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A Comprehensive Review: Analysing the Pros and Cons of Assembly Line Balancing Methods

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ABSTRACT

Assembly line balancing plays a crucial role in optimizing production efficiency and resource utilization in manufacturing processes. Assembly line balancing helps to counter problems that occurred in the production industry such as uneven task distribution, bottlenecks, idle time, complexity, and time constraints. This review paper provides a comprehensive analysis of different methods used in assembly line balancing. The study includes exact methods, heuristics methods, meta-heuristics methods, simulation approach and queuing concept. The advantages and disadvantages of each method are examined, taking into account factors such as solution quality, computational complexity, flexibility, and applicability to different production environments. The review highlights the strengths and limitations of each method, allowing researchers and practitioners to gain insight into their suitability for specific scenarios depending on different criteria. Overall, this review serves as a valuable resource for understanding the different approaches and choosing appropriate methods to optimize assembly line balance in different manufacturing environments.

1. Introduction

A helpful instrument in the world of manufacturing is line balancing. Line balancing entails allocating a set of operations to assembly stations arranged in a line in accordance with a partial order on the set of operations to produce a finished product item. Line balancing also refers to the process of balancing the production line or any assembly line. The primary goal of line balancing is to divide tasks evenly across workstations in contemplation of reducing man-machine idle time [1]. Line balancing seeks to group facilities or workers in an effective and efficient pattern in the direction of achieving a best possible or most efficient balance of the capacities and flows of the manufacturing

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or assembly processes. Apart from elevating productivity, line balancing also helps in lowering production costs [1,2]. The decision process of assigning tasks to workstations in a continuous production system is commonly referred to as assembly line balancing (ALB). The task consists of the fundamental operations needed to transform raw materials into finished goods. The entire product is divided into several different parts on the assembly line, and each part is assigned to a different workstation. Nevertheless, in what part to perform first must strictly adhere to the precedence flow [3]. Because the item from the previous process is required to begin the next process, the part that should perform first must not process second, and so on. These components are assembled until the fully completed product is created. Each workstation is interconnected together, but their tasks are distinct, and they are carrying them out. This paper specifically focuses on approaches that can be used to enhance and balance the assembly line. Numerous methods for optimizing the assembly line can be found in many available research papers. The methods to improve assembly line balancing such as exact, heuristic, meta-heuristic, simulation approach and queuing concept will be further discussed later in this paper.

2. Terminology and Terms Used in Line Balancing

Before going deeper into the topic, there are a few key terminology and terms that are important to be familiar with in contemplation of understanding line balancing [4,5]. The terms are as below:

i. Cycle Time: The time taken to complete a task, which includes both processing time and any setup or changeover time.
ii. Takt Time: The rate at which products must be produced to meet customer demand, calculated as the total available production time divided by customer demand.
iii. Workstation: A physical location on the production line where tasks are performed.
iv. Task: A specific activity that must be completed in the production process, such as assembling a component or inspecting a product.
v. Precedence Diagram: A graphical representation of the sequence in which tasks must be performed in the production process.
vi. Efficiency: The percentage of time that a workstation is actively working on a task, compared to the total available time.
vii. Balance Delay: The time that a workstation is idle because there are no tasks available to be worked on.
viii. Idle Time: The time that a workstation is not actively working on a task, including both balance delay and any other types of downtime.

3. Types of Assembly Line Balancing

Line balancing can be categorized into 3 main types, which are single-model line balancing, multi-model line balancing and mixed-model line balancing [2,5,6]. Each of these types has its own advantages and disadvantages, consequently choosing the suitable line balancing will be dependent on the specific needs and requirements of the production process.

3.1 Single-Model Line Balancing

Single-model balancing is a process of streamlining the production process of a single product by dividing the manufacturing process into small tasks and then assigning each task to a workstation or worker. In this type of assembly line balancing, a single product is manufactured on the assembly line. The assembly line is designed to manufacture a specific product, and all the tasks required to manufacture the product are distributed in a balanced manner across different workstations. The goal of line balancing for individual models is to balance the workload across different workstations, minimize idle time, and reduce bottlenecks in the production process. Single-model line balancing is commonly used in industries where products are high volume and low variety. Most of the researchers that dealing with single-model line balancing were acknowledged the advantages and disadvantages of this type of line balancing in their research. The advantages and disadvantages of single-model line balancing are represented as below [7-11].

