

Assembly Line Balancing: Application in a Furniture Company

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Abstract

The assembly line balancing problem is the process of assigning tasks to workstations in such a way as to reduce lost time and increase the efficiency of the line, while respecting certain technology-driven precedence relationships and constraints such as capacity. Due to the large and complex design of assembly lines, the smallest disruption and unbalance at any one station can affect the entire line performance. To minimize or avoid such disruptions, the assembly line must be balanced. This study focuses on a detailed analysis process to identify specific problems and disruptions in the assembly line. The line balancing application in the study was carried out as a case study in a furniture company's bed base production line. The production line was first surveyed and workflows, task durations and precedence diagrams were identified. The assembly line balancing problem was solved by using Positional Weighting, Largest Candidate and Kilbridge-Wester methods and the results were compared. Thanks to the balancing studies, the workflow has been streamlined, the use of workstations has been optimized and the production processes have been managed more effectively.

Key Words

Assembly line balancing, Workstation, Positional weight, Largest candidate, Kilbridge-Wester, Furniture

1. Introduction

An assembly line is a system consisting of workstations, usually moving on a belt and/or conveyor, created to connect consecutive tasks. These systems are systems in which the work is performed on the part, which is moved by using resources such as moving belts or labor force during production. Tasks are collected at workstations within the existing constraints and the workstations created are located on a line. This problem is called the assembly line balancing problem (ALBP) (Pınarbaşı et al., 2015).

The furniture sector has become an important sector for Turkey's economy (FWGR, 2015). Thanks to the investments and developments made in recent years, significant progress has been achieved in the sector with the establishment of world-class production facilities. In addition, with the spread of dealership systems, the sale of products within the country and worldwide has become easier. The furniture sector develops its products and increases its diversity every year. This situation enables consumers to access products addressing different needs and tastes and increases the competitiveness of the sector. Moreover, the furniture industry is one of Turkey's high value-added sectors, which utilizes domestic resources in the most efficient way in exports and has the least dependence on imported products. This makes a significant contribution to the Turkish economy (FSR, 2020). Overall, the furniture sector continues to make positive contributions to Turkey's economic growth and foreign trade balance.

In the literature, assembly lines have found application in many sectors and ALBP has been solved with different solution methods (Pınarbaşı, 2021). Biber (2018) used Hoffman Method, Helgeson-Birnle (Sorted Positional Weight) Method and Moodie-Young Method in an enterprise operating in the automotive sector. Gündoğdu (2019) used the positional-weighted assembly line balancing method (PWALBM) in a company producing electrical household appliances. Kahya et al. (2018) used the COMSOAL algorithm in a bakery in their study. Tanrıtanır (2014) used the positional weighting method in a drawer workshop. Eryörük et al. (2014) used the positional weighted assembly line balancing method in a textile company. The furniture industry produces products that are large, heavy and difficult to manufacture due to their nature. Assembly lines are a production system that is frequently used in both furniture and other sectors to obtain the main product. Due to the large variety of products in furniture production and the complex stages of the production process, assembly lines are also designed in a large and complex way. The smallest disruption and unbalance in any station can affect the entire line performance. These disruptions occur for technical reasons. The assembly line must be balanced in order to minimize or avoid such disruptions.

ALBP is the process of assigning tasks to workstations in such a way as to reduce lost time and increase the efficiency of the line by complying with certain precedence relations arising from technology and certain constraints such as capacity (Pınarbaşı, 2022). Heuristic and meta-heuristic algorithms have been used in the literature for solving ALBP (Pınarbaşı and Yüzükırmızı, 2023). When the literature on ALBP with problem-specific heuristics is examined, it is seen that there is no study in the furniture sector. According to the Turkish Statistical Institute data, the turnover of the furniture sector is 48.6 billion TL and its ratio to the country-wide turnover is 0.5%. When the general world exports and world furniture sector export figures are analyzed, it is seen that the share of the world furniture sector in the general world exports is 1.01% in 2001, 0.88% in 2010 and 1.08% in 2016 as of 2001-2010-2016-2017. While the world furniture sector realized an export figure of 171.2 billion dollars in 2016 and 181.5 billion dollars in 2017, it is estimated that the trade volume of the furniture sector will exceed 1 trillion dollars in 2030.

In this study, the data on tasks, task times, number of stations, number of production and cycle time were obtained from the time and method study conducted for the real line of a furniture company. As a result of the data obtained, ALBP for a furniture company with a traditional production shop system was solved using positional weighting, largest candidate and Kilbridge-Wester heuristics. The aforementioned heuristic methods are frequently preferred in the ALBP literature due to their easy implementation and user-friendliness (Kılıç, 2010).

