ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume X-5/W2-2025
Unleashing the power of Geospatial & Frontier Technologies for a Sustainable Future – GIFTS Summit 2025,
1–3 September 2025, Symbiosis International University, Pune, India

Impact-Driven Multi-Criteria Decision Approach for Strategic On-Street Parking Placement

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Keywords: Parking placement, multicriteria decision making, microscopic simulation, SUMO, urban traffic management.

Abstract

The strategic placement of on-street parking spaces critically impacts urban traffic flow and parking efficiency, yet conventional approaches often rely on reactive policies and macroscopic models that overlook nuanced traffic interactions. This study proposes a novel impact-driven, multi-criteria decision-making framework. It applies microscopic traffic simulation to evaluate candidate parking locations based on their effects on both local and through traffic. By explicitly distinguishing these impacts, the paper captures spatiotemporal dynamics overlooked so far. The paper quantifies changes in key criteria (travel time, search time, walk time) and systematically ranks parking alternatives using a combination of the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Results highlight that strategic placement can significantly reduce cruising times and congestion without imposing excessive walking burdens. The framework offers a transferable and adaptable decision-support tool for urban planners, with potential applications extending to event planning and autonomous vehicle navigation.

1. Introduction

To alleviate the heightened demand for parking spaces, planning authorities have traditionally focused on expanding both dedicated off-street and on-street parking infrastructures (Shoup, 2018). However, expanding off-street parking is often neither feasible nor desirable, as it requires substantial land resources and has been critiqued for increasing housing costs (Shoup, 2018). These issues are further intensified in low- and middle-income countries, where the majority of cities lack planned parking infrastructure, resulting in inadequate off-street infrastructure and unmarked on-street parking spaces (Parmar et al., 2020). Unlike off-street parking, the space available for on-street parking is inherently limited, particularly in dense urban environments. These spatial constraints necessitate not only expansion but also careful attention to where on-street parking is placed within the road network. Although parking management strategies such as pricing mechanisms could mitigate spillover effects (Shoup, 2018), they cannot address the spatial inefficiencies of poor placement.

Poorly located on-street parking spaces, often due to a lack of systematic planning, result in inadequate availability, inefficient space utilisation, increased safety risks, and disrupted mobility due to frequent manoeuvring, contributing to longer travel times and emissions (Mardiana, 2022, Shnewer et al., 2021). Conversely, well-placed on-street parking can alleviate traffic congestion and reduce the time spent searching for parking (Abdeen et al., 2021). As on-street parking encroaches on areas that could otherwise be used for alternative purposes (Graham et al., 2020), merely maximising the area designated for on-street parking is insufficient. Instead, strategic placement of on-street parking within the road network is required to balance demand and accessibility.

Parking facility placement has been extensively studied in the literature, with most approaches aiming to match parking supply to demand while minimising walking distance, costs, and environmental impact (Shen et al., 2019, Jelokhani-Niaraki and Malczewski, 2015). However, these approaches typically focus only on off-street parking, use analytical or location-allocation models and pay limited attention to the broader impact of parking placement. In particular, they often overlook how increasing parking availability can unintentionally induce further parking demand and contribute to congestion over time. In contrast to off-street parking, on-street parking, which typically occurs on public land, involves different economic considerations, such as fee structures and infrastructure costs, and creates direct interaction between local and through traffic (Jakob and Menendez, 2019). Local traffic (vehicles seeking parking within the vicinity) prioritises proximity to destinations, whereas through traffic (vehicles passing through the area) prioritises unobstructed flow and minimal delays caused by parking manoeuvres (Jakob and Menendez, 2019). These differing priorities underscore the need to evaluate on-street parking placements not just from the perspective of local demand, but also from that of broader traffic circulation.

Despite its importance, the literature on identifying on-street parking locations is limited. Notable contributions include the works of Ceylan (Ceylan et al., 2014) and Gkini (Gkini et al., 2018). Both studies rely on analytical macroscopic analysis and overlook critical factors such as walk time, search time, and cruising. Ceylan excludes parking manoeuvres, while Gkini incorporates them but does not consider dynamic congestion effects; instead, it utilises static traffic assignment to estimate the overall network travel time. Similarly, Wang et al.'s model for determining the optimal on-street parking location also uses analytical models (Shu-chun et al., 2008). Analytical models often rely on simplified, aggregate formulations and assume rational decision-making, overlooking spatial, temporal, and stochastic aspects of parking, limiting their ability to reflect real-world complexity (Levy et al., 2013).

In the absence of robust empirical methods, current planning practices remain largely reactive, guided by observed demand, land use, and policy objectives. Placement of on-street parking spaces are typically constrained by prescriptive design standards, such as minimum setbacks from intersections, hydrants, and crosswalks, rather than assessing the broader impact of location on traffic and interaction among various traffic (Pune Municipal Corporation, 2019, Plymouth Growth and Development Corporation (PGDC), 2014). The design and placement specifications, embedded in zoning codes and design manuals, emphasise visibility and pedestrian protection. Consequently, planning for the placement of on-street parking spaces is more prescriptive than adaptive, lacking a systematic assessment of its impact on traffic flow, accessibility, and network performance.