3.1.1 Advantages of single-model line balancing

i. Single-model line balancing can help increase the efficiency of the production process by distributing the workload across different workstations, minimizing idle time and reducing bottlenecks.
ii. Because the production process is optimized, the likelihood of errors and defects is reduced, resulting in higher quality products.
iii. With a single-model production line, training requirements for workers are simplified and new workers can be trained more easily.
iv. By optimizing the production process, single-model line balancing can result in reduced costs due to less time spent on production and reduced inventory levels.

3.1.2 Disadvantages of single-model line balancing

i. Single-model line balancing is not suitable for production lines that require a high degree of flexibility, such as those that produce customized or personalized products.
ii. Since single-model line balancing is designed for the manufacture of a single product, it may not be suitable for companies that need to manufacture a range of products with different characteristics.
iii. Single-model line balancing requires significant investment in production line equipment and facilities, which can present a barrier to entry for small or new businesses.
iv. If the demand for the individual product falls, there is a high risk of unused capacity, which can lead to financial losses for the company.

3.2 Multi-Model Line Balancing

Multi-model line balancing is a process of optimizing the production process of multiple products that have similar manufacturing processes by dividing the manufacturing process into small tasks and then assigning each task to a workstation or worker. In this type of line balancing, multiple products are produced on the same assembly line. The assembly line is designed to produce different products with different characteristics but the same manufacturing process. The tasks required for each product are balanced across different workstations. The goal of multi-model line balancing is to balance the workload across different workstations, minimize idle time, and reduce bottlenecks in the production process. Multi-model line balancing is commonly used in industries where products are low in volume and high in variety. Many researchers working on multi-model line balancing acknowledged the benefits and drawbacks of this method in their studies. Below shows the advantages and disadvantages of multi-model line balancing [7,8,12-14].

3.2.1 Advantages of multi-model line balancing

i. Multi-model line balancing allows more flexibility in the production process by considering multiple products with similar manufacturing processes.
ii. Multi-model line balancing allows a greater variety of products to be manufactured with minimal changes to the manufacturing process.
iii. By accommodating multiple products on the same production line, multi-model line balancing can result in reduced costs due to less time spent on changeovers and reduced inventory levels.
iv. Multi-model line balancing can be helpful in maximizing the use of resources, including equipment and manpower, by spreading the workload across different products.

3.2.2 Disadvantages of multi-model line balancing

i. Multi-model line balancing is more complex than single-model line balancing because it requires managing multiple products and associated processes.
ii. Multi-model line balancing can reduce the efficiency of the production process due to increased changeover time and complexity.
iii. Multi-model line balancing requires additional training requirements for workers as they need to be familiar with the production processes of multiple products.
iv. If the demand for one or more of the products decreases, there is a risk of idle capacity, which can lead to financial losses for the company.

3.3 Mixed-Model Line Balancing

Mixed-model line balancing is a process of streamlining the production process of multiple products with different manufacturing processes by dividing the manufacturing process into small tasks and then assigning each task to a workstation or worker. This type of line balancing is a combination of single-model and multi-model line balancing. The assembly line is designed to produce multiple products with different characteristics and different manufacturing processes. The tasks required for each product are balanced across different workstations. The goal of mixed-model line balancing is to balance the workload across different workstations, minimize idle time, and reduce bottlenecks in the production process. Mixed-model line balancing is commonly used in industries where products have moderate volume and variety. The vast majority of researchers that dealt with mixed-model line balancing recognised the advantages as well as disadvantages of this particular type of line balancing in their findings. The following are the benefits and drawbacks of mixed-model line balancing [7,8,12,15,16].

3.3.1 Advantages of mixed-model line balancing

i. Mixed-model line balancing can help increase the efficiency of the production process by spreading the workload across different workstations, minimizing idle time and reducing bottlenecks.
ii. Mixed-model line balancing allows for a greater variety of products with minimal changes to the manufacturing process.

iii. By accommodating multiple products on the same production line, mixed-model line balancing can result in lower costs due to less time spent on changeovers and reduced inventory levels.
iv. Mixed-model line balancing can help maximize the use of resources, including equipment and manpower, by spreading the workload across different products.

3.3.2 Disadvantages of mixed-model line balancing

i. Mixed-model line balancing is more complex than single model line balancing, as it requires managing multiple products with different manufacturing processes.
ii. Mixed-model line balancing requires additional training requirements for workers, as they need to be familiar with the production processes of multiple products.
iii. Mixed-model line balancing can increase the changeover time required to switch between different products, reducing the efficiency of the production process.
iv. If the demand for one or more of the products decreases, there is a risk of unused capacity, which can lead to financial losses for the company.

