	A	2.3	-	21	0
2	B	2.3	A	19	0
3	C	1	B	13	0.3
	D	1	B	14	

4	E	1.3	D	14	0
	F	1	D, E	13	
5	G	2	C	11	0.3
6	H	1	F, G	10	0.3
	I	1	H	7	
7	K	1	H	7	0.3
	L	1	H	6	
8	M	1	I, K, L	6	0.3
	N, O	1	M	5	
9	O	2	N	4	0.3
10	P	2	O	2	0.3
Total		21			2.1
rate					0.21

Fourth: Moody Yang algorithm: According to this algorithm, activities are distributed to assembly stations mainly based on the weighted location weights algorithm, as this algorithm is characterized by the use of allocating activities or tasks based on the highest time for any assembly station, as well as distributing surplus times between assembly stations on the condition that The cycle time exceeds the productivity and precedence. This algorithm also divides the activities and precedence's into lists. List a shows the first values of this algorithm and includes the previous and subsequent activities. After that, times are allocated to the activities and the highest time is taken from among the activities. After completion, the first station is opened. List B: This list includes the remaining activities after deleting the activities mentioned in Station A, and the same method is repeated for the other stations. In addition, this algorithm reduced the idle time to 2.1 hours, as shown in Table (5).

Table 5: List of distribution of activities among workstations according to Moody Yang

Tasks	Location weight	Subsequent activity	Task time	previous tasks	Idle time
A	21	B	2.3	-	0
B	19	C, D	2.3	A	0
C	13	G	1	B	0.3
D	14	E, F	1	B	
E	14	F	1.3	D	0
F	13	H	1	D, E	
G	11	H	2	C	0.3
H	10	I, K, L	1	F, G	0.3
I	7	M	1	H	
K	7	M	1	H	0.3
L	6	M	1	H	
M	6	N,O	1	I, K, L	0.3
N	5	O	1	M	
O	4	P	2	N	0.3
P	2	-	2	O	0.3
					2.1

Fifth: Comsoal algorithm: This algorithm helps in choosing the best design for the assembly lines. It works according to several steps, the first of which is creating a list called List A in which the previous and subsequent tasks for all activities of the assembly stations are mentioned, as shown in Table (6).

Table 6: Model (A) according to the Comsoal algorithm

Tasks	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**K**	**L**	**M**	**N**	**O**	**P**
Subsequent activity	B	C, D	G	E, F	F	H	H	I, K, L	M	M	M	O, N	O	P	**0**
Number of previous tasks	0	1	1	1	1	2	1	2	1	1	1	3	1	2	**1**

After completing List A, a new list called B is opened and includes activities that are not preceded by any activity or task. After that, the selected tasks are transferred to List C, which is the third list, in which the final time is allocated to all assembly line activities. This algorithm also proved that time Idle time is 13 minutes, and all of this is shown in Table (7 and 8).

Table 7: Model (B)

Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Tasks	A	B	C, D	G	E, F	H	I, K, L	M	N	O	P
time	2.3	2.3	2	2	2.3	1	3	1	1	2	2

Table 8: Model (C)

Stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Tasks	A	B	C, D	G	E, F	H, I	K, L	M, N	O	P	
Time	2.3	2.3	2	2	2.3	2	2	2	2	2	21
Idel time	0	0	0.3	0.3	0	0.3	0.3	0.3	0.3	0.3	2.1

The results of the lists (A, B, C) are the result of a summary of the relationships between activities and precedences. It is divided into three lists: A, B, and C. When A is saturated, list B is opened, deleting all of A's connections. After B is completed, list C is opened, and so on for the rest. Activities as shown in matrix (2).

