Multi-Criteria Decision Analysis for Optimal Production Schedule Choice

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Abstract

The aim of this study is to present a structured approach for selecting the optimal production schedule using Multi-Criteria Decision Analysis (MCDA) with the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). In modern manufacturing environments, production scheduling involves multiple conflicting objectives, and traditional single-objective optimization techniques are often inadequate for addressing these complexities. To overcome this limitation, the scheduling problem is formulated as a multi-criteria decision-making task, where several feasible production schedules (Schedule 1, Schedule 2, Schedule 3, Schedule 4 and Schedule 5) are evaluated simultaneously based on four (4) selected performance criteria namely: production cost, production time, product quality and resource utilization, with preference weights of 0.3, 0.25, 0.25 and 0.2 respectively. The results indicated that Schedule 2 is the best alternative because it has the highest total net flows of 0.325, followed by Schedule 1, which has total net flows of 0.10625. Next is Schedule 3, which has total net flows of 0.05625, followed by Schedule 4, having total net flows of -0.08125, and finally, Schedule 5, which is the worst ranking alternative, having total net flows of -0.3125. Therefore, PROMETHEE proved to be a viable multi-criteria decision-making tool for selecting the most suitable production schedule among the group of alternatives. This study is significant because it provides a procedure for aiding supply chain managers in selecting the best alternative among a group of similar alternatives using PROMETHEE.

Keywords: *Production Scheduling; Manufacturing; Multi-criteria decision analysis (MCDA); PROMETHEE*

INTRODUCTION

Production scheduling is a critical function in manufacturing and industrial systems, directly influencing productivity, resource utilization, delivery performance, and overall operational efficiency (Khan *et al.*, 2026; Yin *et al.*, 2026). In increasingly competitive and dynamic environments, organizations are required to make complex decisions regarding the selection of optimal production schedules under multiple, often conflicting criteria. Traditional scheduling approaches typically focus on single-objective optimization, such as minimizing production time or maximizing machine utilization. However, real-world production systems involve multiple performance indicators—including cost, time, quality, flexibility, and energy consumption—necessitating more comprehensive decision-making frameworks (Shi *et al.*, 2026; Tavana *et al.*, 2026). This complexity has led to the growing adoption of Multi-Criteria Decision Analysis (MCDA) techniques for evaluating and selecting the most suitable production schedules.

MCDA provides a structured methodology for analyzing decision problems that involve multiple criteria, enabling decision-makers to incorporate both quantitative and qualitative factors into the evaluation process (Wofuru-Nyenke, 2023a, 2024b). Unlike classical optimization methods, MCDA does not seek a single optimal solution based on a single objective; rather, it facilitates the ranking or selection of alternatives based on their overall performance across several criteria (Shende and Popov, 2026; Xu *et al.*, 2026). This is particularly relevant in production scheduling, where trade-offs are inevitable—for example, a schedule that minimizes production time may incur higher costs or reduce product quality. By integrating diverse criteria into a unified framework, MCDA enhances the robustness and transparency of decision-making.

Among the various MCDA techniques, the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) has gained significant attention due to its simplicity, flexibility, and effectiveness in handling complex decision problems. PROMETHEE is an outranking method that compares alternatives pairwise based on preference functions defined for each criterion (Wofuru-Nyenke, 2024a). It enables the decision-maker to express the degree of preference of one alternative over another, considering the importance (weights) of different criteria. The method produces a partial or complete ranking of alternatives through the computation of positive and negative preference flows, ultimately leading to a net flow score that reflects the overall desirability of each option. The application of PROMETHEE in production scheduling is particularly advantageous because it accommodates both qualitative judgments and quantitative data, while also allowing for the incorporation of decision-maker preferences. For instance, criteria such as production cost, completion time, machine idle time, energy consumption, and reliability can be simultaneously evaluated. This makes it a powerful tool for decision support in manufacturing environments characterized by uncertainty and multiple stakeholders.