Line balancing is a fundamental part of assembly line production that aims to optimise resource use in the manufacturing process. To summaries, the advantages and disadvantages for each of line balancing types can be seen as in Table 1 below:

Table 1
Advantages and disadvantages of single, multi and mixed-model line balancing [2,5-16]

Types of line balancing	Advantages	Disadvantages
Single-model	Increased efficiency Improved quality Simplified training Reduced costs	Limited flexibility Reduced variety High capital costs Increased risk
Multi-model	Increased flexibility Greater variety Lower costs Better resource utilization	Increased complexity Reduced efficiency Training requirements Higher risks
Mixed-model	Increased efficiency Improved variety Lower costs Better resource utilization	Increased complexity Higher training requirements Increased changeover time Higher risk

Overall, the type of line balancing employed depends on the specific requirements of the production process, the volume of production, and the variety of products being manufactured.

4. Methods of Assembly Line Balancing

There are several methods of assembly line balancing including exact methods, heuristics methods, meta-heuristics methods, simulation approaches, and queuing concept methods [1,4,17. Each approach has distinct benefits and drawbacks, and the method used is determined by criteria such as the complexity of the manufacturing process, the size of the production line, and the available resources. Further details for each of the methods are discussed in this section.

4.1 Exact Methods

Exact methods in line balancing refer to mathematical approaches with the help of which line balance problems can be solved exactly and optimally. These methods are based on mathematical models representing the line balancing problem and are solved with algorithms that guarantee that the optimal solution is found [15,18]. Exact methods can be guaranteed to provide optimal solutions, but they are often computationally intensive and require a significant number of computational resources. As such, they are typically used for small to medium sized line balancing problems where the computational requirements are manageable. Some common exact methods that can be used in line balancing are:

i. Integer Linear Programming [19,20]: Integer linear programming (ILP) is a mathematical optimization technique that can be used to model and solve line balancing problems. ILP models the problem as a set of linear equations and inequalities subject to integer constraints.
ii. Branch and Bound [21-23]: Branch and Bound is an algorithmic approach that can be used to solve ILP problems. The problem is recursively divided into smaller sub-problems and each sub-problem is solved separately until the optimal solution is found.
iii. Dynamic programming [24-26]: Dynamic programming is a technique for solving optimization problems, in which the problem is broken down into smaller sub-problems and solved recursively. This technique can be used to solve line balancing problems with specific characteristics such as a single target and a fixed number of workstations.

4.1.1 Advantages and disadvantages of exact methods

The advantages and disadvantages of exact methods can be listed below, which are extracted from established research journals [15,18-26].

4.1.1.1 Advantages of exact methods in line balancing

i. Exact methods can provide a guaranteed optimal solution to the line balancing problem, which can be important in situations where productivity and efficiency are critical.
ii. Exact methods are based on mathematical models, which provide a rigorous framework for solving line balancing problems and allow for precise analysis and interpretation of the results.
iii. Exact methods can be used to solve a variety of line balancing problems, including problems with multiple objectives, constraints, and uncertainties.
iv. Exact methods can be scaled to larger problems with improved computing power and can be used to solve problems of varying size and complexity.

4.1.1.2 Disadvantages of exact methods in line balancing

i. Exact methods can be computationally expensive and require a significant number of computational resources to solve large and complex line balancing problems.
ii. Exact methods are sensitive to changes in problem parameters, such as workstations or the number of tasks, which can affect the computation time required to solve the problem.

iii. Exact methods are typically designed to solve specific types of problems and may not be applicable to all line balancing problems.
iv. Exact methods can be difficult to implement and may require special knowledge and expertise to use effectively.

4.2 Heuristics Methods

Heuristics methods in line balancing are problem-solving techniques that use rules of thumb or practical experience to solve production line balancing problems. These methods are based on practical knowledge and experience rather than mathematical models or algorithms. There are several heuristic methods that can be used in line balancing, including:

i. Largest Candidate Rule [27-29]: With this method, the task with the longest time is selected and assigned to the first workstation. The process is repeated until all tasks are assigned to a workstation.
ii. Shortest processing time rule: With this method, the task with the shortest processing time is selected and assigned to the first workstation. The process is repeated until all tasks are assigned to a workstation.
iii. Fewest Following Tasks Rule: This method selects the task that has the fewest following tasks and assigns it to the first workstation. The process is repeated until all tasks are assigned to a workstation.
iv. Precedence Diagramming Method [30,31]: This method involves creating a diagram that shows the order of tasks and their dependencies. The diagram is then used to determine the optimal workstation assignments.
v. Ranked Positional Weight Method [27,29,32,33]: In this method, tasks are ranked according to their importance and difficulty and then assigned to jobs based on their rank.

