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A fuzzy MCDM and simulation approach for traffic flow enhancement

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Abstract

Irbid city faces numerous traffic challenges, especially at intersections and traffic circles which are realized as the most problematic areas. This issue could be explained due to continuous development of private vehicle ownership, rapid urbanization and inadequate infrastructure of transportation. The main aim of this study is to discover cost effective and practical solutions for enhancing traffic flow through developing the road networks efficiency, particularly at of the most congested roundabouts in Irbid City. This study integrated MCDM technique, particularly Fuzzy VIKOR and Fuzzy FUCOM, with simulation methodology for the purposes of enhancing traffic flow. The main reason behind employing simulation-based approach is to examine solution efficiency prior to real-world application, in the way that support data-driven decision making. Whereas MCDM is used for solutions ranking based on specific criteria. After that, diverse solutions scenarios were modeled and tested using VISSIM simulation tool. The study results clarified the superiority of the Transit Signal Priority (TSP) scenario over all other suggested solutions, and across all tested volume levels. The results help decision makers to allocate limited budgets more efficiently, through specifying the most efficient enhancement scenarios, and having a better insight regarding performance gains.

Keywords: Fuzzy FOCUM, MCDM, Fuzzy VIKOR, Simulation, Traffic Flow, TSP, VISSIM.

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1. Introduction

The continuous development of privately owned vehicles rates have added loads on already overburdened road networks. Furthermore, the rapid urban development resulted in constructing severe traffic congestion, dense air pollution, and noticeable economic inadequacies especially in Irbid city which is recognised as the Jordan's second-largest

city [1]. Therefore, there was an urgent need to find innovative solutions to alleviate these challenges, which posed long-term threats to urban sustainability and hindered daily mobility.

Multi-Criteria Decision Making (MCDM) methods were also implemented to cover these complexities. For example, Fuzzy VIKOR often used to harmonize conflicting objectives in transportation planning, which as a result could reduce decision-making ambiguities [2]. Moreover, prior to implementation, simulations were utilized to anticipate how suggested policies might influence traffic dynamics, travel durations, and the quality of urban life [3]. The Full Consistency Method (FUCOM) was additionally employed to determine weighted criteria for traffic solutions [4, 5].

Simulation technology has been widely considered as a significant tool in traffic management due to its traffic flow optimization and reducing travel time ability. The main idea of this system is to reduce traffic congestion, through dynamically altering signal timing in real life by integrating roadway layouts, traffic regulations, intersection designs, and driving behaviors. But there are several challenges have noticed when employing simulation for traffic management. The main factors that could control simulations accuracy are the data quality, as the deficiencies in data collection could cause inefficiencies [6].

The study focuses on integrating MCDM methodologies with simulation techniques to develop traffic flow in Irbid. This study also aims to guide policymakers and urban planners in addressing Irbid traffic congestion problems. Traffic circles and intersections

The main areas in roads that are considered as problematic places are traffic circles and intersections, which hugely demands creative interventions. Various obstacles were noticed when employing such interventions, although the urgent demand for traffic enhancements. For instant, the existence of financial constraints, infrastructural deficits, regulatory complexities and data inadequacies [7]. Improving traffic flow and enhancing public transportation were realised essential for congestion reduction, air quality enhancement, and developing the overall quality of life. While having structured methodologies for solving traffic problems accounting for multiple, often conflicting criteria—were lacking.

Multi-Criteria Decision Making (MCDM) methods were used to cover these gaps, especially Fuzzy VIKOR and Fuzzy FUCOM that were employed in this study, integrated by simulation approaches. The later simulation approach was used to assess solution efficiency prior to the real implementation, so supporting the decision-making practices [3]. The following questions are the main questions that this study seeks to cover:

1. What are the main factors that influence the effectiveness of traffic flow in Irbid?
2. What are the feasible solutions to the congestion problem in Irbid?
3. How can the Fuzzy VIKOR and Fuzzy FUCOM methodologies be combined to create a robust decision-making framework that takes into account the complexities of traffic flow management in Irbid?
4. What is the effectiveness of the VISSIM microscopic simulation results in improving traffic flow?
5. What are the potential impacts of the selected solutions on improving traffic flow, reducing congestion, and increasing the use of the public transportation system in Irbid?

The main objectives the study seeks to cover are the definition and evaluation of the feasible solutions to the congestion problem in Irbid, including the assessment of their effectiveness. Moreover, this study aims to develop a Fuzzy MCDM model integrating FUCOM, Fuzzy FUCOM, VIKOR, and Fuzzy VIKOR to assess competing criteria and identify optimal traffic solutions, additionally to identify the most effective proposed interventions (including: signalizing the roundabout, overpass construction, geometric redesign, adaptive (smart) roundabout, one-way traffic and transit signal priority control system) using VISSIM microscopic simulation. The main contribution of the study is as the integration of MCDM and Fuzzy VIKOR could help authorities in Irbid's transportation to have a structured, data-driven tool to prioritize transportation improvement strategies.

This study paper will be divided into six main sections, which are: the introduction first above discussed section, the literature review, the methodology, the analysis and results, the discussion, and the final section which is study conclusions.