The contributions and findings of the article to the literature can be given as follows.

- This study is the first study for the bed base production line in the furniture sector.
- The study is comprehensive study in terms of examining the details of the bed base production process and carrying out all time and method studies.
- The study includes an application of ALBP in the furniture sector and contributes to the literature with the comparative use of three different ALBP specific heuristics.

The study is organized as follows after the introduction. In the second section, literature review is given. In the third section, the definition of ALBP is mentioned and its importance is explained with examples. The three heuristics used in the study are mentioned in the fourth section. The fifth section contains the details of the implementation studies and numerical results. The study is concluded with a conclusion section.

Abbreviations

ALBP	Assembly Line Balancing Problem
PWALBM	Positional Weighted Assembly Line Balancing Method
PWM	Positional Weight Method
KWM	Kilbridge-Wester Method
LCM	Largest Candidate Method
CP	Constraint Programming
TS	Tabu Search
GA	Genetic Algorithm
PS	Particle Swarm Optimization
SA	Simulated Annealing
FF	First-Fit
PW	Positional Weight

2. Literature Review

The results of the literature review on ALBP are given in Table 1. Since the subject of the study is heuristics specific to ALBP, the literature is focused on this topic. The literature is categorized as assembly line type, objective function used, problem solution method and application area.

When the literature is evaluated in terms of assembly line type, it is seen that ALBP-specific heuristics are mostly used in balancing U-type assembly lines. Some studies (Kara, 2004; Kılıç, 2010; Çalışkan, 2020; Altuntaş and İşlier, 2010; Aksoy et al., 2014; Kurşun and Kalaoğlu, 2010) can be given as examples of these studies. Subsequent studies on U-type lines have been carried out on parallel lines. Some literature studies for parallel ALBP solution Akin (2015), Gündoğdu (2019), Kayar and Akyalçın (2014) and Altunay et al. (2017) can be given as an example. Literature studies for the solution of two-sided ALBP can be given as Mete and Ağpak (2013), Lee et al. (2001), Purnomo et al. (2013) as examples. For straight ALBP solution, literature studies (Çelik and Arslankaya, 2023; Pachghare and Dalu, 2014) can be given. There are also studies on the combination of assembly line types in the literature. For example, studies on two-sided U-type ALBP can be given as Delice (2019). It is seen in the literature that there are few studies on straight lines.

In the literature, ALBP is generally focused on three different objectives (Alakaş and Pınarbaşı, 2023). These are minimization of number of station (m), minimization of cycle time (c) and maximization of line performance (p). Mostly, the maximization of line performance has been observed in the literature (Pınarbaşı and Alakaş, 2020). Çalışkan (2020) can be given as examples. It was observed that the next objective is the minimization of the number of stations. Özcan (2007) and Çerçioğlu et al. (2009) study the ALBP for minimizing the number of stations. The other common objective is cycle time minimization (Özgen, 2016; Akin, 2015).

In the literature, it has been observed that three methods are more frequently used in ALBP solution: Positional Weight Method (PWM), Kilbridge-Wester Method (KWM) and Largest Candidate Method (LCM). Literature studies (Çalışkan, 2020; Akin, 2015) can be given as examples for the Positional Weight Method. There are also studies in literature where different methods are combined. For example, Kılıç (2010) used Kilbridge-Wester Method, Positional Weight and Simple Heuristic Methods in his study. Studies in which the constraint programming (CP) model is applied have also been examined in the literature. For example, Alağaç et al. (2016) and Pınarbaşı and Alakaş (2021) can be given for CP modeling approach.

In the literature, it is seen that ALBP applications are mostly carried out in the Automotive Industry. Examples of other application places are ready-made clothing sectors, garment and textile sectors. It has been seen in the literature that two studies are published on the furniture industry.

3. Assembly Line Balancing Problem

The assembly line balancing problem addresses the unbalance and inefficiencies that may occur in the production process on an assembly line. The causes of this unbalancing include factors such as time, workload, or resource distribution between workstations on the assembly line. As a result of this unbalance, time losses, additional costs, and quality issues arise in the production process. In such cases, assembly line balancing aims to optimize the workstations, use resources effectively, and increase the efficiency of the system. The solution to the ALBP involves using mathematical and analytical models that consider factors such as the workload, task times, and capacities of workstations for analysis. These analyses focus on decisions regarding the layout of workstations, task sequencing, and resource allocation. Ultimately, assembly line balancing is crucial for solving system problems, improving efficiency, and ensuring that businesses remain competitive while maintaining customer satisfaction.