Three key limitations are identified in the existing literature. First, the predominant focus on off-street parking overlooks drivers' preference for on-street parking. Second, existing studies on on-street parking often rely on macroscopic or analytical models, which fail to capture the nuanced behaviours of individual drivers and the spatiotemporal variability of traffic conditions. Third, existing approaches do not adequately distinguish between the conflicting impacts on local and through traffic. The primary research question addressed in this study is: *How can the impact associated with on-street parking on both local and through traffic be effectively incorporated into on-street parking space placement decisions?*

To address these gaps, this study focuses on the identification of locations for on-street parking using a microscopic simulation integrated with a Multi-Criteria Decision-Making (MCDM) approach, providing a valuable decision-support tool for urban policymaking. Unlike traditional approaches, this research evaluates placement based on the impact incurred by both through and local traffic within a specified locality, as the distinction between traffic types is most meaningful within a locality rather than across a city. Moreover, unlike macroscopic analytical approaches, microscopic simulation-based tools model each vehicle as an independent agent whose decisions unfold over time and space, enabling a more detailed representation of individual driver decisions and traffic interactions. This study presents a structured methodology for assessing on-street parking locations, which can be extended to various scenarios, such as policymaking for special events requiring additional parking spaces and decision-making for autonomous vehicles determining optimal parking locations.

The remainder of the paper is structured as follows: Section 2 outlines the proposed methodology, with its application demonstrated in Section 3. Section 4 reports and discusses the findings, and Section 5 concludes with limitations and future research directions.

2. Proposed Methodology

On-street parking placement decisions often involve balancing conflicting objectives. Placing parking away from major throughways to minimise disruptions to through traffic may lead to increased walking and searching times for local traffic. Conversely, prioritising local traffic by placing parking near destinations may introduce delays for through traffic. To address these conflicting priorities, this study proposes a methodology that quantifies the impact of placing on-street parking on both traffic types using a microscopic simulation. Once the impacts are quantified, an MCDM approach is employed to evaluate, rank and thus identify locations that balance impact on through traffic, local traffic, and planning objectives.

The microscopic simulation requires the acquisition of input data, including road network geometry, traffic and parking demand patterns, origin-destination information, and distribution of existing parking infrastructure. These data may be obtained through field surveys, traffic sensors, or synthetically generated to reflect a comprehensive range of scenarios. A baseline is established by simulating the prevailing conditions of the network, using observed demand patterns and existing parking supply. This serves as a reference against which the relative impacts of various parking placement alternatives are measured. Subsequently, a set of candidate locations for new or reallocated on-street parking spaces is identified. In practice, these locations are informed by parking demand, land-use characteristics and existing parking policies and regulations.

The primary metric for evaluating the impact on through traffic is the change in travel time. Any disruption or improvement to the steady flow of through traffic caused by the placement of on-street parking spaces is reflected in travel times. To assess the impact on local traffic, three key metrics are considered: change in travel times, search times, and walk times. While additional parameters such as parking costs, fuel costs, and emission costs may also be incorporated. This study focuses exclusively on the three primary metrics, as travel time and search time are strongly correlated with fuel consumption and emissions. Moreover, on-street parking fees are typically flat or spatially uniform in many jurisdictions, thus contributing minimally to the differentiation of placement alternatives. For local traffic, travel time is defined as the total trip duration, excluding search time and parking duration. Search time is assessed when a driver does not find their preferred parking space and must look for an alternative, calculated as the time elapsed between reaching the initially preferred parking spot to locating an available parking space. Walking time, for each vehicle, is calculated as the pedestrian travel distance between the final parking location and the destination, divided by the average walking speed. The cumulative impact is quantified using Eq.1 as the average absolute change in the corresponding metric for each vehicle in the respective traffic type, relative to the baseline. This change is computed for each parking placement alternative under evaluation.

$$\Delta x_{\text{avg}}^{\text{alt}} = \frac{1}{N} \sum_{i=1}^{N} \left(x_i^{\text{alt}} - x_i^{\text{baseline}} \right) \tag{1}$$

where x represents a specific metric, such as travel time, search time or walk time, $\Delta x_{\text{avg}}^{\text{alt}}$ denotes the average absolute change in metric x for a given parking placement alternative. The term x_i^{alt} is the value of metric x for each vehicle i for that alternative, while x_i^{baseline} is the corresponding value for the same vehicle in the baseline. N denotes the total number of vehicles contributing to the traffic demand.