2. Literature Review

This section reviews existing knowledge and prior studies regarding traffic congestion, management and improvement approaches to establish the academic context for the research as follow:

2.1. Approaches for Traffic Improvement and Management

The dramatic expansion of traffic volume, additionally to the increment of vehicle ownership has added a huge load on roads construction and infrastructure. So, the traditional systems of traffic management, such as fixed time traffic signals or either the manually adapted schedules, often face challenges to adjust to actual traffic conditions in this rapid urbanization era, which resulted in delays, traffic jams and ineffective roads usage [8].

Therefore, various alternatives for traffic enhancements were suggested in previous literature including: signalization or roundabout conversion, overpasses/underpasses, geometric redesign, intelligent transportation systems (ITS), transit signal priority (TSP) control and adaptive traffic control, which are the main focus of this study, and that separately discussed in previous research. For instant, Intelligent transportation systems (ITS) are one of the modern technologies that widely discussed in previous studies as an essential traffic management alternative [9]. Several advantages can be derived from employing ITS as a transportation management technique, such as reducing the rate of accidents, improving vehicles average speed, and minimizing travel time intervals, which as a result will enhance the overall quality of transportation modes. Others found that geometric redesign is another technique to have an effective operation at intersections, such as adjusting geometric conditions through adding additional lanes or through the addition of the right lane [10, 11]. Transit Signal Priority (TSP) also plays an essential role in traffic management, as well enhancing the public transportation

effectiveness through minimizing urban congestion, which made this strategy essential to add sustainable mobility features in urban areas. Moreover, Signalized intersections are often used for the purposes of regulating traffic such as decreasing disturbance, reducing accidents, developing rod capacity by reducing time losses, and minimizing vehicle delays [12]. Furthermore, Vujanić, et al. [13] clarified that altering intersections to roundabouts will reduce the overall vehicles *collisions* percentage to 76%, and 80% reduction in injury crashes. Moreover, overpasses or underpasses are another widely discussed alternative in previous literature.

2.2. Multi-Criteria Decision Making (MCDM in Road Construction Evaluation and Transportation Planning:

Multi-Criteria Decision Making (MCDM) methods are recently widely employed in transportation planning, and road construction practices. This technique enables engineers and decision makers to rank alternatives, compare solutions and take the best decisions according to all these criteria together [14]. VIKOR is recognised as one of the main MCDM method that is widely utilized in road construction, as it aids in finding a solution that is considered the best when compared with all other criteria, but still considers trade-offs when not all criteria can be fully satisfied [15]. The main purpose behind developing the VIKOR approach is to cover MCDM issues, such as conflicting, complicity, and uncertain criteria [16]. Previous studies also showed that VIKOR and Fuzzy VIKOR are realised efficient for risk ranking and as a way to choose the best solution when considering various factors [15]. Another MCDM approach has recently developed which is recognised as the Full Consistency Method (FUCOM). This approach only demands little comparisons, make it easier to use than AHP. Fuzzy FUCOM allows for judgments using ranges or words. FUCOM and its fuzzy version have been used to prioritize critical risks in modular and sustainable construction and to decide which risks are most important [2]. Table 1 summarizes some of the most used MCDM methods in road construction risk management, their main applications, and special features:

Table 1.
Common MCDM Methods in Road Construction Management Development.

Method	Main Use	Key Feature	Reference
VIKOR	Risk mitigation, solution ranking	Compromise solution, ranks options	Gao, et al. [17]
Fuzzy VIKOR	Uncertain, subjective data	Works with fuzzy scores	Mehrparvar, et al. [18]
FUCOM	Criterion weighting	High consistency, fewer comparisons	Stević, et al. [19]
Fuzzy FUCOM	Prioritizing critical risks	Uses linguistic scales	Milinković, et al. [20]

MCDM models have been applied to various areas in roads construction, including material selection, risk assessment, and project management [21]. They are effective for handling complex decisions that involve both numbers (quantitative) and expert opinion (qualitative), which are both important in engineering practice [22].

2.3. Simulation Approaches in Traffic Studies

The simulation approaches of transportation and infrastructure have been developed by time passing to become cheaper, simpler, safer, and more efficient to evaluate the impact of weather changes, schedule risk analysis on cars. PTV VISSIM is a widely investigated as an important traffic simulation tool in previous studies. Various traffic engineering issues were solved through VISSIM simulation, including reconstruction of intersections to analyze their advantages, selecting the best roads and highways segment, constructing capacity analysis, public transportation planning and development, traffic, public transport and human resource planning, and transportation management [23]. This simulation tool was selected specifically according to its superior capabilities in vehicle routing, stability, comprehensive total output, and extensive animation and supporting documents.

This modelling approach utilize advanced algorithms to simulate the individual vehicles act, while considering some traffic aspects such as behavior of driver, lane changes and traffic signals. The results from simulation modelling can help decision makers, such as transportation planners, to define the existed challenges, examine various solutions before performing any alterations to the transportation infrastructure [24]. In summary, VISSIM simulation approach can be used in optimizing traffic signals timing, adjusting road layout, and enhancing public transportation performance through reducing congestion and enhancing accessibility.