One of the fundamental concepts in ALBP is the concept of a task. A task refers to a work element that cannot be further subdivided into smaller workpieces. Tasks can have specific characteristics, and the most important of these is the task time. The task time refers to the time required to complete any task.

In an assembly line, the term "station" represents a specific point, processing location, or stage of the production process. Each station is a point where the assembly of the product or a specific operation takes place. For example, in a car assembly line, each station is a point where different components or parts of the vehicle are assembled. At one station, the engine may be assembled, while at another station, tires may be installed, or interior upholstery may be fitted. The stations on the assembly line determine the flow of the production process and ensure that the assembly of the product progresses step by step without interruptions. Each station has a specific function, and the correct sequencing and arrangement are critical for the efficient operation of the assembly line. A station that is well-designed and carefully planned in terms of layout and function during management can improve the efficiency of the assembly line and the effectiveness of the production process.

Cycle time is an important concept in assembly line balancing. It refers to the time required to produce a product on a workstation. In other words, cycle time is the time elapsed from the production of one product on the assembly line until the production of the next product. Accurately determining the cycle time is crucial for the efficient operation of the assembly line. The cycle times of the workstations affect the overall speed of the assembly line. Therefore, the ALBP also addresses the optimization of cycle times.

Table 1. Literature Review

Paper	Line layout	Objective	Solution method	Application Area
Kara (2004)	U-Type	m	COMSOAL	Automotive Supply Industry
Akın (2015)	Parallel	c	PWM	Furniture Industry
Gündoğdu (2019)	Parallel	p	PWM	White Goods Factory
Eryürük et al. (2014)	Parallel	c	PWM	Textile Factory
Aksoy et al. (2014)	U-Type	m	PWM	Safety Equipment Manufacturing Company
Kurşun and Kalaoğlu (2010)	U-Type	p	KWM	Garment Business
Çalışkan (2020)	U-Type	p	PWM	Garment Business
Kılıç (2010)	U-Type	c	KWM, PWM, Simple Intuitive	Ready-made clothing sector
Özcan (2007)	U-Type	m	TS	
Pınarbaşı and Alakaş (2021)	Straight	m	CP	
Biber (2018)	U-Type	p	Hoffman, Helgeson Birnie, Moodie-Young	Automotive Business
Kahya et al. (2018)	Straight	c	COMSOAL	White Goods Factory
Tanrıtanır (2014)	U-Type	m	PWM	Drawer Workshop
Özgen (2016)	Parallel	c	LCM, KWM	Ready-made clothing sector
Altunay et al. (2017)	Parallel	c	LCM	
Altuntaş and İşlier (2010)	U-Type	p	LCM	Automotive Industry
Çerçioğlu et al. (2009)	Parallel	m	SA	Automotive Industry
Mete and Ağpak (2013)	Two Sided	m	Resource Constrained Mathematical Model	Automotive Industry
Delice (2019)	Two Sided - U-Type	p	PSO	Automotive Industry
Lee et al. (2001)	Two Sided	p	GA	Automotive Industry
Purnomo et al. (2013)	Two Sided	m	GA, FF	Automotive Industry
Hwang and Katayama (2007)	U-Type	m	GA	
Çelik and Arslankaya (2023)	Straight	p	KWM, PWM	Electric Industry
Alağaç et al. (2016)	Mixed	c	CP	An Industrial Organization
Pachghare and Dalu (2014)	Straight	p	KWM	Machine Manufacturing Factory
Kayar and Akyalçın (2014)	Parallel	m	COMSOAL, Moodie-Young, KWM	Textile Factory
Akargöl. (2023)	Straight	m	HOFFMAN	Furniture Industry
Arıkan (2024)	U-Type	c	SA	

c: cycle time, m: station number, p: positional weight, PWM: Positional Weight Method, KWM: Kilbridge-Wester Method, TS: Tabu Search, GA: Genetic Algorithm, PS: Particle Swarm Optimization, LCM: Largest Candidate Method, SA: Simulated Annealing, FF: First-Fit, CP: Constraint Programming

Precedence relationships are another concept used in the assembly line balancing process. A precedence relationship refers to the order of tasks between workstations on the assembly line. It determines which task must be completed first at a workstation. Different tasks may need to be performed at various workstations, and some tasks may need to be completed before others. For example, the assembly of one part may need to be completed before the assembly of another part, or a specific test may need to be performed before other tasks are completed. The Precedence relationship is important for maintaining order and increasing efficiency. By establishing the correct precedence relationships, tasks on the assembly line can be completed on time, and the production process can proceed smoothly and without interruptions.