For each candidate on-street parking location, a simulation run is conducted to quantify the four criteria metrics: through traffic travel time, local traffic travel time, search time, and walk time. Given the multiple and conflicting metrics, an MCDM approach is necessary to systematically rank the parking alternatives. The Analytic Hierarchy Process (AHP) (Saaty, 1980) is used to derive the relative importance (weights) of these metrics. AHP generally consists of four key steps: hierarchy construction, pairwise comparison, weight calculation, and consistency checking. Pairwise comparisons are performed to determine the relative importance of key criteria metrics. These comparisons populate a reciprocal matrix $A = [a_{ij}]$, where each element a_{ij} represents the relative importance of criterion i over criterion j. Then the priority weights, $W = [w_i]$, where each element w_i denotes the derived weight of criterion i, are computed using the row-average method, well documented in the literature (Malczewski and Rinner, 2015). The Consistency Ratio (CR) is used to validate the consistency of weights, as required in methods such as AHP (Malczewski and Rinner, 2015). CR ≤ 0.10 indicates acceptable consistency.

With the criteria weights determined, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is employed to rank the parking location alternatives. The procedure, well documented in the literature (Malczewski and Rinner, 2015), involves identifying the positive ideal solution A^+ and the negative ideal solution A^- using:

$$A^+ = \left(\max_i v_{ij} \,|\, j \in I, \min_i v_{ij} \,|\, j \in J\right) \tag{2}$$

$$A^- = \left(\min_i v_{ij} \,|\, j \in I, \max_i v_{ij} \,|\, j \in J\right) \tag{3}$$

Here, I represents the benefit criteria (where higher values are preferred), and J represents the cost criteria (where lower values are preferred). This ensures that the ideal solution A^+ is a theoretical configuration with maximum benefits and minimum costs, while the negative ideal solution A^- represents the opposite scenario with minimum benefits and maximum costs. In this study, reduced through traffic travel time and improved parking accessibility (through lower search and walk times) are considered benefit criteria, while increased disruption to traffic flow is treated as a cost criterion.

Using AHP-derived weights, the Euclidean distances (d_i^+ and d_i^-) of each alternative from the positive ideal solution and the negative ideal solution, respectively, are calculated. The relative closeness R_i of each alternative to the ideal solution is then calculated as:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{4}$$

Finally, the alternatives are ranked in descending order of R_i, with the alternative having the highest R_i being the most preferred.

The AHP-TOPSIS framework offers a systematic, interpretable, and robust decision-support framework well-suited for spatial planning problems with heterogeneous, non-compensatory criteria (Malczewski and Rinner, 2015). Alternatives such as Weighted Linear Combination assume full trade-offs, and more complex methods, such as ELECTRE and ANP, are computationally demanding (Malczewski and Rinner, 2015). The AHP-TOPSIS framework enables the integration of preferences from both user groups: local traffic and through traffic. Additionally, since the candidate parking locations are informed by existing planning practices, the preferences of decision-makers are inherently incorporated into the evaluation.

Figure 1 summarises this methodology, outlining the steps from simulation initialisation to parking alternative evaluation.

2.1 Validation

The proposed methodology is validated to ensure that the framework yields consistent results, establishing methodological credibility. A simplified road network (Fig.,2), where the outcomes can be theoretically anticipated, is used. Vehicles enter the simulation from the green edge on the left and exit from the green edge on the right. Through traffic primarily follows the shortest path, the straight edge. In the baseline, six on-street parking spaces are located in front of the destination. The

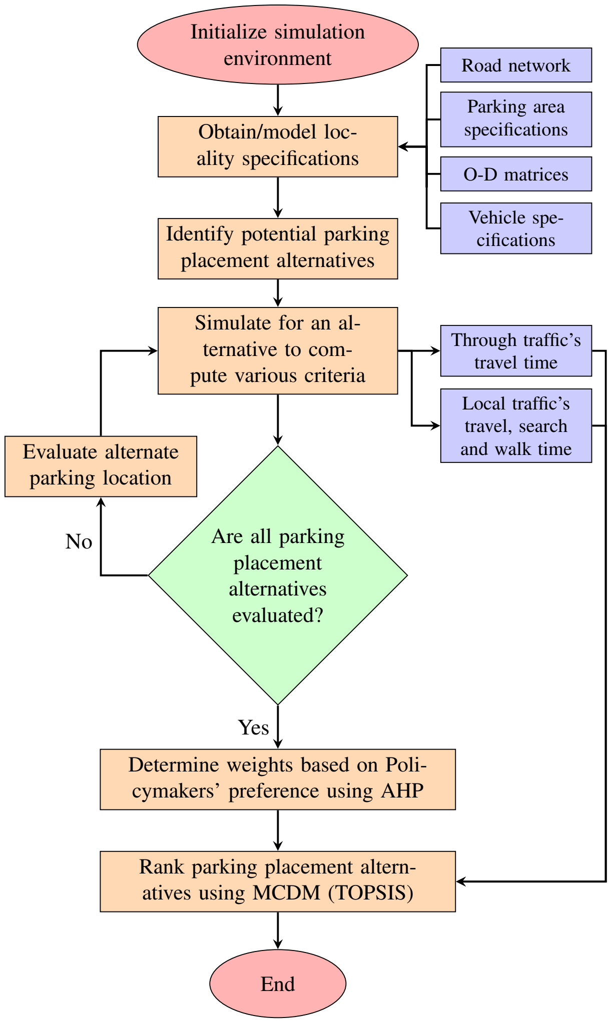

Figure 1. Flowchart illustrating the simulation-based methodology for on-street parking space placement.