Several core research gaps were identified after reviewing the previous literature. The main gaps in this study can be summarized as follow:

1) Limited context-specific research on Jordanian road projects.
2) Insufficiently explored integration of MCDM and simulation in construction/ traffic management.
3) Lack of comprehensive, unified theoretical frameworks connecting all stages of traffic or road management and development.
4) There is a scarcity of studies that examine traffic infrastructure problems and propose appropriate solutions in specific area in Jordan like Irbid city.
5) There is a lack of studies that evaluate proposed solutions and prioritize them according to their effectiveness and implementation urgency.
6) There is a scarcity of studies that assess solutions and scenarios and determine the best option based on performance and risk metrics.
7) There is a lack of studies that address the current traffic situation and offer long-term solutions in Jordan.

This study aims to address these gaps, providing new knowledge and practical tools for public transportation development in Jordanian road construction projects.

3. Methodology

This research adopts a mixed-methods approach to evaluate and rank alternative traffic management strategies for Abdel Raof Al-Tal Circle in Irbid, Jordan. The methodology integrates expert-based Multi-Criteria Decision Making (MCDM), specifically the FUCOM and VIKOR methods (including fuzzy versions), with open-access traffic simulation tools as clarified in Figure 1.

The following methodology steps were followed to achieve the study objectives:

- Define the evaluation criteria and possible alternatives: Criteria are chosen based on previous studies on road traffic and infrastructure [25, 26] additionally to experts' opinions. The alternatives to be evaluated include signalizing the roundabout, constructing an overpass, geometric redesign, adaptive (smart) roundabout, one-way traffic, and transit signal priority control systems.
- Data collection via expert questionnaire: A structured questionnaire is prepared and distributed to (8) transportation experts, engineers, and local planners.
- FUCOM for criteria weighting is applied to prioritize and weight the evaluation criteria. Experts rank the criteria by importance, and FUCOM calculations are used to determine the final weights. All FUCOM calculations are conducted in Google Colab using open-source Python code, which increases transparency and reproducibility.
- VIKOR for alternative ranking: After determining criteria weights, the VIKOR method is applied to rank the traffic alternatives.
- Traffic simulation for scenario testing is used to validate and contextualize MCDM results; VISSIM Simulation Software is carried out. The main reasons behind choosing this software specifically are because of its flexibility, accuracy, additionally to its wide acceptance in previous academic research [27, 28].

Abdul Raouf Al-Tal (ARAT) roundabout will be used as a case study for the study, and will be applied to evaluate the MCDM strategies used and their effectiveness in finding optimal solutions to traffic problems. The methodology was executed in three structured phases: (1) criteria identification and weighting, (2) alternative evaluation and ranking, and (3) simulation validation and sensitivity testing.