This study focuses on the design of an assembly line for a production workshop with a specific number of tasks. Therefore, tasks, task times, precedence relationships between tasks, and cycle time studies are determined for the production workshop. Using the obtained data, the station layout for the designed assembly line is determined. So, the gap that the study fills in the literature can be stated as follows: To make an application for the assembly line balancing problem in the furniture industry and to present a practical application of three different heuristics with a real data set. In addition, this study includes a practical application of PWM, LCM and KWM heuristic methods. While these heuristics offer advantages due to their easy applicability and understandability, they are disadvantageous in terms of providing the optimal solution to the problem. For this reason, they are often preferred for ALBP solutions in practice. According to the literature review in Table 1, although these heuristics have applications in many sectors, they are rarely applied in the furniture sector. Furthermore, this study is the first application of LCM and KWM methods in the furniture sector.

4. Methods

4.1. Positional weight method

The positional weight method is a technique used in the solution of assembly line balancing problems. According to the method, each task has a positional weight. The positional weight (PW) of each task is calculated by summing the times of all successor tasks sequentially. First, a positional weight matrix table is created according to the precedence relationships, and the positional weights are determined. Then, these positional weights are sorted from largest to smallest, and workstations are created such that the total time at each station does not exceed the pre-determined cycle time. The algorithmic flowchart of the PW method is shown in Figure 1.

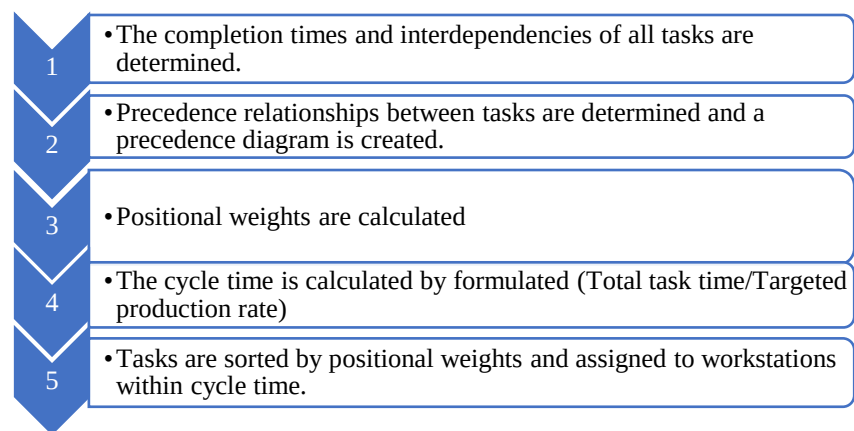


Figure 1. Positional Weight Method Flowchart

4.2. Largest candidate method

The Largest Candidate Method is a technique used in the assembly line balancing process. In the largest candidate rule, the task with the largest task time is assigned to the station, regardless of its successors. While creating stations, tasks with the largest task times are prioritized, but the total time of a station should not exceed the cycle time. The flowchart of the LCM is shown in Figure 2.

