Systematic Review

Evaluating the Location of the Park-and-Ride System Using Multi-Criteria Methods: A Systematic Review

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Abstract: The park-and-ride (P&R) system is crucial for urban development and mobility as its strategic location helps to reduce congestion, reduce pollution, and encourage the use of public transport. Various methods have been proposed to determine its optimal location, ranging from algorithms and mathematical equations to multi-criteria approaches that consider a set of criteria and sub-criteria. Multi-criteria methods are diverse, and it is essential to know which methods have been applied to the optimal location of a P&R system. This study addresses the existing gaps in multi-criteria methods used in the localization of a P&R system through a systematic review based on the PRISMA protocol, examining 25 articles published between 2014 and 2024 in Science Direct, Scopus, and Web of Science (WOS). The results highlight that the multi-criteria AHP method is the most relevant and widely used. The criterion of accessibility to public transport is the most important criterion for setting up a P&R system in an urban environment. The flexibility of the multi-criteria AHP method, combined with other factors, makes it relevant in the process of P&R locations. However, the multi-criteria methods found in this research show that a wide range of multi-criteria methods have not yet been applied. Future research should focus on developing comprehensive systems that combine multiple multi-criteria methods, which is essential to optimize mobility solutions adapted to the specific characteristics and objectives of each city in establishing a P&R system.

Keywords: park and ride; systematic review; multi-criteria; transportation

1. Introduction

The P&R system is an urban mobility strategy that combines the use of private vehicles with public transport [1–3]. P&R allows users to park their car in a designated place (usually on the outskirts of the city or near a transport hub) and continue their journey to their final destination using public transport, such as buses, trams, or trains [4–7]. P&R is framed by the idea of intermodal travel, where the use of different transport modes is integrated

into a single journey [8–11]. The main objectives are to reduce vehicle congestion in central urban areas, minimize environmental pollution, and make the use of public transport and urban infrastructure more efficient [12–15].

Various factors, such as vehicle congestion [16], air quality [17], public transport accessibility [18], and land use planning [19], influence the decision-making process for integrating P&R into cities [20–23]. For example, several studies consider that the implementation of P&R as a mode of transportation provides an incentive to switch from private vehicles to public transportation, thus contributing to reducing traffic congestion in urban areas [24,25]. Improving air quality is also an incentive when integrating P&R since, by reducing traffic in cities, CO2 and greenhouse gases are also reduced, which causes air pollution levels to drop considerably [26,27]. Moreover, the accessibility of public transport can play an essential role in P&R facilities as it is integrated with the users' needs [28,29]. Another influential part of urban development is land use planning since implementing P&R facilities in optimal traffic flow locations will provide urban and integrated development of the transport systems passing through it [30,31].

One of the most critical components of the P&R system is its location [32]. Studies highlight that the location and placement of P&R facilities directly influence users and other modes of transport around them [33,34]. For example, well-located P&R systems adjacent to high-frequency public transport routes could directly influence the efficiency of user accessibility and minimize the likelihood of traffic congestion in city centers [35,36]. Population growth and urban sprawl also ensure the sustainability of future P&R facilities [37–46]. Likewise, the optimal site selection of P&R systems is influenced by factors such as proximity to residential areas and transportation hubs and accessibility to main roads [47,48]. The choice of location not only affects the accessibility of the system for users but also determines the effectiveness of the public transport system [49–51].

A suitable location should consider proximity to significant arteries entering the city, availability of land, and connection to efficient and frequent public transport lines. Users will be more willing to use the service if the location is optimal [52–54].

The implementation of a P&R system is one of the most crucial factors for its success and effectiveness [55]. A strategic location not only increases accessibility for users but also optimizes the performance of the public transportation system to which it is linked.

It is imperative that the P&R be located close to the city's main arteries and access roads. This makes it possible to detect the flow of vehicles before they enter congested areas, reducing traffic and pollutant emissions in the urban center [56–58]. With locations at crucial access points, drivers can easily transition to public transport without making significant deviations from their usual route.

The methods used to determine the optimal location of a P&R system are varied. Transport authorities and urban planners have adopted approaches that integrate mathematics, algorithms, and Geographic Information Systems (GISs) to make more informed and accurate decisions [59–61]. Mathematical methods allow planners to model and simulate different mobility scenarios. Computational algorithms such as genetic algorithms allow a vast number of possible locations and combinations to be explored, quickly assessing which ones offer the best results according to the stated objectives [62–66]. Geographic information systems (GIS) are also essential tools in this process GIS integrates spatial and demographic data to visualize and analyze the interaction between different geographical and social factors [67–69].