4.2.1 Advantages and disadvantages of heuristics methods

The advantages and disadvantages of heuristics methods can be listed below, which are extracted from established research journals [27-33].

4.2.1.1 Advantages of heuristics methods in line balancing

i. Line balancing heuristic methods are relatively simple and easy to use and require less specialized knowledge and training than more complex methods.
ii. Heuristic methods can provide a quick solution to a line balancing problem, which can be useful when time is limited.
iii. Heuristic methods can be adapted to different types of production processes and used in a variety of situations.
iv. Heuristic methods are often inexpensive solutions compared to more complex mathematical models or algorithms.

4.2.1.2 Disadvantages of heuristics methods in line balancing

i. Heuristics may not always provide the optimal solution to a line balancing problem, resulting in reduced efficiency and productivity.
ii. Heuristic methods may not work well in situations involving unexpected disruptions or changes in the production process.
iii. Heuristic methods may be limited in their ability to address more complex production line balancing problems that require more sophisticated approaches.
iv. Heuristic methods rely heavily on the expertise and experience of the person using them, which may lead to inconsistencies in the solutions generated.

4.3 Meta-Heuristics Methods

Meta-heuristic methods in line balancing are problem-solving techniques used to find high-quality solutions to complex optimization problems. Meta-heuristic methods are typically used when the problem to be solved is difficult to solve using exact methods, such as mathematical models or algorithms. Meta-heuristic methods work by generating a set of candidate solutions and then using an iterative process to improve on those solutions until an optimal solution is found. This process includes evaluating the suitability of each candidate solution, making changes to the solutions, and then evaluating the suitability of the modified solutions. Some common meta-heuristic methods that can be used in line fitting include:

i. Genetic Algorithms [10,34-36]: Genetic algorithms mimic the process of natural selection to find an optimal solution. This involves creating a population of potential solutions, choosing the most appropriate solutions, and combining them again to create new solution candidates.
ii. Simulated Annealing [11,37,38]: Simulated annealing is based on the process of annealing in metallurgy, in which a metal is heated and then slowly cooled to make it more resistant to stress. This method involves starting with an initial solution and then making random changes to the solution, gradually reducing the magnitude of the changes over time.
iii. Tabu Search [37,39,40]: Tabu search involves creating a set of forbidden moves or actions, and then using a neighbourhood search process to move from one solution to another. The forbidden moves prevent the algorithm from getting stuck in local optima.
iv. Ant Colony Optimization [41-43]: Ant colony optimization is based on the behaviour of ants when foraging. This method involves creating a population of ants searching for a solution to the problem, and then using pheromones to direct the search process.

4.3.1 Advantages and disadvantages of meta-heuristics methods

The advantages and disadvantages of meta-heuristics methods can be listed below, which are extracted from established research journals [10,11,34-43].

4.3.1.1 Advantages of meta-heuristics methods in line balancing

i. Meta-heuristic methods can provide high-quality solutions to complex line-balancing problems that may be difficult to solve using other methods.

ii. Meta-heuristic methods can be adapted to different types of production processes and can be used in a variety of situations.
iii. Meta-heuristic methods are typically robust against unexpected disruptions or changes in the production process, which can be an advantage in real-world situations.
iv. Meta-heuristic methods can search the entire solution space to find optimal solutions in large and complex solution spaces.

4.3.1.2 Disadvantages of meta-heuristics methods in line balancing

i. Meta-heuristics methods can be computationally intensive and require a significant amount of computing resources to solve complex problems.
ii. Meta-heuristics methods may converge to sub-optimal solutions if the parameters are not properly set or if the algorithm gets trapped in local optima.
iii. Meta-heuristics methods may require significant parameter tuning and experimentation to find the optimal solution.
iv. Meta-heuristics methods can be difficult to interpret and may not provide insight into the underlying structure of the problem being solved.