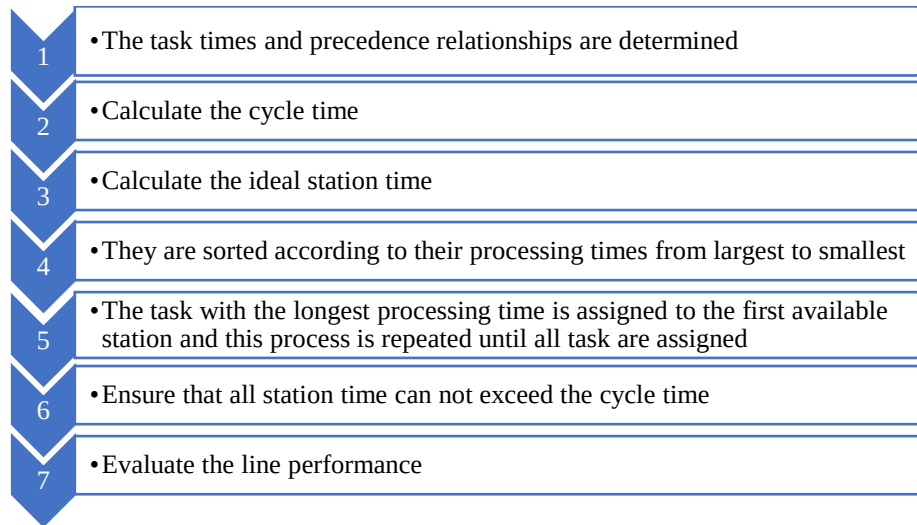


Figure 2. Largest Candidate Method Flowchart

4.3. Kilbridge-Wester method

The Kilbridge-Wester method is a classical technique used in assembly line balancing problems to distribute the workload in a balanced manner. This method aims to achieve the best balance by following a specific order when assigning tasks to workstations. It is used in the assembly line balancing process to balance the workloads of workstations. The KWM seeks to balance the workloads of workstations while also improving the overall efficiency of the line. The number of tasks and the times associated with these tasks need to be known. The precedence relationships between the tasks must also be known. The constraints, such as which task should be performed after another, must be understood. The cycle time must be known based on the planned production quantity.

Workloads are determined based on the workstations. When there is an unbalance in the workload between workstations, task transfers are made between workstations to eliminate this unbalance. While making task transfers, the distances between workstations, task times, and material movements are considered. As a result of the task transfers, the overall performance of the line is improved, and unbalance between workstations is minimized.

The KWM ensures the efficient use of workstations on the assembly line and fair distribution of workloads. This method is an effective tool for maintaining the balance between the locations of workstations and their workloads, and it increases the overall efficiency of the assembly line. The algorithmic flowchart of the method is shown in Figure 3.

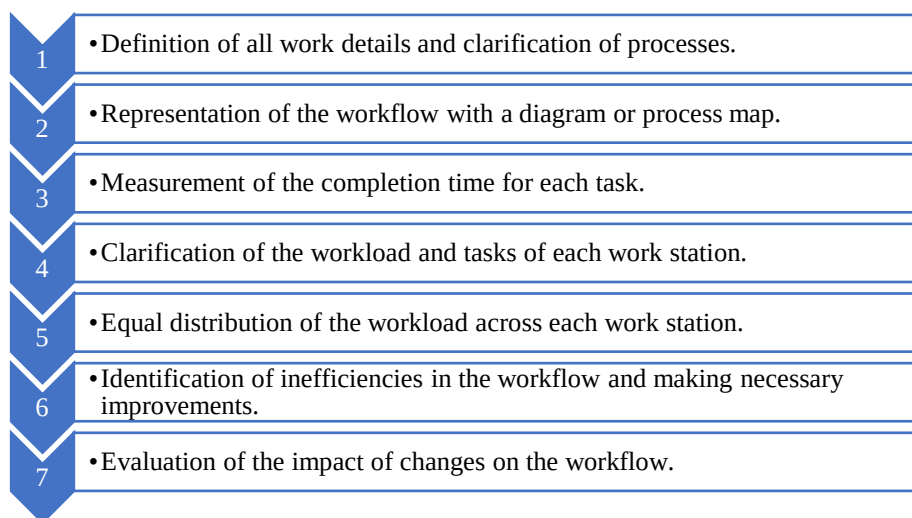


Figure 3. Kilbridge-Wester Method Flowchart

5. Application and Numerical Results

5.1. Work study and application area

A furniture factory has been selected as the application area for the assembly line balancing study. The factory has more than 140 branches across Turkey and approximately 2,000 employees. The company sells both domestically and internationally. As a result, the factory experiences periods where it operates at full capacity, with potential for capacity expansion. The company wants to design the bed base production workshop as an assembly line to meet this high demand.

The study began with an analysis of the current state of the bed base production workshop. During this analysis, the factory's operations are carefully examined using observation-based methods, and the issues in the current system are identified. This critical stage allowed for an objective evaluation of the factory's strengths and weaknesses, enabling the development of more effective solutions. To improve the workflow in the factory, a comprehensive process is conducted, starting with the determination of the line type, and involving the detailed examination of key elements such as cycle times, tasks, and work studies. The cycle time is calculated by dividing the daily working hours by the daily number of bed bases produced. The cycle time is found to be 187 seconds, as 154 bed bases are produced in eight working hours. This calculation is made to assess the factory's daily production performance and measure the effectiveness of the workflow. It was determined that there are 14 tasks in bed base production, and the data related to these tasks is provided in Table 2. Improvement and adjustments are made through the work studies conducted in the bed base production workshop. The precedence diagram is created based on the tasks. Based on the calculated and recorded information, steps are taken toward solving the ALBP. Workstations are determined based on the precedence diagram and task times, ensuring that the cycle times of the stations are not exceeded.