In recent years, the integration of MCDA methods like PROMETHEE into production scheduling has become increasingly relevant due to the rise of smart manufacturing and Industry 4.0 (Aoufi and Aksa, 2025; Elattar and ELWakil, 2026; Okpala *et al.*, 2026; Wofuru-Nyenke, 2021a). Advanced production systems now generate large volumes of data, enabling more informed and data-driven decision-making (Wofuru-Nyenke, 2023b; Wofuru-Nyenke *et al.*, 2023). However, the abundance of data also introduces complexity, as decision-makers must evaluate numerous scheduling alternatives under varying conditions. MCDA frameworks help to manage this complexity by systematically structuring the decision problem, assigning appropriate weights to criteria, and providing clear rankings of alternatives. Furthermore, the need for sustainable manufacturing practices has introduced additional criteria into production scheduling decisions, such as environmental impact and energy efficiency (Igbokwe *et al.*, 2026; Okpala, 2026; Okpala and Okpala, 2026; Wofuru-Nyenke, 2021b; Wofuru-Nyenke *et al.*, 2019). Traditional scheduling models often overlook these aspects, focusing primarily on economic objectives. MCDA approaches, particularly PROMETHEE, offer the flexibility to incorporate sustainability-related criteria alongside conventional performance measures. This aligns production scheduling decisions with broader organizational goals, including environmental responsibility and long-term sustainability.

Despite its advantages, the successful application of PROMETHEE in production scheduling depends on careful selection of criteria, appropriate determination of weights, and the choice of suitable preference functions. These elements require expert judgment and may introduce subjectivity into the decision-making process (Agrawal, 2022; Sarwar *et al.*, 2022). Nevertheless, when properly implemented, PROMETHEE provides a transparent and systematic approach for evaluating complex scheduling alternatives, reducing ambiguity and improving decision quality. This study focuses on the application of MCDA, specifically the PROMETHEE method, for selecting the optimal production schedule among multiple alternatives. By considering a comprehensive set of criteria relevant to modern manufacturing systems, the research aims to demonstrate the effectiveness of PROMETHEE in supporting informed and balanced decision-making. The approach not only enhances the evaluation of production schedules but also contributes to improved operational performance and strategic alignment in industrial systems. The main aim of this study is to utilize PROMETHEE for selecting the best production schedule from a group of similar alternatives. PROMETHEE provides the decision maker with a ranking of alternatives based on global or total net flows. The following sections describe the underlying equations of PROMETHEE, and the results of applying the equations to the production schedule selection problem.

METHODOLOGY

In the PROMETHEE method, alternatives are pairwise compared in order to find the most appropriate alternative. The set of alternatives to be ranked is denoted by $A = \{a_1, a_2, \cdots, a_n\}$ and the set of criteria is denoted by $F = \{f_1, f_2, \cdots, f_m\}$. Also, denoting the evaluation of alternative a_j on criterion f_i by $f_i(a_j)$ and assuming that $f_i(a_j)$ is a numeric value. A preference matrix is generated from the data and is used in calculating the global flows. The global pairwise preference degrees computed between all the ordered pairs of alternatives constitute the preference matrix. The global preference degrees are obtained from the criterion preference degrees by means of the weighted sum and provide the basis for deducing the global flows.

Unicriterion Preference Degrees

The unicriterion preference degree P_{ij}^k, which can also be denoted as $P_k(a_i, a_j)$, is calculated for each ordered pair of alternatives (a_i, a_j). This unicriterion preference degree, P_{ij}^k, depicts how much more preferred alternative a_i is to a_j based solely on criterion f_k. P_{ij}^k will be a number between 0 and 1, and is a function of $f_k(a_i) - f_k(a_j)$, the more this difference, the stronger the unicriterion preference degree. A choice between three different types of preference functions has to be made by the decision maker, which in turn determines the preference degree. Considering the linear preference function with q as the indifference threshold and p as the preference threshold, the equation for the unicriterion preference degree is given by (Brans *et al.*, 2005; Brans and Vincke, 1985) :

$$P_{ij}^k = \begin{cases} 0 & \text{if} \quad f_k(a_i) - f_k(a_j) \le q \\ \frac{[f_k(a_i) - f_k(a_j) - q]}{[p-q]} & \text{if } q < f_k(a_i) - f_k(a_j) < p \\ 1 & \text{if} \quad f_k(a_i) - f_k(a_j) \ge p \end{cases} \quad (1)$$