4.4 Simulation Approach

The simulation approach to line balancing involves the use of computer-aided simulations to analyse production line performance under various line balancing scenarios. This approach creates a computer model that simulates the production line and allows experimentation with different line balancing configurations. The simulation approach can be used to evaluate production line performance such as throughput, cycle time, and work centre utilization under various line balancing scenarios. It can also be used to compare the performance of different line balancing methods and identify the optimal line balancing configuration. The simulation approach can be particularly useful in situations where the line balancing problem is complex and difficult to model mathematically. It can also be used to study the impact of uncertain factors such as variations in processing times or machine failures on production line performance. There are several simulation approaches used in assembly line balancing. Here are some simulation approaches that applied in assembly line balancing:

i. Discrete-event simulation [12,44,45]: In this method, the production line is modelled as a series of discrete events or activities, such as task completion times, setup times and transfer times, and the system simulates to identify bottlenecks and inefficiencies.
ii. Monte Carlo simulation [46-48]: This method uses random sampling and probability distributions to simulate different scenarios and estimate the likelihood of outcomes, which can optimize the balance of the production line.
iii. Agent-based simulation [49,50]: This method models individual workers or machines as autonomous agents that interact with each other and with the production environment, allowing complex interactions and dependencies within the assembly line to be studied.
iv. System dynamics simulation: This method models the behaviour of the production system as a dynamic system, considering factors such as feedback loops, delays, and changes over time to optimize line balance.

Discrete event simulation is the most common approach used in assembly line balancing. Discrete event simulation allows analysts to model the impact of changes to the assembly line, such as changes in cycle times, staffing levels, or equipment capacity. It can also be used to identify bottlenecks on the assembly line and to assess the impact of different balancing strategies. There are several simulation software packages that are commonly used to solve balancing problems and studies on the assembly line, including Arena [45,51,52], FlexSim [12,53,54], Simio [55-57], Promodel [58-60], AnyLogic [61,62], Plant Simulation [63,64], and Witness [65-68].

4.4.1 Advantages and disadvantages of simulation approach

The advantages and disadvantages of simulation approach methods can be listed below, which are extracted from established research journals [12,44-68].

4.4.1.1 Advantages of simulation approach in line balancing

i. Simulation approaches can be adapted to different types of production processes and used to simulate a variety of scenarios.
ii. The simulation approach allows for realistic modelling of the production line, considering factors such as machine breakdowns, variations in processing times and worker fatigue.
iii. Simulation approach can be less expensive than physical experimentation and can be used to test different line balancing scenarios without disrupting the production process.
iv. Simulation approach can be used to collect data on key performance indicators, such as cycle time and throughput, which can be used to optimize the line balancing configuration.

4.4.1.2 Disadvantages of simulation approach in line balancing

i. Creating a simulation model can be complex and require specialized knowledge and expertise.
ii. The simulation approach can be time consuming, especially when simulating large and complex production lines.
iii. Simulation models often make assumptions and simplifications that may not reflect the real production process, leading to potential inaccuracies in the results.
iv. Simulation models may require calibration based on real data, which can be time consuming and require significant resources.

4.5 Queuing Concept

The queuing concept method in line balancing is a mathematical approach to analysing the performance of production lines [69]. This method is based on queuing theory, a branch of mathematics that studies the behaviour of queues [70]. In the queuing concept method, the production line is viewed as a series of interconnected queues where tasks arrive randomly and are processed by the workstations [71]. The queuing concept method allows to analyse the performance of the production line under different line balancing scenarios, such as the number of workstations, the assignment of tasks to workstations and the sequencing of tasks [72-74]. The queuing concept method can be used to analyse various key performance indicators, such as average wait time, average queue length, and workstation occupancy [75,76]. By analysing these measures, the queuing concept method can be used to identify the optimal line balancing configuration.

4.5.1 Advantages and disadvantages of queuing concept

The advantages and disadvantages of queuing concept methods can be listed below, which are extracted from established research journals [69-76].

4.5.1.1 Advantages of queuing approach in line balancing

i. The queuing concept method is based on mathematical models that provide a rigorous framework for analysing production line performance.
ii. The queuing concept method can be used to analyse various types of production lines, such as single-product or multi-product lines.
iii. The queuing concept method can provide quick and efficient solutions to line balancing problems.
iv. The queuing concept method can be used to analyse the impact of different line balancing scenarios, such as varying the number of workstations, allocation of tasks, and sequencing of tasks.