Both the data in Table 2 and on-site observations have shown that the task of "Stapling the cover" creates a bottleneck in the current situation. To prevent this from obstructing the flow on the assembly line, the task has been divided into two parts and performed by two separate personnel simultaneously. The precedence relationships have been established according to Table 3. Table 4 contains the information regarding the determined precedence relationships.

Table 2. Current Task List

No	Tasks	Time (sec)
1	Placing the boards on the skeleton	40
2	Stapling the skeleton	64
3	Applying adhesive to the skeleton	42
4	Covering the skeleton with cardboard	57
5	Applying white coating to the skeleton	52
6	Hammering for cutting the fibres	37
7	Fitting the cover onto the skeleton	82
8	Stapling the cover	255
9	Installing the safety protector on the base	90
10	Assembling the interior of the base	72
11	Installing internal parts to the base	48
12	Installing the shock absorber to the base	70
13	Attaching the board to the base	53
14	Packaging the base	38

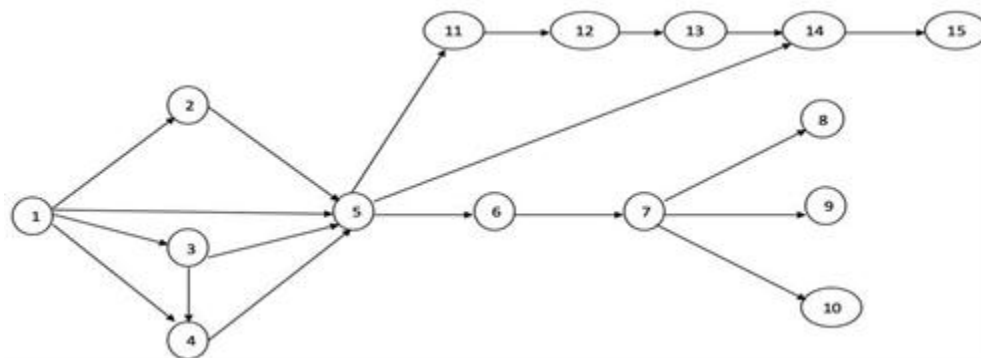
Table 3. Revised Task List

No	Tasks	Time (sec)
1	Placing the boards on the skeleton	40
2	Stapling the skeleton	64
3	Applying adhesive to the skeleton	42
4	Covering the skeleton with cardboard	57
5	Applying white coating to the skeleton	52
6	Hammering for cutting the fibres	37
7	Fitting the cover onto the skeleton	82
8	Stapling the right side of the cover	128
9	Stapling the left side of the cover	128
10	Installing the safety protector on the base	90
11	Assembling the interior of the base	72
12	Installing internal parts to the base	48
13	Installing the shock absorber to the base	70
14	Attaching the board to the base	53
15	Packaging the base	38

Table 4. Precedence Relationships

Task	Predecessor
1	-
2	1
3	1
4	1-3
5	1-2-3-4
6	5
7	6
8	7
9	7
10	7
11	5
12	11
13	12
14	5-13
15	14

Based on the information provided in Table 4, a precedence diagram has been created. The precedence diagram is shown in Figure 4.

**Figure 4.** Precedence Diagram

5.2. Positional weight method results

In this section, the precedence diagram has been evaluated using the PWM. The weight matrix used in the PWM is provided in Table 5.

Table 5. Positional Weight Matrix

Premise	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	PW
1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1001
2					1	1	1	1	1	1	1	1	1	1	1	862
3				1	1	1	1	1	1	1	1	1	1	1	1	897
4					1	1	1	1	1	1	1	1	1	1	1	855
5						1	1	1	1	1	1	1	1	1	1	798
6							1	1	1	1						465
7								1	1	1						338
8																128
9																128
10																90
11												1	1	1	1	281
12													1	1	1	209
13														1	1	161
14															1	91
15																38

In the positional weight matrix created based on the precedence diagram, all tasks that precede a given task are marked for that task. The sum of the processing times of the referenced task and all its preceding tasks forms the positional weight of that task. The positional weights calculated for all tasks are then sorted from largest to smallest, as shown in Table 6.