However, if a Gaussian preference function is considered, the equation for the unicriterion preference degree is given by (Ishizaka and Nemery, 2013):

$$P_{ij}^k = \begin{cases} 1 - \exp\left(\frac{-\left(f_k(a_i) - f_k(a_j)\right)^2}{2s^2}\right) & \text{if } f_k(a_i) - f_k(a_j) \ge 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where s is the inflexion point. P_{ij}^k and P_{ji}^k are not symmetric numbers but respect the condition $0 \le P_{ij}^k + P_{ji}^k \le 1$.

Global Preference Degree

After calculating the ordered unicriterion preference degrees, the global preference degree, π_{ij}, can be computed taking the weights of each criterion into account. Denoting w_k as the weight associated to criterion f_k. If the weight respects the condition $\sum_{k=1}^{q} w_k=1$, then the global preference degree of alternative a_i on a_j is given by (Ishizaka and Nemery, 2013):

$$\pi(a_i, a_j) = \pi_{ij} = \sum_{k=1}^{q} w_j \cdot P_{ij}^k \quad (3)$$

where w_j is the weight of a criterion j, and P_{ij}^k is the unicriterion preference degree. This global preference degree lies between 0 and 1, and respects the constraint $0 \le \pi_{ij} + \pi_{ji} \le 1$. Therefore, $\forall i: \pi_{ii} = 0$.

Global Flows

The ordered preference degrees are summarized into a unique score for each alternative, using the positive and negative flows. Denoting by $\Phi^+(a_i)$ the positive flows of alternative a_i and $\Phi^-(a_i)$ the negative flows of alternative a_i. Their values can be computed as follows (Ishizaka and Nemery, 2013):

$$\Phi^+(a_i) = \frac{\sum_{j=1}^{n} \pi_{ij}}{n-1} \quad (4)$$

$$\Phi^-(a_i) = \frac{\sum_{j=1}^{n} \pi_{ji}}{n-1} \quad (5)$$

where π_{ij} is the global preference degree of alternative a_i on a_j, and π_{ji} is the global preference degree of alternative a_j on a_i.

Net Flows

The net flows, $\Phi(a_i)$, summarizes the positive and negative flows with one formula, given by (Ishizaka and Nemery, 2013):

$$\Phi(a_i) = \Phi^+(a_i) - \Phi^-(a_i) \quad (6)$$

where $\Phi^+(a_i)$ is the positive flows of alternative a_i and $\Phi^-(a_i)$ is the negative flows of alternative a_i. The net flow is a number between -1 and 1. The higher this number is, the better the alternative will be.

RESULTS AND DISCUSSION

In this section, the results of applying the PROMETHEE method to the production schedule choice problem are presented. The objective is to rank five (5) different production schedule alternatives based on four (4) criteria, namely: production cost, production time, product quality, and resource utilization. The production cost refers to the total expenses incurred in manufacturing products using a particular production schedule. The production time refers to the total duration required to manufacture products using a particular production schedule. The product quality refers to the degree to which a product meets industry standards. Resource utilization is the degree to which the production schedule utilizes staff and equipment against its total capacity. The cost criterion is to be minimized, the time criterion is to be minimized, the product quality criterion is to be maximized, and the resource utilization criterion is to be maximized for each of the production schedule alternatives. Table 1 shows the raw performance data of the various production schedules and the selection criteria.

Table 1: Performance of the five (5) production schedules evaluated on four (4) criteria.