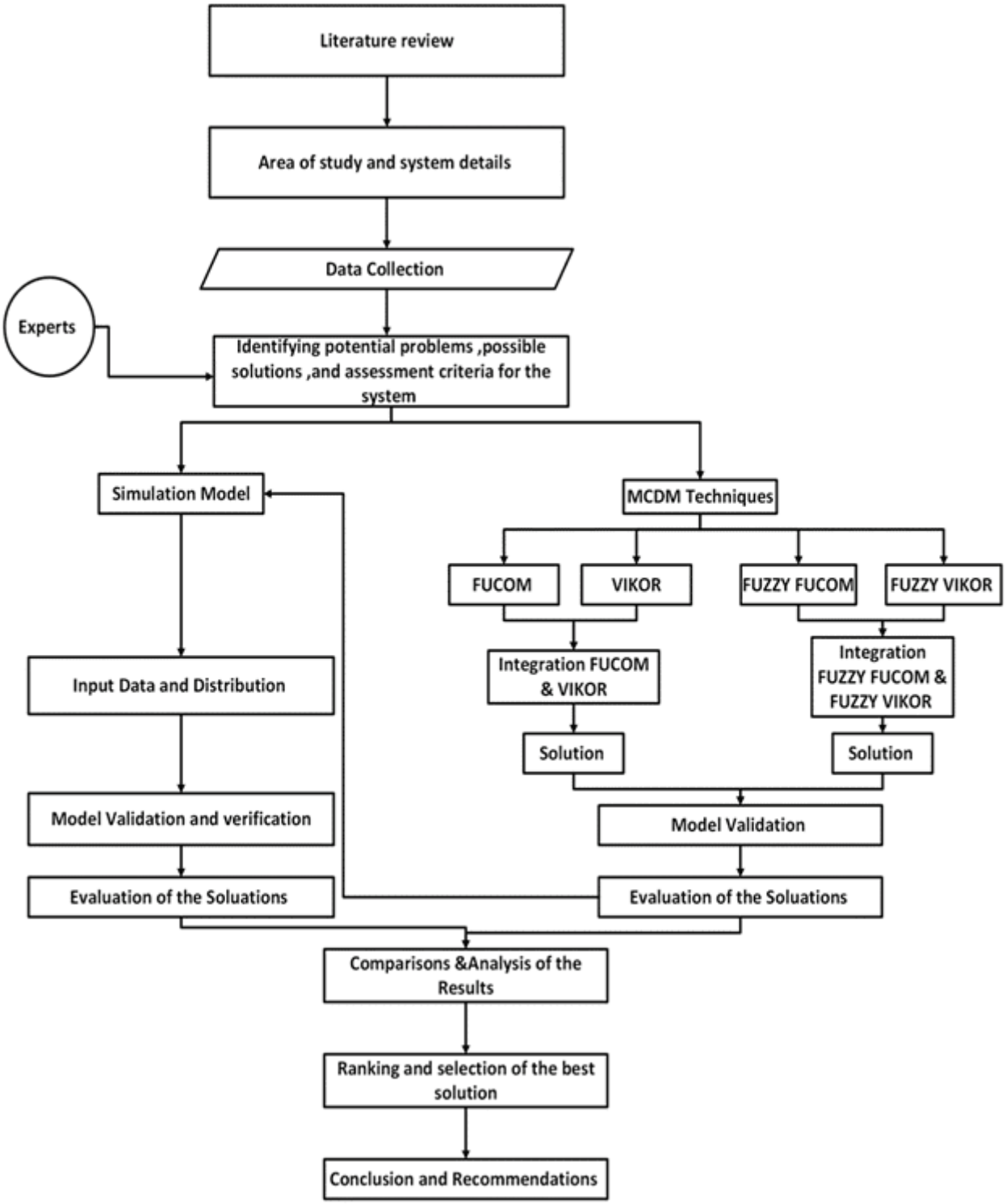

Figure 1.
Research methodology work steps.

4. Results Discussion

4.1. MCDM Analysis: VIKOR-Based Prioritization of Traffic Alternatives

Using the calculated weights, VIKOR analysis was implemented to rank the six proposed traffic solutions:

A1: Signalized Roundabout: this alternative could aid in developing the road performance through improving the efficiency and capacity at roundabouts, particularly those experiencing high traffic volumes.

A2: Over-Under Pass: it is the most suitable alternative for major high-traffic-volume intersections, as it can enhance travel capacity and speed.

A3: Geometric Design Improvement: improving road performance through optimizing the physical roundabout features, such as lanes number, and curves geometric.

A4: Adaptive Traffic Lights: enhancing traffic flow and efficiency through integrating smart control systems and sensors, which provide the roundabout with the abilities of adapting according to the actual traffic conditions.

A5: One-Way Conversions: can reduce traffic conflicts and simplify traffic flow, especially at intersections with high-volume traffic and different turning actions.

A6: Transit Signal Priority: can enhance public transport effectiveness by adjusting traffic signals to reduce public transportation delays, enhancing schedule consistency, while coordinating carefully with existing traffic flows.

4.1.1. Crisp VIKOR Results

Using crisp data and FUCOM weights, the VIKOR ranking is summarized in Table 2.

Table 2.
Crisp VIKOR Results Using FUCOM Weights.

Alternative	S Score	R Score	Q Score	Rank
A4_AdaptiveLights	-0.4974	0.0000	0.0000	1
A6_TransitPriority	-0.4972	0.0000	0.0000	1
A2_OverUnder	0.0000	0.0000	0.5000	3
A1_Signalized_rb	-0.3653	0.0844	0.6329	4
A3_Geometric	-0.3652	0.0843	0.6328	4
A5_OneWay	-0.3655	0.0846	0.6331	4

Results indicate that Adaptive Traffic Lights (A4) and Transit Signal Priority (A6) are joint top-ranking alternatives. Their S and R scores are optimal, suggesting minimal group regret and compromise.

4.1.2. Fuzzy VIKOR Results

Fuzzed version (centroid of L, M, U) was also used to evaluate the same decision matrix, and to assess the results robustness under uncertainty. Table 3 shows the fuzzy-based VIKOR results.

Table 3.
Fuzzy VIKOR Results (Centroid-Based).

Alternative	S Score	R Score	Q Score	Rank
A4_AdaptiveLights	-0.4974	0.0000	0.0000	1
A6_ TransitPriority	-0.4972	0.0000	0.0000	1
A2_OverUnder	0.0000	0.0000	0.5000	3
A1_Signalized_rb	-0.3655	0.0847	0.6332	4
A3_Geometric	-0.3652	0.0843	0.6328	4
A5_OneWay	-0.3654	0.0845	0.6330	4

The results showed high consistency between crisp and fuzzy approaches; as no changes has observed in the ranking order. This can be explained by the absence of ambiguity in the underlying data. Figure 2 represents comparison of S scores for VIKOR alternatives:

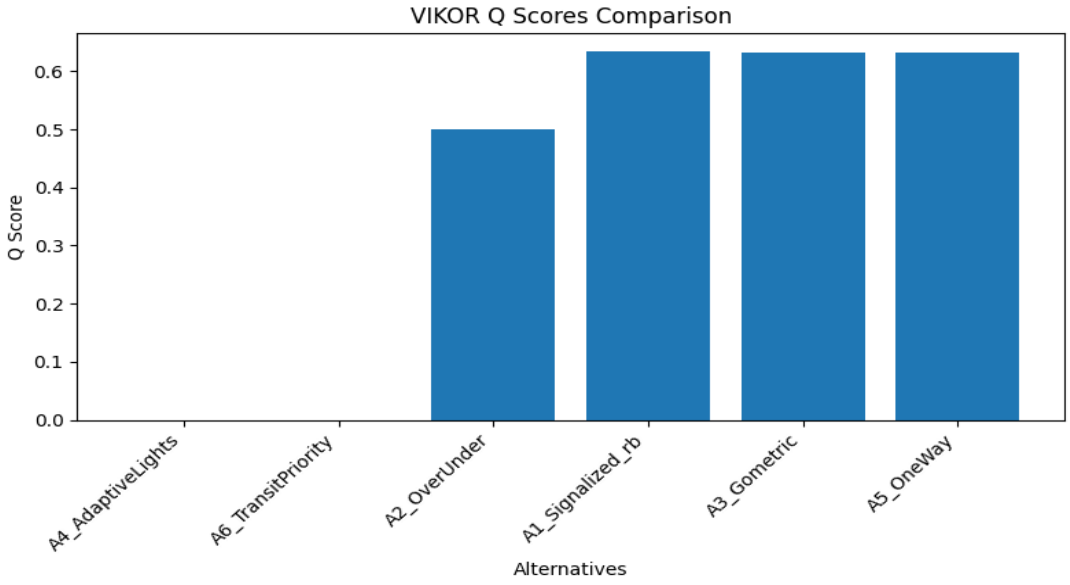

Figure 2.
Comparison of S Scores for VIKOR Alternatives.

According to the analysis results, the top-performing alternatives for improving traffic flow in Irbid are:

- A4: Adaptive Traffic Lights
- A6: Transit Signal Priority (TSP) Control System

These alternatives showed highest performance in crisp and fuzzy simulations under different criteria and experts' estimations. Their performance showed the best cost-efficiency, traffic conditions adaptability, and environmental impact after implementation. While conservative solutions including A1 (Signalized Roundabout) and A5 (One-Way Systems) ranked the lower according to their weak performance in key sustainability and cost indicators.

4.2. Simulation Analysis

The top three defined scenarios from the fuzzy MCDM techniques, the Baseline Roundabout Operation (BRO), Adaptive Signal Control (ASC), and Transit Signal Priority (TSP), were simulated through VISSIM simulation software for the peak period under high-demand conditions. The assumptions that considered in the simulation is that traffic arrivals follows a steady and Poisson distribution, which represent typical random arrival patterns under urban environments. All vehicles are assumed to have homogeneous behavior, with similar acceleration, deceleration, and car-following characteristics. Additionally, the geometry of the investigated intersection is considered constant such as turning features, and lane configuration, without facing and disturb situations, such as weather changes influences, incidents, etc. Moreover, key modelling assumptions included stable traffic patterns, consistent driver behavior, and absence of unusual disruptions such as incidents, celebrations or roadwork. The employed input data, and traffic arrival characteristics are clarified in Table 4.

Table 4.
Simulation Input Data.

Parameter	Value	Unit
Simulation Tool	Python (NumPy/Matplotlib)	
Total Run Time	3600	Seconds
Warm-up Period	600	Seconds
Data Collection Period	3000	Seconds
Number of Replications	5	Runs
Vehicle Speed Distribution	Normal (μ=50, σ=5)	km/h
Car-Following Model	Simplified Deterministic	
Random Seed Range	1 to 5	

The simulation results, summarized in Table 5 provide a quantitative basis for comparing the effectiveness of the proposed interventions against the existing fixed-time control.

Table 5 illustrates the quantitative basis for comparing the effectiveness of the proposed signal-controlled interventions against the existing roundabout control.

Table 5.
Comparison between different solutions scenarios.

Scenario	Average Vehicle Delay (s/veh)	Average Queue Length (veh)	Throughput (veh/hr)	Average Travel Time (s)
1. Baseline Roundabout Operation (BRO)	1285.69	5.35	360	1292.36
2. Adaptive Signal Control (ASC)	1122	4.79	464	1128.67
3. Transit Signal Priority (TSP)	919.18	4.09	593	925.85

The substantial improvement in the TSP scenario, particularly the increase in throughput, suggests that the mechanism of green-extension could be used to prioritize the bus inadvertently, resulted in a more accurate signal timing plan for all traffic movements, through effectively reducing the wasted time between cycles and better matching the green time to the actual general traffic demand. This finding discusses how the TSP strategy could manage public transport priority and improve the efficiency of the overall traffic flow at the intersection.

4.3. Validation and Comparative Analysis: MCDM vs. Simulation

This section validates the theoretical prioritization derived from the Multi-Criteria Decision-Making (MCDM) analysis against the empirical performance data obtained from the VISSIM microscopic traffic simulation**.** To facilitate direct comparison, the theoretical ranking from the MCDM analysis (using the TSP, ASC, and Baseline concepts) is integrated with the key Measures of Effectiveness (MOEs) from the VISSIM simulation. The effectiveness of key MOEs measures for the three studied scenarios are presented in Table 6.