Matrix table (2): Distribution of relationships between activities according to the Comsoal algorithm

P	**O**	**N**	**M**	**L**	**K**	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**A**	**Tasks**
													1		A
											1	1			B
								1							C
									1	1					D
									1						E
							1								F
							1								G
				1	1	1									H
			1												I
			1												K
			1												L
	1	1													M
	1														N
1															O
															P
															Relation

List A

P	**O**	**N**	**M**	**L**	**K**	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**B**	**Tasks**
											1	1		B
								1						C
									1	1				D
									1					E
							1							F
							1							G
				1	1	1								H
			1											I
			1											K
			1											L
	1	1												M
	1													N
1														O
														P
1	2	1	3	1	1	1	2	1	2	1	1	1	0	Rotation

List B

P	**O**	**N**	**M**	**L**	**K**	**I**	**H**	**G**	**F**	**E**	**D**	**C**	**Tasks**
								1					C
									1	1			D
									1				E
							1						F
							1						G
				1	1	1							H
			1										I
			1										K
			1										L
	1	1											M
	1												N
1													O
													P
1	2	1	3	1	1	1	2	1	2	1	0	0	Relation

List C

Sixth: Evaluating the results of the algorithms: The results of (7) indicate that the reality of the factory situation consists of 15 stations, and the efficiency rate is 60%, while the idle time is 15 hours, and the production cycle time is 2.6 hours, while 54 workers work in the factory, and the percentage of delay or imbalance 40%.

The results of the theoretical measurement of the assembly lines show that the number of stations was 10, and the efficiency rate was 91%, while the idle time was 2.9 hours, while the production cycle time was 2.3 hours, and the number of required workers became 38 workers instead of 54 workers, and the delay rate reached 9%. This result was consistent with the results of the algorithms adopted by the current study, which means there is accuracy in choosing the subject of the study and accepting its hypothesis, and this serves the researched factory. It must be noted that the difference between the results of the theoretical measurement and the three algorithms is the idle time, as the idle time according to the theoretical measurement reached 2.3 hours. While the idle time in the algorithms reached 2.1 hours, we advise the factory management to apply one of the algorithms in arranging the assembly lines to ensure reduction of idle time, efficiency, etc.

Measurement indicators	Reality factory situation	Theoretical measurement assembly line	Weighted positional weighting algorithm	Moody and Yang algorithm	Comsoal algorithm
stations	15	10	10	10	10
efficiency	60%	91%	91%	91%	91%
Idle time is hourly	15	2.9	2.1	2.1	2.1
Cycle time	2.6	2.3	2.3	2.3	2.3
Number of employees	54	38	38	38	38
Percentage of delay or inefficiency	40%	9%	9%	9%	9%

Fourth axis: Conclusions and proposals

First: Conclusions: The study reached several conclusions:

1. The reality of the factory situation revealed that the idle time in the factory is 15 hours per day, and that the production cycle time for making one truck is 2.3 hours, which indicates that the production quantity is 3 trucks per day, and the number of hours of suffocation is one hour in the air ducting station, Thus, the efficiency rate reached 60%, which is a fairly low percentage.
2. The study found that there is a discrepancy or deviation in the distribution of tasks between stations, which may lead to an increase in the number of bottlenecked stations and an increase in idle time, which negatively affects the production cycle time. This results from a weak study of the causes of bottlenecks, as well as a weakness in the reasons for studying the idle time in the factory.
3. Weak experience in applying the correct scientific method in measuring the required number of stations, which leads to an increased need for workers and time, and also makes the process of distributing activities and work to the stations in a blurry manner.
4. When the three algorithms were applied, the number of stations was reduced to 10 stations instead of 15 stations. The idle time according to the scientific method was also reduced to 2.9 hours instead of 15 hours. The idle time according to the three algorithms became 13 minutes, while the efficiency ratio reached 92%, which is better than the efficiency of the line approved by the factory management, which is 60%.

Second: Proposals: In light of the conclusions, we present the following proposals:

1. Use correct scientific indicators to measure the number of stations required to ensure the elimination of idle time and the speed of providing the product to the market.
2. Apply one of the three algorithms adopted by the current study in order to choose the optimal balance for the assembly line, which will reduce bottlenecks in the stations and increase the overall production efficiency of the assembly line.
3. Develop short-term plans lasting one or two months to schedule production operations in the assembly line, so that the factory management can determine the number of workers required to indicate the need for additional time or not or reduce idle time.
4. Holding training workshops for workers to develop their skills and enable them to carry out the tasks assigned to them with the least possible time and effort.

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