	Cost (₦)	Time (s)	Product Quality (%)	Resource Utilization (%)
Objective	**MIN**	**MIN**	**MAX**	**MAX**
Schedule 1	50,000,000	432,000	80	50
Schedule 2	40,000,000	604,800	60	80
Schedule 3	45,000,000	345,600	75	60
Schedule 4	60,000,000	259,200	95	50
Schedule 5	55,000,000	518,400	85	40

Table 2: Criteria preference parameters.

Criterion	Function	Weight (w_i)	Indifference Threshold (q_i)	Preference Threshold (p_i)
Cost	Linear	0.3	4,000,000	7,000,000
Time	Linear	0.25	30,000	70,000
Product Quality	Linear	0.25	10	20
Resource Utilization	Linear	0.2	10	20

Table 2 shows the weight, indifference threshold and preference threshold for all the criteria. From Table 2, the cost criterion has a linear preference function, a weight of 0.3, an indifference threshold of 4,000,000, and a preference threshold of 7,000,000. Also, the time criterion has a linear preference function, a weight of 0.25, an indifference threshold of 30,000, and a preference threshold of 70,000. Furthermore, the product quality criterion has a linear preference function, a weight of 0.25, an indifference threshold of 10 and a preference threshold of 20. Moreover, the resource utilization criterion has a linear preference function, a weight of 0.2, an indifference threshold of 10 and a preference threshold of 20.

Table 3 shows the differences between evaluations of the production schedules on the cost criterion. From Table 3, considering the cost criterion which has to be minimized, all

Table 3: Differences between evaluations of the production schedules on cost criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	10000000	5000000	-10000000	-5000000
Schedule 2	-10000000	0	-5000000	-20000000	-15000000
Schedule 3	-5000000	5000000	0	-15000000	-10000000
Schedule 4	10000000	20000000	15000000	0	5000000
Schedule 5	5000000	15000000	10000000	-5000000	0

Table 4: Differences between evaluations of the production schedules on time criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	-172800	86400	172800	-86400
Schedule 2	172800	0	259200	345600	86400
Schedule 3	-86400	-259200	0	86400	-172800
Schedule 4	-172800	-345600	-86400	0	-259200
Schedule 5	86400	-86400	172800	259200	0

Table 5: Differences between evaluations of the production schedules on product quality criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	15	35	20	10
Schedule 2	-15	0	20	5	-5
Schedule 3	-35	-20	0	-15	-25
Schedule 4	-20	-5	15	0	-10
Schedule 5	-10	5	25	10	0

Table 6: Differences between evaluations of the production schedules on resource utilization criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	-30	-10	0	10
Schedule 2	30	0	20	30	40
Schedule 3	10	-20	0	10	20
Schedule 4	0	-30	-10	0	10
Schedule 5	-10	-40	-20	-10	0

production schedules compared with themselves result in a difference of 0. Schedule 1 compared with Schedule 2 results in a difference of 10000000. Schedule 1 compared with Schedule 3 results in a difference of 500000. Schedule 1 compared with Schedule 4 results in a difference of 10000000. Finally, Schedule 1 compared with Schedule 5 results in a difference of 5000000.

Table 4 shows the differences between evaluations of the schedules on the time criterion. From Table 4, considering the time criterion which has to be minimized, all schedules compared with themselves result in a difference of 0. Schedule 1 compared with Schedule 2 results in a difference of 172800. Schedule 1 compared with Schedule 3 results in a difference of 86400. Schedule 1 compared with Schedule 4 results in a difference of 172800. Finally, Schedule 1 compared with Schedule 5 results in a difference of 86400.

Table 5 shows the differences between evaluations of the schedules on the product quality criterion. From Table 5, considering the product quality criterion which has to be maximized, all schedules compared with themselves result in a difference of 0. Schedule 1 compared with Schedule 2 results in a difference of 15. Schedule 1 compared with Schedule 3 results in a difference of 35. Schedule 1 compared with Schedule 4 results in a difference of 20. Finally, Schedule 1 compared with Schedule 5 results in a difference of 4800. Table 6 shows the differences between evaluations of the schedules on the resource utilization criterion.