local traffic demand is set at 28 vehicles per hour, each parking for 15 minutes, exceeding capacity and inducing cruising behaviour. To alleviate the parking shortfall, four additional spaces are proposed to be placed on one of the four network edges, resulting in four candidate placement alternatives labelled as Alt 1 through Alt 4 in Fig. 2.

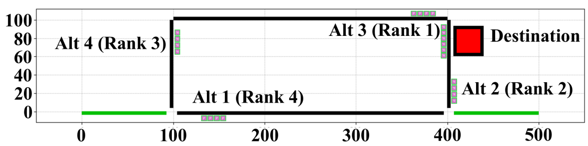

Figure 2. The road network used for validation, depicting the expected rankings of alternative on-street parking space placements (brackets).

First, the ranking of these alternatives is theoretically anticipated based on their expected impact on through and local traffic. Alternative 1, located directly along the through traffic route, is expected to cause the most significant disruptions, as parking manoeuvres at this location would directly impact through traffic. Alternative 2, which requires local traffic to make a full detour to access the parking spaces, is expected to have the second most significant impact. Alternatives 3 and 4, located off the through traffic route, are expected to cause less disruption. However, these alternatives differ in their impact on walk time. Alternative 3 is closest to the destination, followed by Alternative 2, then 4, and lastly 1. Taking these impacts into account, the expected ranking is determined as 4, 2, 1, and 3.

Then, simulations are conducted for each alternative. The highest preference is assigned to through traffic travel time, followed by walk time, with search time and local traffic travel time having the lowest preferences, using the same preference structure as the theoretical ranking. The AHP-derived weights reflect the stated priorities: through traffic is weighted highest (0.507), followed by walk time (0.271), with lower emphasis on search time (0.154) and local traffic (0.068). The consistency ratio (CR) is 0.03, indicating that the derived weights are consistent. The relative closeness and the corresponding TOPSIS rankings for each placement alternative, calculated using 4, are shown in Table 1. The calculated ranks align well with the expected rankings, demonstrating the reliability of the methodology.

Placement Alternative	Expected Rank	Relative Closeness	Calculated Rank
1	4	0.009018	4
2	2	0.949744	2
3	1	0.986558	1
4	3	0.809705	3

Table 1. TOPSIS rankings of parking placement alternatives.

The successful reproduction of expected rankings validates the methodology as a robust tool for evaluating parking placement in complex scenarios. The next section demonstrates its application to a more realistic urban network.

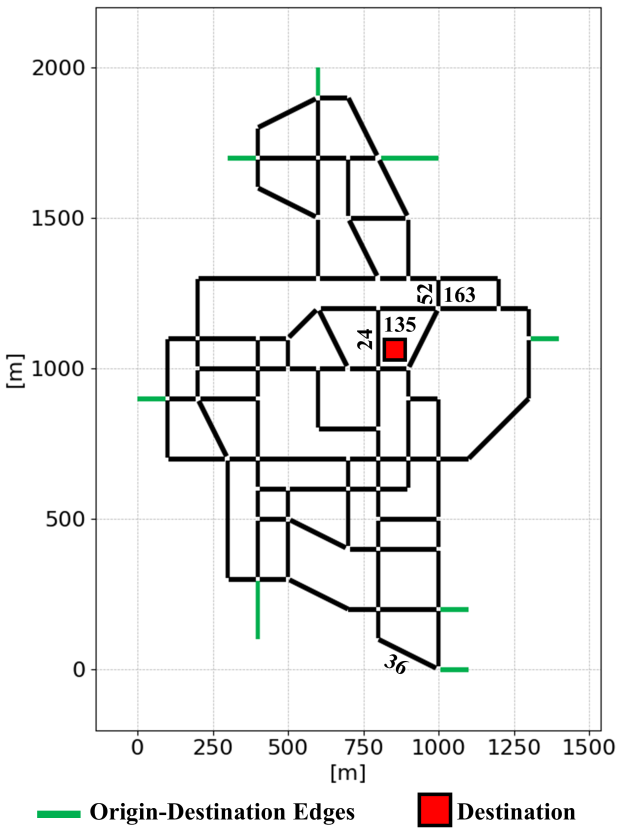

Figure 3. The road network used for demonstration, showing various numerical edge IDs.