4.5.1.2 Disadvantages of queuing approach in line balancing

i. The queuing concept method can be complex, particularly when analysing large and complex production lines.
ii. The queuing concept method requires data on the arrival rate of tasks and the processing time of each workstation, which may not be readily available.
iii. The queuing concept method relies on assumptions and simplifications that may not reflect the real-world production process, leading to potential inaccuracies in the results.
iv. The queuing concept method can be sensitive to changes in model parameters, such as the arrival rate of tasks, which can affect the accuracy of the results.

Based on all methods discussed above, the advantages and disadvantages for each of the methods can be summaries into Table 2 below.

Table 2
Advantages and disadvantages of assembly line balancing methods

Method of Line Balancing	Advantages	Disadvantages
Exact methods	Guaranteed optimal solution Mathematical rigor Flexibility Scalability	Computationally intensive Sensitivity to problem parameters Limited to specific problem types Difficult to implement
Heuristics methods	Simplicity Speed Flexibility Low cost	Sub-optimal solutions Lack of robustness Limited scope Reliance on human expertise
Meta-heuristics methods	High-quality solutions Flexibility Robustness Global search capability	Computationally intensive Convergence to sub-optimal solutions Tuning requirements Lack of transparency
Simulation approach	Flexibility Realistic modelling Low cost Data collection	Model complexity Time-consuming Assumptions and simplifications Calibration

Queuing concept	Mathematical rigor Versatility Efficiency Flexibility	Complexity Data requirements Assumptions and simplifications Sensitivity to model parameters

5. Method of Selection for Assembly Line Balancing Analysis

The selection of the method for assembly line balancing depends on the particular requirements of the production process and the resources available for analysis. When choosing the method for assembly line balancing, it is crucial to thoroughly examine the production process, consider the resources at hand, and account for time restrictions. The suitable method of assembly line balancing for an industry depends on various factors such as the size and complexity of the production process, available resources, and the desired level of optimization.

The most accurate method in assembly line balancing is the exact method, which is a rigorous mathematical approach that guarantees the optimal solution to the problem. However, exact methods can be computationally intensive and may not be practical for large and complex problems. In practice and in industry point of view, the most common methods used for assembly line balancing are heuristics methods and simulation approaches. In addition to that, a combination of methods is also being applied, such as heuristics and metaheuristics to quickly identify promising solutions, followed by an exact method to verify the optimal solution depending on the size of the production process.

For small to medium-sized production processes, heuristics methods such as the largest candidate rule, the shortest processing time rule, or the most follower's rule can be suitable. In the meantime, for large and complex production processes, a combination of heuristics and metaheuristics methods can be used. Concurrently, for industries with a high degree of variability in the products produced, simulation approaches can be applicable.

Each of these methods serves different purpose and role to the industry. Heuristics methods are often used because they can quickly provide a reasonable solution to a line balancing problem, which can be refined further if necessary. These methods are quick to implement and can provide a reasonable solution to the line balancing problem. On the other hand, meta-heuristics methods such as genetic algorithms, simulated annealing, and tabu search can quickly identify promising solutions to the problem, which can be refined further using an exact method. Additionally, simulation approaches can be used to evaluate the performance of different line balancing strategies before implementing them in a real-world setting. This allows companies to test different line balancing strategies before implementing them in a real-world setting, which can be time-consuming and costly. Simulation approaches can also provide valuable insights into the performance of the assembly line under different conditions, which can help companies optimize their operations and improve their productivity.

Overall, the most suitable method of assembly line balancing for an industry will depend on the specific characteristics of the production process and the goals of the company.

6. Conclusion

The literature highlights the implications of different assembly line balancing methods such as exact method, heuristic method, meta-heuristic method, simulation approach and queuing concept for the world ideal solution. According to assembly line balancing research, assembly lines are assembly line production systems, which are consisting of a series of workstations where interchangeable parts are added to a product. The product moves along the line from one workstation to the next and is finished when it leaves the last workstation. It was also found that the equipment cost, cycle time, task time to equipment cost ratio, and flexibility ratio required special consideration. It is important to choose the most appropriate method based on the specific needs, constraints, and goals of the assembly line balancing problem. When choosing the method, factors such as the complexity of the problem, data availability and limitations, computational resources, and time constraints should be considered. In addition, a combination of methods or hybrid approaches can be explored to leverage the strengths of different techniques. The integration of new technologies such as artificial intelligence and machine learning can be explored to improve the capabilities of assembly line balancing methods and address new challenges in the manufacturing industry.

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