Table 6.
Key Measures of Effectiveness (MOEs) from the VISSIM-style simulation.

Scenario	MCDM Rank (Hypothetical)	Simulation Avg Delay (s/veh)	Simulation Throughput (veh/hr)	Correlation
Transit Signal Priority (TSP)	1 (Best)	919.18	593	Best-performing scenario in both delay and throughput.
Adaptive Signal Control (ASC)	2 (Balance)	1122	464	Performs worse than TSP; better than BRO.
Baseline (Roundabout Operation (BRO))	3 (Worst)	1285.69	360	Lower MOE values than ASC and TSP therefore it is worst scenario.

The relation between the theoretical MCDM ranking and the empirical simulation performance (Average Vehicle Delay) are also visually explained in Figure 3. The figure confirms the overall validity of the MCDM approach, as the inverse relation showed that the lower MCDM Rank (better) corresponds to a lower Average Delay (better), which is clearly visible for the TSP and Baseline scenarios.

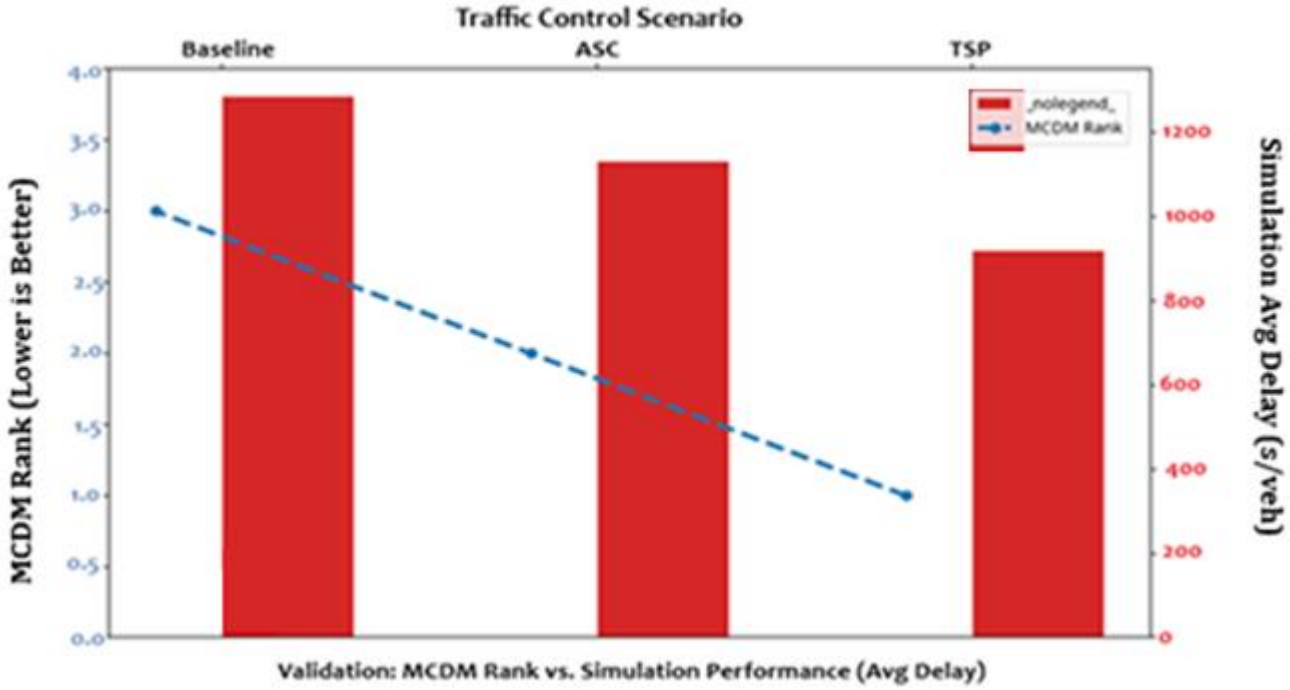

Figure 3.
Validation MCDM Rank Vs simulation AVG delay.

5. Discussion

The VIKOR analysis application, either in fuzzy or in crisp methods, showed a clear prioritization of the proposed traffic alternatives theoretically. The ranking results clarified that Adaptive Traffic Lights (A4) and Transit Signal Priority (A6) are the most optimal solutions. The microscopic traffic VISSIM simulation was performed to empirically asses the three core control strategies performance under different traffic demand conditions, offering an accurate evaluation of their practical effectiveness. The results are clarified according to the observed performance across across Low (540 veh/hr), Medium (900 veh/hr), and High (1260 veh/hr) traffic volumes.