3. Experimental Design

To demonstrate the proposed methodology, we apply it to a hypothetical road network using SUMO (Simulation of Urban Mobility), an open-source microscopic traffic simulator (Lopez et al., 2018). SUMO incorporates well-established car-following and lane-changing models grounded in traffic flow theory. The chosen street network reflects real-world conditions, as urban networks often show unsymmetrical and broken-grid layouts. Although real-world data can be used, acquiring detailed microscopic data is challenging. Microscopic simulations require detailed vehicle-level O-D data and parking destinations. However, empirical traffic data, often macroscopic in nature, lacks this granularity, and its disaggregation into microscopic inputs is methodologically unreliable without strong behavioural assumptions. Importantly, the use of hypothetical data does not limit real-world applicability or validity of the proposed methodology. The framework can be applied to real-world networks by adjusting input parameters such as traffic demand, parking demand, and network structure accordingly.

Key simulation parameters, including network dimensions, traffic and parking demand, and vehicle behaviour assumptions, are summarised in Table 2. The hypothetical road network (Figure 3) spans 2 km by 1.5 km and comprises 114 edges, with a combined length of 32.25 km. Each link represents a bidirectional two-lane road, excluding highways and arterials, where on-street parking is typically prohibited. Out of these 114 edges, eight serve as entry and exit for all traffic, resulting in 64 origin-destination (O-D) pairs, highlighted by green-colored edges in the figure. Parking is permitted only on the remaining 106 edges, with both lanes available for parking. This configuration yields a total of 212 potential parking locations, each comprising eight on-street parking spaces measuring 6 meters in length and 3 meters in width, which is within the range commonly used in various jurisdictions (Pune Municipal Corporation, 2019).

Parameter	Value
Road network span	2 km by 1 km
Total number of edges	114
Total length of road network	32.25 km
Total number of O-D pairs	64
Number of parking alternatives	212
Parking space dimensions	6 m by 3 m
Simulation duration	4 hrs
Through traffic demand	2560 vehicles per hour
Parking demand	64 vehicles per hour
Parking duration	15

Table 2. Simulation configuration and input parameters for network, traffic, and parking conditions.

The traffic demands, both through and local, are assumed to be uniformly distributed for simplicity, with vehicles entering at equal intervals and exhibiting the same demand for each origin-destination (O-D) pair. Alternative distributions could be incorporated without altering the methodology. Vehicles follow dynamic routing, selecting the shortest path based on current travel times and traffic conditions in the network. Parking manoeuvres may temporarily disrupt through traffic: if a lane change is possible, vehicles adapt; otherwise, the following vehicles must wait. Similarly, parking vehicles adhere to SUMO's default behaviour, selecting parking spaces based on proximity to their intended destination and travel time to the parking spot. The simulation duration is set to 4 hours or 14,400 timesteps of 1 second each, as results stabilise within this period. All vehicles in the simulation are uniform, each with a length of 5 meters and a maximum speed of 70 km/h. Parking manoeuvres require an extra 20 seconds when entering and 10 seconds when leaving an on-street parking area.

The network features a single destination. In the baseline setup, there are 10 on-street parking spaces and a parking demand of 64 vehicles per hour for 15 minutes. This results in a parking load of 16 vehicle-hours per hour, exceeding the available capacity of 10 vehicle-hours, equivalent to 160% utilization. This excessive demand leads to significant cruising behaviour as drivers search for available parking spaces. To address this shortfall, eight additional on-street parking spaces are proposed, increasing the parking supply and reducing utilisation to 88%, consistent with the optimal occupancy level recommended in the literature (Shoup, 2018). Importantly, the additional number of spaces is just enough to accommodate existing demand at the optimal utilisation level, thereby avoiding induced demand from excess supply. The proposed methodology is subsequently employed to determine the location of these additional parking spaces in a manner that minimises the overall impact of their placement. A 15-minute parking duration, typical of short-term urban parking, is chosen to maintain homogeneity in the demonstration; varying the duration would affect only the specific outcomes, not the applicability of the methodology. The network reaches its maximum capacity at a through traffic volume of 3,840 vehicles per hour, beyond which vehicle insertion backlogs occur. Consequently, through traffic demand is 2,560 vehicles per hour, just below the maximum capacity, ensuring a high impact on through traffic. This configuration allows for a comprehensive assessment of the trade-offs between parking availability and traffic flow efficiency.