Table 6. Sorted Positional Weights

Task	Time (sec)	PW
1	40	1001
3	42	897
2	64	862
4	57	855
5	52	798
6	37	465
7	82	338
11	72	281
12	48	209
13	70	161
8	128	128
9	128	128
14	53	91
10	90	90
15	38	38

Based on Table 6 and the precedence diagram, the tasks are assigned to stations as shown in Table 7, ensuring that the total time and cycle time do not exceed 187 seconds.

Table 7. PWM Results

Station	Task	Time (sec)	PW	Station Time (sec)
Station 1	1	40	1001	146
	3	42	897	
	2	64	862	
Station 2	4	57	855	146
	5	52	798	
	6	37	465	
Station 3	7	82	338	154
	11	72	281	
Station 4	12	48	209	171
	13	70	161	
	14	53	91	
Station 5	8	128	128	166
	15	38	38	
Station 6	9	128	128	128
Station 7	10	90	90	90

5.3. Results of the largest candidate method

In the LCM, tasks are first sorted in descending order according to their task times, as shown in Table 8.

Table 8. Sorted Task for LCM

Task	Predecessor	Time (sec)
9	7	128
8	7	128
10	7	90
7	6	82
11	5	72
13	12	70
2	1	64
4	1,3	57
14	5,13	53
5	1,2,3,4	52
12	11	48
3	1	42
1	-	40
15	14	38
6	5	37

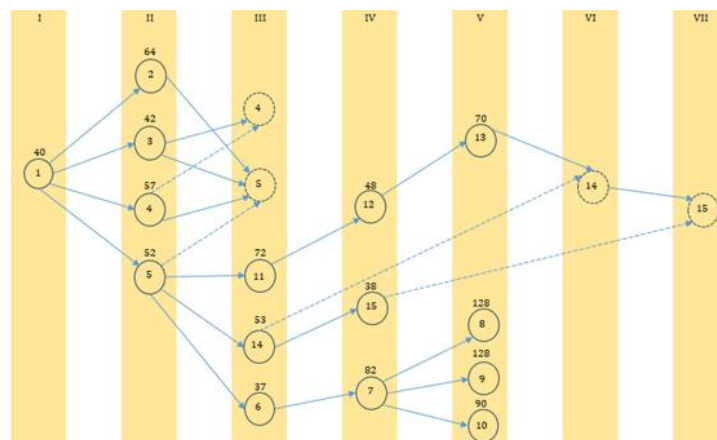
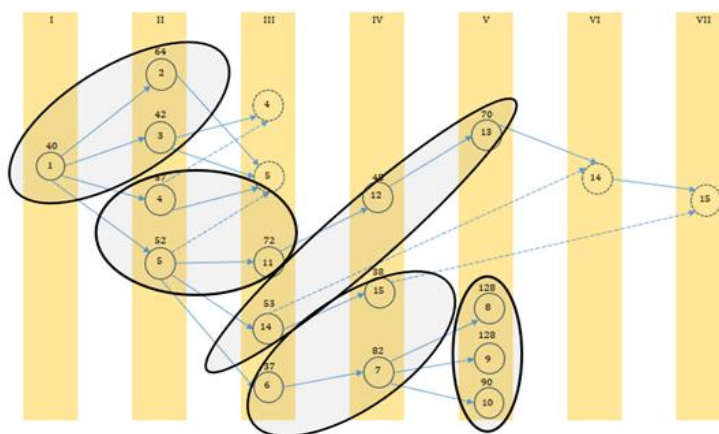
Table 9. LCM Results

Station	Task	Time (sec)	Candidate	Cumulative time (sec)
Station 1	1	40		40
	2	64	2,3	104
	3	42	3	146
Station 2	4	57	4	57
	5	52	5	109
	11	72	6,11	181
Station 3	12	48	6,12	48
	13	70	6,13	118
	14	53	6,14	171
Station 4	15	38	6,15	38
	6	37	6	75
	7	82	7	157
Station 5	9	128	9,8,10	128
Station 6	8	128	10,8	128
Station 7	10	90		90

The task with the longest processing time is assigned to the first possible station according to the precedence diagram, and this process is repeated for the other tasks. The task assignments obtained as a result of evaluating the largest candidate method with the precedence diagram are reported in Table 9.

5.4. Results of the Kilbridge-Wester method

The first task for the Kilbridge-Wester method is to divide and draw the precedence diagram into regions. The purpose of this is to determine the workload and tasks by considering the precedence and task times before assigning the tasks to stations. Figure 5 shows the precedence diagram grouped according to the method.