The results continuously showed The Transit Signal Priority (TSP) scenario as the most effective and robust solution across all tested volume levels. Moreover, the VISSIM simulation results indicated a significant practical limitation of the Adaptive Signal Control (ASC) scenarios, as the initial simple ASC logic was found to be slightly effective under High Volume, yielding results close to the Baseline. The result was explained due to the high demand which reach the intersection to the saturated situations, causing the simple queue-based logic to continuously trigger the maximum green time, thereby reverting the control to an inefficient fixed-time cycle. The Baseline (Roundabout Operation) scenario worked as the control group for the analysis. Its performance showed the need for new intervention as it showed high delay rates and low throughput under high volume. On the other hand, it is surprisingly showed a better performance than the simple ASC under medium volume, while BRO works worse than ASC under high or low volume. This highlights the inherent stability of ARAT Roundabout control; while inefficient, it does not introduce the instability or potential for catastrophic failure that was observed with the simple ASC logic.

The integrated methodology showed the final, and robust preference of the TSP alternative after the strategic prioritization of the MCDM, and the tactical validation of the simulation.

6. Conclusions

This study modeled and tested three key control scenarios under varying traffic volumes which are: Baseline Roundabout Operation (BRO), Adaptive Signal Control (ASC), and Transit Signal Priority (TSP). the results clearly clarified the outperformance of the TSP scenario over all other alternatives in all performance measures. The TSP results showed a 28.5% reduction in average vehicle delay, and a 64.7% intersection throughput enhancement under high-demand conditions. The results clarified that adding signal adjustments to prioritize public transportation could benefit the entire traffic system through congestion reduction and intersection effectiveness enhancement.

The results also ranked the Adaptive Signal Control (ASC) system as a high performer in MCDM phase, while it is ranked the second according to the simulation results. The ASC performance parameters measures clarified a high sensitivity to high traffic volume, representing It appears that its success depends on a number of factors, such as moderate traffic and well-calibrated sensor systems. The used method in this study offered a comprehensive realization of both the theoretical potential and the practical act of each alternative. The findings confirmed that Transit Signal Priority (TSP) is the most reliable and efficient approach for urban intersections in Irbid, Jordan. Thus, this study concludes thar TSP implementation offers a sustainable, technology-supported solution that aligns with broader urban mobility goals. In the long term, although adaptive and AI based systems are considered future valuable strategies, but TSP represents the most feasible solution for direct enhancement in intersection and the overall effectiveness of traffic systems especially at rapidly growing cities such as Irbid.

The results provide decision makers, especially at Irbid Municipality and traffic officials, with an accurate guide of how allocating limited budgets more efficacy, by specifying the most effective enhancement scenarios, and having a better clear insight regarding performance gains. This study also suggested that the combined Fuzzy MCDM and simulation-based approach is considered as a comprehensive decision-support system capable of enhancing traffic flow efficiency, reducing congestion, and supporting sustainable urban mobility planning.

The proposed solutions for traffic improvement play a significant role in addressing recurrent congestion struggles at roundabouts or other similar traffic facilities. Through enhancing the efficiency of the traffic flow, and reducing operational blockages, such solutions could contribute in having smoother vehicle movement and more reliable travel conditions, particularly during peak hours.

Future studies should focus on integrating other Fuzzy MCDM hybrid framework, with the microsimulation modeling**,** as this approach effectively bridges the gap between expert judgment and real-world operational performance. The component of fuzzy logic is mainly recommended to handle uncertainty and subjectivity in expert-based evaluations of traffic control strategies.

References

[1] H. Al-Masaeid, "Traffic accidents in Jordan," *Jordan Journal of Civil Engineering*, vol. 3, no. 4, pp. 331-343, 2009.

[2] A. Pervez, "Prioritizing critical risk factors using fuzzy FUCOM: Application in modular construction," *Journal of Building Engineering*, vol. 45, p. 103591, 2022.

[3] A. Wismans, "The role of impulsivity and delay discounting in student compliance with COVID-19 protective measures," *Personality and Individual Differences*, vol. 179, p. 110925, 2021.

[4] M. C. Ong, Y. T. Leong, Y. K. Wan, and I. M. L. Chew, "Multi-objective optimization of integrated water system by FUCOM-VIKOR approach," *Process Integration and Optimization for Sustainability*, vol. 5, no. 1, pp. 43-62, 2021. https://doi.org/10.1007/s41660-020-00146-3

[5] J. Camargo Pérez, M. H. Carrillo, and J. R. Montoya-Torres, "Multi-criteria approaches for urban passenger transport systems: A literature review," *Annals of Operations Research*, vol. 226, no. 1, pp. 69-87, 2015. https://doi.org/10.1007/s10479-014-1681-8

[6] J. Högdahl and M. Bohlin, "A combined simulation-optimization approach for robust timetabling on main railway lines," *Transportation Science*, vol. 57, no. 1, pp. 52-81, 2023. https://doi.org/10.1287/trsc.2022.115

[7] M. H. Abdelwahab, E. D. Mohammed Ali, and M. A. Mustafa, "Assessment of wind erosion using remote sensing techniques in Atbara Area, River Nile State, Sudan," *Sudan Journal of Desertification Research*, vol. 6, pp. 1–14, 2014.

[8] V. Kolluri, "Revolutionizing healthcare delivery: The role of AI and machine learning in personalized medicine and predictive analytics," *Well Testing Journal*, vol. 33, no. S2, pp. 591-618, 2024.