4. Results and Discussion

We conducted 212 simulations, each corresponding to a potential on-street parking location, to evaluate the impact of parking placement on through and local traffic. For each simulation, the average absolute changes in key criteria (in seconds) before and after the placement of additional on-street parking spaces were quantified. Table 3 summarises these values across all potential parking placement locations. These statistics illustrate the variability in impact across parking alternatives. While additional parking generally improves local traffic conditions, evidenced by substantial reductions in mean search and travel times, some placements worsen outcomes, even with increased supply. For the given network and demand, changes in through traffic are relatively modest, whereas local traffic is more sensitive to parking placement. For example, through traffic travel time mostly improved (mean = -17.6s), while walk time increased (mean = 278.5s), reflecting the trade-off between traffic flow and accessibility. The wide range and variance indicate that parking placement can lead to drastically different outcomes depending on location, reinforcing the need for a systematic evaluation framework.

The results revealed that on-street parking placement had a varied impact, with certain locations causing more significant disruptions than others. For instance, placing additional on-street parking on edge ID 24 (Fig. 3) yielded the greatest improvement in through traffic travel time, whereas placement on edge ID 36 (Fig. 3) resulted in the most significant enhancement in

	Through Traffic	Local Traffic	Search Time	Walk Time
Minimum	-20.9	-2512.2	-2928.9	28.1
Maximum	11.6	2939.5	2622.8	572.8
Mean	-17.6	-2470.0	-2810.4	278.5
Median	-18.4	-2501.6	-2854.7	275.7
Variance	3.9	376.8	394.8	109.9

Table 3. Statistics of the average absolute changes in key criteria (in seconds) before and after the placement of additional on-street parking spaces across all placement candidates.

local traffic travel time. These findings suggest that the impact of parking placement is highly location-dependent, with trade-offs between different criteria. While some locations may offer significant improvements in one aspect (e.g., search time), they may also result in greater disruptions to other aspects (e.g., through traffic flow). For example, parking placement at edge ID 163 (Fig. 3) led to the highest average increase in through traffic travel time, with nearly 47% less improvement in search time compared to maximum improvement, but resulted in an average walk distance of approximately 120 meters only. In contrast, edge ID 135 (Fig. 3) showed the greatest improvement in search time, although it resulted in 25% less improvement in through traffic travel time relative to the maximum improvement.

Criteria	Through Traffic	Local Traffic	Search Time	Walk Time
Through Traffic	1.00	6.00	4.00	2.00
Local Traffic	0.17	1.00	0.33	0.25
Search Time	0.25	3.00	1.00	0.50
Walk Time	0.50	4.00	2.00	1.00

Table 4. Pairwise comparison of preferences for weight determination using the AHP.

After completing simulations for all 212 potential parking locations, pairwise preferences, shown in Table 4, were used to derive criterion weights through the AHP. For demonstration, through traffic travel time was assigned the highest priority, followed by walk time. In practice, decision-makers would provide these pairwise comparisons based on actual priorities. These weights, together with the raw impact values from the simulations, were then used to rank all alternatives using TOPSIS. Figure 4 presents a heatmap of the road network, where each edge is colour-coded based on its rank, illustrating the relative desirability of each parking placement location. Lower ranks (closer to 0), shown in blue, represent the most preferred locations with the least impact, while higher ranks (closer to 212), shown in red, indicate the least desirable placements.

As shown in Figure 4, selecting different ranked locations for parking placement results in distinct impacts on key criteria. For instance, placing parking on the lane immediately before the destination edge results in the least increase in walking distance, with an average of only 28 meters. However, it causes a significant increase in search time, averaging 44 minutes, which exceeds the threshold where drivers are likely to abandon their search (Pan et al., 2019). The trade-offs extend further: opting for the 10th-ranked option over the top-ranked one increases the maximum walking distance by approximately 292 meters, which is close to the 400-meter threshold, beyond which drivers tend to abandon driving (Pan et al., 2019). Choosing the 100th-ranked alternative results in an increase in walking distance of around 700 meters, significantly exceeding this threshold.

Although edges located far from the destination and along ma-

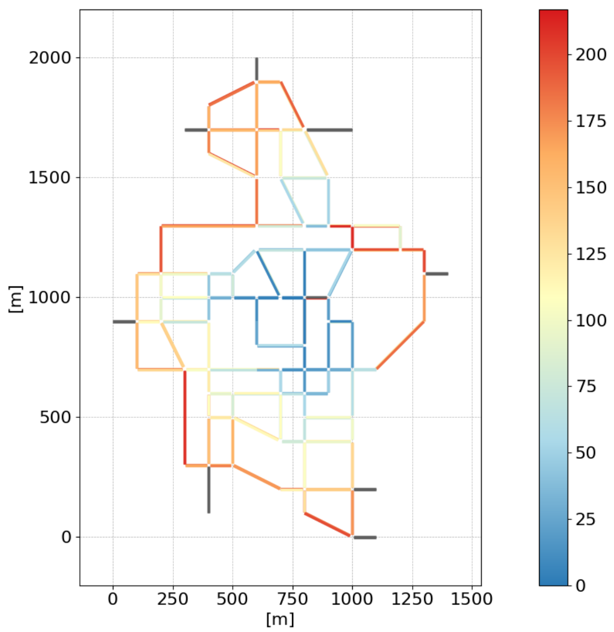

Figure 4. Heatmap ranking edges for on-street parking placement (0 to 212) when through traffic travel time is prioritised.