**Figure 5. Kilbridge-Wester Grouped Precedence Diagram****Figure 6. Kilbridge-Wester Marked Precedence Diagram**

Since the goal is to distribute the workflow equally across each workstation, marking has been done on the precedence diagram, as shown in Figure 6. Based on the markings, the tasks have been assigned to the stations. The results of the task assignments are presented in Table 10.

Table 10. KWM Results

Station	Task	Section	Time (sec)	Station Time (sec)	Predecessor
1	1	I	40		-
	2	II	64	146	1
	3	II	42		1
2	4	II, III	57		3
	5	II, III	52	181	1-2-3-4
	11	III	72		5
3	12	IV	48		11
	13	V	70	171	12
	14	III, VI	53		5-13
4	6	III	37		5
	7	IV	82	157	6
	15	IV, VII	38		14
5	8	V	128	128	7
6	9	V	128	128	7
7	10	V	90	90	7

According to the results of three different heuristic methods, the LCM and KWM methods identify the same station times, while the PWM shows a different distribution of station numbers. It is possible to obtain some managerial insights based on the performance evaluation. The assembly line manager can choose the appropriate heuristic method for the process and implement the line balancing accordingly. In addition, evaluating the performance of assembly lines with three different methods will provide managers with important data for trade off analysis. Examples of these trade off analyses include decisions such as determining the number of stations, determining the cycle time, and new line investments.

Table 11. Performance comparison

	Line Efficiency	Smoothness Index
MM	0,89	57,645
PWM	0,84	99,870
LCM	0,79	125,698
KWM	0,79	125,698

Table 11 reports the performance comparison results of the three heuristics. Line efficiency ($\text{total task time} / (m \cdot c)$) and smoothness index ($\sqrt{\sum_{k=1}^m (c - st_k)^2}$, st_k : total task time of station k) were determined as performance criteria. The ranking of the methods in terms of line efficiency is given as PWM (0.84), LCM (0.79) and KWM (0.79). The smoothness index values are determined as 99,870 for PWM and 125,698 for LCM and KWM. Considering these results, it can be said that PWM is the most effective and balanced heuristic. However, the problem has been solved with a mathematical model (MM). MM determines the optimal number of stations as six. In addition, the line efficiency of MM is determined as 0.89, while the smoothness index is reported as 57.645. In this case, it can be said that PWM produces the closest solution to MM. It is possible for the mathematical model to produce effective solutions for a 15-task problem, as in the work study. However, it is known that the effectiveness of mathematical models decreases as the problem size increases (Çelik and Arslankaya, 2023). Additionally, mathematical models require more expertise and resources than heuristics (Scholl, 1999). This study was carried out as a sample and pilot application in the bed base department of a furniture company. In the future, it is planned to solve ALBP in departments of the company with a larger number of tasks. For this reason, the study focuses on easy-to-use and easily applicable heuristics for ALBP solution.

6. Conclusion

This study addresses the solution to the assembly line balancing problem in a furniture factory. Three different methods were evaluated and compared for solving the problem. These methods are the positional weight, largest candidate, and Kilbridge-Wester methods. In PWM, all predecessor tasks for each task are marked, and the total processing times of these tasks form the location weight of the respective task. Tasks are sorted in descending order of location weights, and as a result, seven stations are determined. In the LCM, tasks are sorted in descending order according to their processing times. The task with the longest processing time is assigned to the first station according to the precedence diagram, and this process is repeated until all tasks are assigned, resulting in seven stations. In the KWM, regions are created in the precedence diagram, considering the predecessors and task times. This process helps determine the workload and tasks. The goal is to distribute the workload evenly across all stations, and as a result, seven stations are determined.

According to the analysis results, PWM is selected as the most suitable method for the line. Using this method, the furniture company, which previously produced a maximum of 112 bed bases during an 8-hour shift, reached a maximum production capacity of 168 bed bases per shift according to the planned arrangement. This study shows an increase of 50%, highlighting the suitability of the chosen method for the company.

This study plays an encouraging role, especially for companies with traditional assembly lines involved in mass production. Additionally, the balancing of the assembly line and the organization of production processes are critical for increasing efficiency and optimizing workflow. The analyses conducted and the methods applied demonstrate how productivity increases and improvements in production capacity can be achieved, creating a model for similar businesses. This study aims to contribute to the development of industry by providing guidance for those wishing to make similar improvements in other industrial facilities. Moreover, it can inspire future research and optimization efforts, enabling companies to gain a competitive advantage.

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