From Table 6, considering the resource utilization criterion which has to be maximized, all schedules compared with themselves result in a difference of 0. Schedule 1 compared with Schedule 2 results in a difference of 200. Schedule 1 compared with Schedule 3 results in a difference of 500. Schedule 1 compared with Schedule 4 results in a difference of 0. Finally, Schedule 1 compared with Schedule 5 results in a difference of 10. Table 7 shows the pairwise comparison matrix for the cost criterion.

From Table 7, comparing the differences with the preference and indifference thresholds based on the cost criterion, Schedule 1 has a preference degree of 1 over Schedule 4, and a preference degree of 0.333333333 over Schedule 5. Moreover, the preference degrees of Schedule 2 over Schedule 1, Schedule 3, Schedule 4 and Schedule 5 are 1, 0.333333333, 1, and 1. The preference degrees of Schedule 3 over Schedule 1, Schedule 4, and Schedule 5 are 0.333333333, 1, and 1. The preference degree of Schedule 5 over Schedule 4 is 0.333333333. This means that based on the cost criterion, Schedule 2 and Schedule 3 are preferred over Schedule 1, Schedule 4 and Schedule 5.

Table 8 shows the pairwise comparison matrix for the time criterion. From Table 8, comparing the differences with the preference and indifference thresholds based on the time criterion, Schedule 1 has a preference degree of 1 over each of Schedule 2, and Schedule 5. Moreover, the preference degree of Schedule 3 over Schedule 1, Schedule 2, and Schedule 5 is 1. Again, the preference degree of Schedule 3 over Schedule 1, Schedule 2 and Schedule 5 is 1. Furthermore, the preference degree of Schedule 4 over Schedule 1, Schedule 2, Schedule 3 and Schedule 5 is 1. This means that based on the time criterion, Schedule 4 is preferred.

Table 9 shows the pairwise comparison matrix for the product quality criterion. From Table 9, comparing the differences with the preference and indifference thresholds based on the product quality criterion, when the preference degree is 0, it

Table 7: Pairwise comparison matrix for the cost criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	0	0	1	0.333333333
Schedule 2	1	0	0.333333333	1	1
Schedule 3	0.333333333	0	0	1	1
Schedule 4	0	0	0	0	0
Schedule 5	0	0	0	0.333333333	0

Table 8: Pairwise comparison matrix for the time criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	1	0	0	1
Schedule 2	0	0	0	0	0
Schedule 3	1	1	0	0	1
Schedule 4	1	1	1	0	1
Schedule 5	0	1	0	0	0

Table 9: Pairwise comparison matrix for the product quality criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	0.5	1	1	0
Schedule 2	0	0	1	0	0
Schedule 3	0	0	0	0	0
Schedule 4	0	0	0.5	0	0
Schedule 5	0	0	1	0	0

Table 10: Pairwise comparison matrix for the resource utilization criterion.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	0	0	0	0
Schedule 2	1	0	1	1	1
Schedule 3	0	0	0	0	1
Schedule 4	0	0	0	0	0
Schedule 5	0	0	0	0	0

Table 11: Pairwise preference matrix.

	Schedule 1	Schedule 2	Schedule 3	Schedule 4	Schedule 5
Schedule 1	0	0.375	0.25	0.55	0.35
Schedule 2	0.5	0	0.55	0.5	0.5
Schedule 3	0.35	0.25	0	0.3	0.75
Schedule 4	0.25	0.25	0.375	0	0.25
Schedule 5	0	0.25	0.25	0.1	0

indicates that the difference in product quality is lower than the indifference threshold, and there is no difference between the two production schedules being compared. On the other hand, when the preference degree is 1, it indicates that the difference between the two production schedules being compared is greater than the preference threshold; therefore, there is a difference between the two schedules being compared.