[9] M. T. Purwantoro, *Sistem Transportasi Cerdas dalam Konsep Smart City*. Bandung, Indonesia: CV Cendekia Press, 2020.

[10] Y. Zhang, D. J. Sun, and A. Kondyli, "An empirical framework for intersection optimization based on uniform design," *Journal of Advanced Transportation*, vol. 2017, no. 1, p. 7396250, 2017. https://doi.org/10.1155/2017/7396250

[11] T. G. Abate, "Evaluating the performance of signalized intersection and the associated economic impact of congestion: A case study on Ras Mekonnen Street of Addis Ababa, Ethiopia," M.S. Thesis, 2018.

[12] H. G. Demir and Y. K. Demir, "A comparison of traffic flow performance of roundabouts and signalized intersections: a case study in Nigde," *The Open Transportation Journal*, vol. 14, no. 1, pp. 120–132, 2020. https://doi.org/10.2174/1874447802014010120

[13] M. Vujanić, M. Savićević, B. Antić, and D. Pešić, "Safety effectiveness of converting conventional intersections to roundabouts: Case study in the city of Niš," *Promet-Traffic&Transportation*, vol. 28, no. 5, pp. 529-537, 2016. https://doi.org/10.7307/ptt.v28i5.1849

[14] K. Tang, "Integrated MCDM methods for construction risk assessment: A systematic review," *Automation in Construction*, vol. 135, p. 104120, 2022.

[15] V. Shahhosseini and M. H. Sebt, "Prioritization of key risks in construction projects using the VIKOR method," *KSCE Journal of Civil Engineering*, vol. 15, pp. 1097–1106, 2011.

[16] G. M. Magableh, "Evaluating wheat suppliers using fuzzy MCDM technique," *Sustainability*, vol. 15, no. 13, p. 10519, 2023. https://doi.org/10.3390/su151310519

[17] Z. Gao, R. Y. Liang, and T. Xuan, "VIKOR method for ranking concrete bridge repair projects with target-based criteria," *Results in Engineering*, vol. 3, p. 100018, 2019. https://doi.org/10.1016/j.rineng.2019.100018

[18] M. Mehrparvar, J. Majak, and K. Karjust, "A comparative analysis of Fuzzy AHP and Fuzzy VIKOR methods for prioritization of the risk criteria of an autonomous vehicle system," *Proceedings of the Estonian Academy of Sciences*, vol. 73, no. 2, pp. 116-123, 2024. https://doi.org/10.3176/proc.2024.2.04

[19] Ž. Stević, I. Tanackov, and M. Subotić, "Evaluation of road sections in order assessment of traffic risk: Integrated FUCOM-MARCOS model," *Engineering Management in Civil Engineering*, vol. 1, no. 2, pp. 41–54, 2020.

[20] A. Milinković, D. Brkljač, S. Škorić, Ž. Stević, A. Danilevičius, and D. K. Das, "Evaluation of potentials for urban planning using the fuzzy fucom-imf swara-fuzzy opara model," *Buildings*, vol. 15, no. 5, p. 803, 2025. https://doi.org/10.3390/buildings15050803

[21] W. H. Lam, K. F. Liew, and W. S. Lam, "Selection of materials in construction industry with multi-criteria decision making models," in *E3S Web of Conferences (Vol. 405, p. 04015). EDP Sciences*, 2023.

[22] G. A. Kiker, T. S. Bridges, A. Varghese, T. P. Seager, and I. Linkov, "Application of multicriteria decision analysis in environmental decision making," *Integrated Environmental Assessment and Management*, vol. 1, no. 2, pp. 95-108, 2005. https://doi.org/10.1897/IEAM_2004a-015.1

[23] R. N. Prakash and K. K. Arunprakaash, "A study on green human resource management at Meshl Web Pvt Ltd Tirupattur," *Trends Banking, Accounting Business*, vol. 3, no. 1, pp. 250–454, 2024.

[24] S. M. Hafram, S. Valery, and A. H. Hasim, "Calibrating and validation microscopic traffic simulation models VISSIM for enhanced highway capacity planning," *International Journal of Engineering*, vol. 36, no. 8, pp. 1509-1519, 2023. https://doi.org/10.5829/ije.2023.36.08b.11

[25] A. U. Khan, Y. Ali, D. Pamucar, and L. Vasa, "Risk management for cold supply chain: case of a developing country," *Acta Polytechnica Hungarica*, vol. 19, no. 8, pp. 161-185, 2022.

[26] X. Zhu, X. Meng, and M. Zhang, "Application of multiple criteria decision making methods in construction: A systematic literature review," *Journal of Civil Engineering and Management*, vol. 27, no. 6, pp. 372-403, 2021.

[27] PTV Group, *PTV Vissim 2022 user manual*. Karlsruhe, Germany: PTV Planung Transport Verkehr AG, 2022.

[28] M. Fellendorf and P. Vortisch, *Microscopic traffic flow simulator VISSIM. In J. Barceló (Ed.), Fundamentals of traffic simulation.* Berlin, Germany: Springer, 2010.