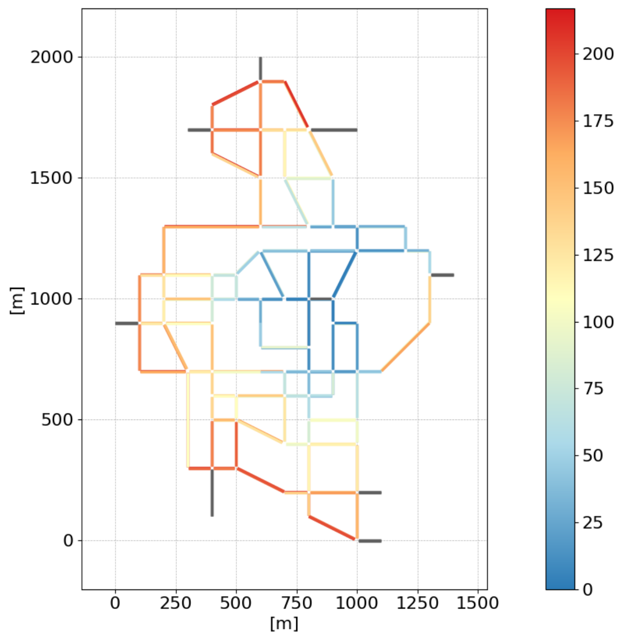

Figure 6. Heatmap ranking edges for on-street parking placement (0 to 212) when local traffic walk time is prioritised.

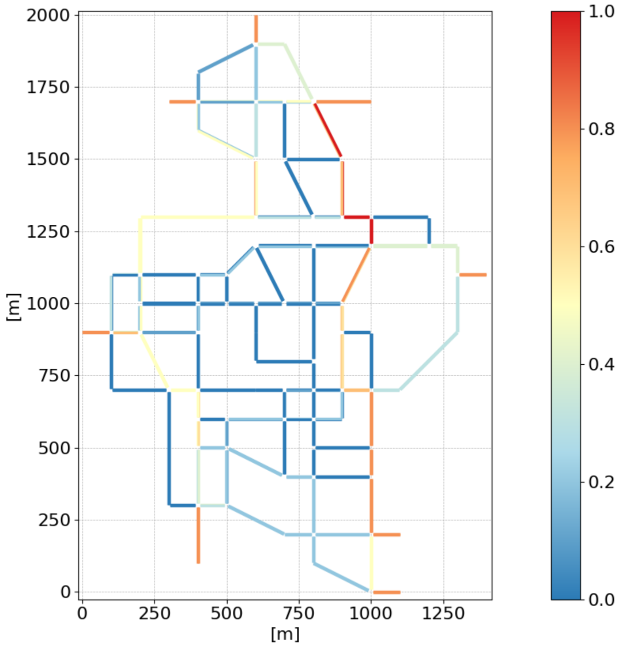

Figure 5. Betweenness centrality values normalised between 0 and 1.

jor throughways generally receive higher ranks (less preferred for parking placement). The betweenness centrality analysis, Figure 5, shows that, contrary to intuitive assumptions, parking rankings are not strictly correlated with centrality. This indicates that the parking placement preference is not solely determined by the proximity of parking locations to through traffic routes or destinations of local traffic, but is shaped by factors such as the interaction of through and local parking demand, and alternative routing options.

Furthermore, changes in decision-makers' preferences have a substantial effect on the ranking of parking locations. For example, when prioritising through traffic travel time, the parking location on the lane opposite the destination edge drops to rank 52. Conversely, when walking distance is prioritised, its rank improves significantly to 2. Figure 6 illustrates the rankings under the scenario where decision-makers prioritise walking time. As the weights adjust to reflect the preference for walk time, the ranks of on-street parking alternatives change significantly. For instance, the rank of edge ID 52 (Fig. 3) improved from 209 to 16. This dynamic ranking adjustment underscores the novelty and relevance of this study.

5. Conclusions and Future Work

This study presents a comprehensive framework for the strategic placement of on-street parking spaces by integrating microscopic traffic simulation with MCDM techniques. By distinguishing the impacts of parking on through and local traffic, the methodology identifies configurations that minimise disruptions to traffic flow while addressing parking demand efficiently. It ensures that the parking supply is increased only to the extent necessary to meet existing demand at optimal utilisation, thereby avoiding induced demand. The results underscore the importance of strategic parking placement, demonstrating that thoughtfully placed on-street parking spaces can alleviate congestion and cruising times, particularly in high-demand areas, without introducing undue walking distances. Findings revealed that the choice of the location of on-street parking placement is highly sensitive to the preferences of policymakers, such as minimising through traffic delays or reducing local traffic walking distances. The proposed methodology overcomes the limitations of existing reactive planning approaches by offering a proactive, impact-based decision-making framework.