Table 10 shows the pairwise comparison matrix for the resource utilization criterion. From Table 10, comparing the differences with the preference and indifference thresholds based on the resource utilization criterion, when the preference degree is 0, it indicates that the difference in resource utilization is lower than the indifference threshold, and there is no difference between the two production schedules being compared. When the preference degree is between 0 and 1, it implies that the difference between the production schedules being compared is between the indifference and preference thresholds. On the other hand, when the preference degree is 1, it indicates that the difference between the two production schedules being compared is greater than the preference threshold; therefore, there is a difference between the two production schedules being compared.

Table 11 shows the pairwise preference matrix considering all the criteria and their weights. From Table 11, the total positive flows, total negative flows and total net flows for each production schedule were calculated, and these data are shown in Table 12. From Table 12, the total positive flows were calculated by averaging all the row preference degrees of a production schedule compared to other production schedules, excluding the preference degree of the production

Table 12: Total positive flows, total negative flows and total net flows.

Production Schedules	Total Positive Flows	Total Negative Flows	Total Net Flows
Schedule 1	0.38125	0.275	0.10625
Schedule 2	0.5125	0.28125	0.23125
Schedule 3	0.4125	0.35625	0.05625
Schedule 4	0.28125	0.3625	-0.08125
Schedule 5	0.15	0.4625	-0.3125

schedule compared with itself. The total negative flows were calculated by averaging all the column preference degrees of a production schedule, excluding the preference degree on the diagonal. The total net flows were obtained by subtracting the negative flows from the positive flows.

Fig. 1 is a plot of total net flows versus production schedule type, and it shows the ranking of the production schedules based on the total net flows. From Fig.1, Schedule 2 is the best alternative because it has the highest total net flows of 0.10625, followed by Schedule 1, which has total net flows of 0.23125. Next is Schedule 3, which has total net flows of 0.05625, followed by Schedule 4, having total net flows of -0.08125, and finally, Schedule 5, which is the worst ranking alternative, having total net flows of -0.3125. This provides the ranking of the various production schedules under consideration based on production cost, production time, product quality and resource utilization criteria having linear preference functions.

CONCLUSION

In conclusion, this study has demonstrated the effectiveness of Multi-Criteria Decision Analysis (MCDA), specifically the PROMETHEE method, as a robust framework for selecting optimal production schedules in complex manufacturing environments. Unlike traditional single-objective scheduling approaches, the MCDA-based model accommodates multiple, often conflicting criteria, enabling a more comprehensive and realistic evaluation of scheduling alternatives. By incorporating factors such as cost, completion time, machine utilization, quality, and other relevant performance indicators, the approach ensures that decision-making aligns with both operational and strategic objectives. The application of PROMETHEE provides a systematic and transparent ranking of production schedules through the use of preference functions and weighted criteria. The computation of positive, negative, and net preference flows allows decision-makers to clearly identify the strengths and weaknesses of each alternative, facilitating informed and balanced choices. Furthermore, the flexibility of the method makes it suitable for integrating both quantitative data and qualitative judgments, which is essential in real-world production scenarios characterized by uncertainty and diverse stakeholder interests.

The findings of this study highlight that the PROMETHEE-based MCDA approach not only improves decision quality but also enhances the efficiency and responsiveness of production systems. It enables organizations to better manage trade-offs, optimize resource utilization, and adapt to dynamic production requirements. The scheduling problem was formulated as a multi-criteria decision-making task, where several feasible production schedules (Schedule 1, Schedule 2, Schedule 3, Schedule 4 and Schedule 5) were evaluated simultaneously based on four (4) selected performance criteria namely: production cost, production time, product quality and resource utilization, with preference weights of 0.3, 0.25, 0.25 and 0.2 respectively. The results

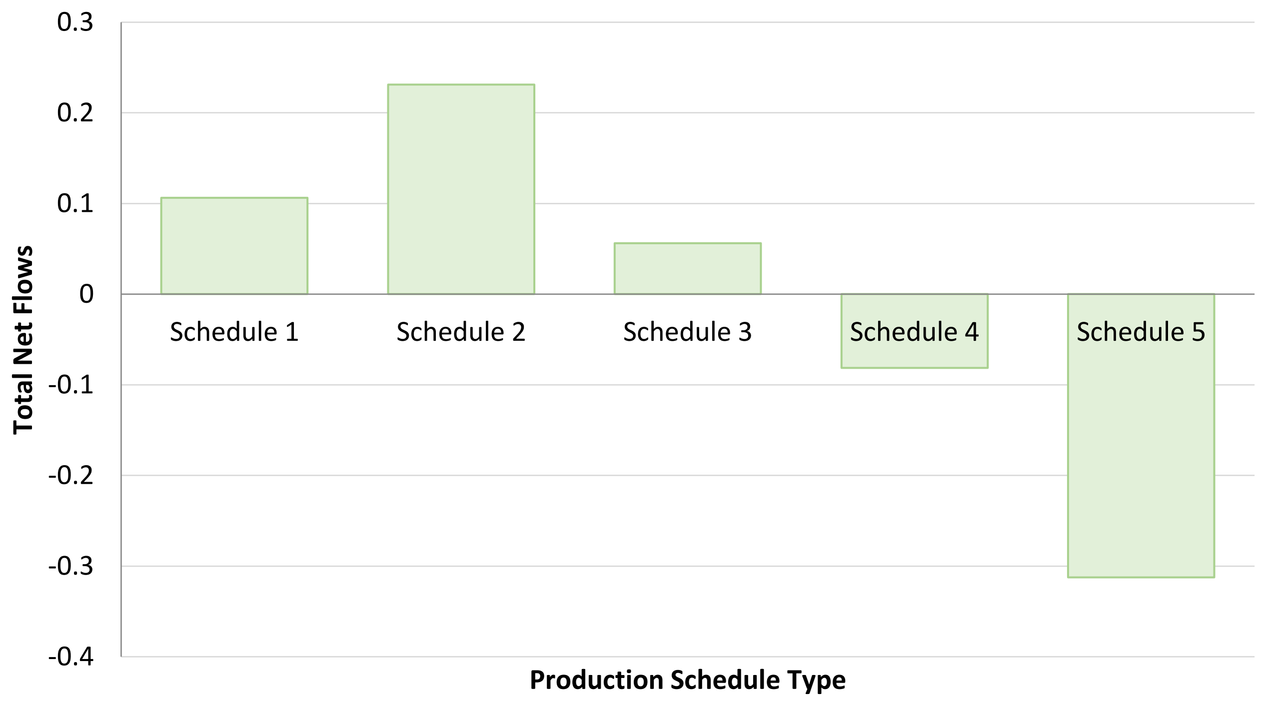

Fig. 1: Plot of total net flows versus production schedule type.

indicated that Schedule 2 is the best alternative because it has the highest total net flows of 0.325, followed by Schedule 1, which has total net flows of 0.10625. Next is Schedule 3, which has total net flows of 0.05625, followed by Schedule 4, having total net flows of -0.08125, and finally, Schedule 5, which is the worst ranking alternative, having total net flows of -0.3125. Additionally, the framework can be extended to incorporate emerging considerations such as energy efficiency and environmental sustainability, further increasing its relevance in modern manufacturing contexts. However, the effectiveness of the approach depends on the careful selection of evaluation criteria, the appropriate assignment of weights, and the definition of suitable preference functions. Future research may focus on integrating objective weighting techniques, hybrid MCDA models, or artificial intelligence methods to further enhance decision accuracy. Overall, the integration of MCDA and PROMETHEE into production scheduling represents a valuable advancement in decision support systems, offering a practical and scalable solution for optimizing production performance in increasingly complex industrial environments.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

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