However, several limitations in this study present opportunities for future work. First, the study evaluated parking placement at individual locations in isolation, overlooking the potential effects of parking placement at multiple locations simultaneously. Furthermore, the study considered a single destination, whereas real-world scenarios typically involve multiple destinations. Future research should investigate both the synergistic and competing effects of multiple destinations. Second, the study assumed uniform traffic and parking demand, though real-world demand is often spatially and temporally varied. Lastly, the study does not account for heterogeneity in vehicles, such as varying sizes, types, and parking durations, as well as drivers' parking preferences and search behaviours. Incorporating non-uniform demand, vehicle diversity, and behavioural variability would improve the realism and accuracy of the simulation framework. Despite these limitations, urban planners and decision-makers can leverage the framework to minimise the adverse impacts of parking by strategically placing on-street parking spaces and concentrating parking in low-impact areas to mitigate the negative effects of cruising for parking and improve overall traffic conditions.

References

Abdeen, M. A. R., Nemer, I. A., Sheltami, T. R., 2021. A balanced algorithm for in-city parking allocation: A case study of Al Madinah city. *Sensors*, 21(9), 3148.

Ceylan, H., Baskan, O., Ozan, C., Gulhan, G., 2014. Determining on-street parking places in urban road networks using meta-heuristic harmony search algorithm. *Computer-based Modelling and Optimization in Transportation*, Springer International Publishing, 163–174.

Gkini, C., Iliopoulou, C., Kepaptsoglou, K., Vlahogianni, E. I., 2018. Model for planning and sizing curbside parking lanes in urban networks. *Transportation Research Record: Journal of the Transportation Research Board*, 2672(20), 1–11.

Graham, D., Sarraf, S. K., Lundy, T., MohammadMehr, A., Uppal, S., Lee, T. Y., Zarkoob, H., Kominers, S. D., Leyton-Brown, K., 2020. Smarter parking: Using AI to identify parking inefficiencies in Vancouver.

Jakob, M., Menendez, M., 2019. Macroscopic Modeling of On-Street and Garage Parking: Impact on Traffic Performance. *Journal of Advanced Transportation*, 2019, 1–20.

Jelokhani-Niaraki, M., Malczewski, J., 2015. A group multicriteria spatial decision support system for parking site selection problem: A case study. *Land Use Policy*, 42, 492-508.

Levy, N., Martens, K., Benenson, I., 2013. Exploring cruising using agent-based and analytical models of parking. *Transportmetrica A: Transport Science*, 9(9), 773–797.

Lopez, P. A., Behrisch, M., Bieker-Walz, L., Erdmann, J., Flötteröd, Y.-P., Hilbrich, R., Lücken, L., Rummel, J., Wagner, P., Wießner, E., 2018. Microscopic traffic simulation using SUMO. *The 21st IEEE International Conference on Intelligent Transportation Systems*, IEEE.

Malczewski, J., Rinner, C., 2015. *Multicriteria Decision Analysis in Geographic Information Science*. Advances in geographic information science, 1 edn, Springer.

Mardiana, T. S., 2022. Parking needs in Kabupaten Blora: A case study of provincial highways. *KnE Social Sciences*.

Pan, S., Liang, Z., Chen, Q., 2019. When will car owners abandon car driving? Analysis based on a survey of the parking experiences of people in Changsha, China. *International Journal of Modern Physics B*, 33(15), 1950148.

Parmar, J., Das, P., Azad, F., Dave, S., Kumar, R., 2020. Evaluation of Parking Characteristics: A case study of Delhi. *Transportation Research Procedia*, 48, 2744-2756.

Plymouth Growth and Development Corporation (PGDC), 2014. Plymouth parking management plan: Final report. `https://tinyurl.com/ynhnjrme`. Accessed: 2025-04-16.

Pune Municipal Corporation, 2019. Urban street design guidelines. `https://tinyurl.com/4693cnru`. Accessed: 2025-04-16.

Saaty, T. L., 1980. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. McGraw-Hill, New York.

Shen, T., Hua, K., Liu, J., 2019. Optimized Public Parking Location Modelling for Green Intelligent Transportation System Using Genetic Algorithms. *IEEE Access*, 7, 176870-176883.

Shnewer, F. M., Handhal, M. M., Al. Saedi, A. S. J., 2021. Studying and evaluating the capacity of parking at commercial street in Amara city, Iraq. *IOP Conference Series: Materials Science and Engineering*, 1090(1), 012083.

Shoup, D., 2018. *Parking and the City*. Routledge.

Shu-chun, W., Jun, C., Hui, Z., 2008. The optimization model of setting the curb parking facilities. *2008 International Conference on Information Management, Innovation Management and Industrial Engineering*, 1, 416–421.