Multi-criteria methods play a crucial role in the selection of optimal locations for a P&R system [70–72]. These methods are instrumental in contexts where multiple factors must be considered simultaneously and where decisions cannot be based on a single criterion but should be based on a balanced combination of several criteria. Multi-criteria methods allow urban planners to evaluate and compare different location alternatives based on a set of pre-defined criteria. Within the MCDA, the Hierarchical Analysis Method (AHP), another technique within the multi-criteria methods, is TOPSIS (TOPSIS), which evaluates alternatives based on their proximity to the ideal solution. Furthermore, using multi-criteria

optimization models allows these methods to be integrated within a computational framework, where criteria can be modeled and optimized simultaneously [73–75]. These models not only identify optimal locations but can also simulate the impact of different decisions, providing decision-makers with a more complete picture of the potential consequences of their choices.

Although the siting of a P&R system can be performed using various methods, there is little evidence relating to the application of multi-criteria methods. It is essential to know which methods have been used and to what extent they have been applied in this area. Therefore, this research focuses on contributing in the following ways:

1. Literature review: A systematic review of existing approaches for the P&R locations based on multi-criteria methods is presented, thus addressing the gap identified in the current literature.
2. Effectiveness evaluation: Evaluations are carried out to measure the effectiveness of multi-criteria methods applied in P&R locations.
3. Innovative methodology: Innovative methods based on multi-criteria approaches are explored and demonstrated.

The primary aim of this study is to examine the various multi-criteria methodologies employed in P&R locations. It seeks to enhance the existing body of knowledge to establish a basis for future research and advancements in this field of study. This contribution is anticipated to enhance the criteria for selecting P&R system locations and to serve as a guideline for advancing this field. The analysis of the current literature identifies several research avenues for future studies in P&R locations.

This investigation is structured in the following manner: Section 2 outlines the methodology utilized, encompassing the systematic review approach and the criteria for study selection. Section 3 outlines the results derived from the study, highlighting the key findings and trends observed. Section 4 offers a comprehensive examination of the results, exploring their implications and linking them to prior studies. Finally, Section 5 presents the conclusions of the study, emphasizing the contributions made to the field and proposing potential avenues for future investigations.

2. Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology is a protocol that provides guidelines for transparently reporting the work of other authors [76,77]. This protocol can help researchers summarize the existing literature using an iterative, step-by-step, meticulous, explicit, and transparent process [78–80]. Although this protocol was first created for evidence-based medical research, its use has been extended to other areas [81,82]. Its application is essential in this context, as it facilitates a structured and reproducible analysis, thus increasing the validity and reliability of the results obtained. This methodological scheme is fundamental to ensure that the findings are accurate and replicable by other researchers in future research. In the study developed by the authors of [83], through the PRISMA protocol, 158 publications were analyzed to address critical knowledge gaps regarding digital technologies and technological advances in the transportation sector. Through the PRISMA protocol, different methods for anomaly detection for Connected and Autonomous Vehicles (CAVs) can also be analyzed [84]. Mason et al. [85], through 6 databases (CINAHL, EMBASE, EMCARE, Medline, PsycINFO, Web of Science), conducted a systematic review to determine what measures are used to assist parents whose children require interhospital neonatal transport; in total, 831 articles were chosen, from which 61 articles were selected. José Gonçalves Henriques et al. [86] included 74 articles between 2018 and 2023 to determine how artificial intelligence (AI) technologies are currently used in the tourism sector and how they can be used in the future to improve the customer experience when interacting with different aspects of tourism. Mohammad et al. [87] conducted a PRISMA systematic review to facilitate academics and practitioners' access to smart transportation and mobility practices in Saudi Arabia. Likewise, the systematic review and the PRISMA protocol were employed to im-

prove decision-making in transportation problems. For this purpose, 58 articles published between 2003 and 2019 were considered.

The PRISMA protocol, in general, facilitates obtaining information in different areas of research. Based on a systematic search, the protocol helps perform an exhaustive database review [88]. This allows researchers to obtain synthesized, accurate, and interesting results [89].

2.1. Research Methodology

A systematic search was carried out in September 2024 using the PRISMA protocol as the primary source of information. The information was composed of several articles published between 2014 and 2024 (see Table A1). The study was conducted in three databases (Scopus, Web of Science, and Science Direct), employing advanced searches (see Table 1). Different sets of keyword strings were used in these searches. In the Scopus and Science Direct databases, 137 and 103 articles were obtained, respectively. Likewise, 9 articles were obtained from the Web of Science (WOS), identifying 249 articles.

Table 1. Advanced search within the database.

Database	Advanced Search
Scopus	"Multi-Criteria" AND "methods" AND "Park and Ride"
Science Direct	"Multi-Criteria" AND "methods" AND "Park and Ride"
WOS	((ALL = (Multi Criteria)) AND ALL = (methods)) AND ALL = (Park and Ride)

2.2. Screanning Criteria

All articles on the multi-criteria methods that integrate P&R were selected. The screening criteria's first step was determining which articles were duplicates. Overall, 19 articles were excluded because of duplication. Next, records that were not relevant were filtered out, i.e., articles that were part of review articles, book chapters, books, conference abstracts, editorials, and encyclopedias were excluded, as well as articles that did not belong to the English language. Finally, articles that do not use multi-criteria methods in P&R scenarios were excluded. Thus, 169 articles were excluded (see Figure 1).

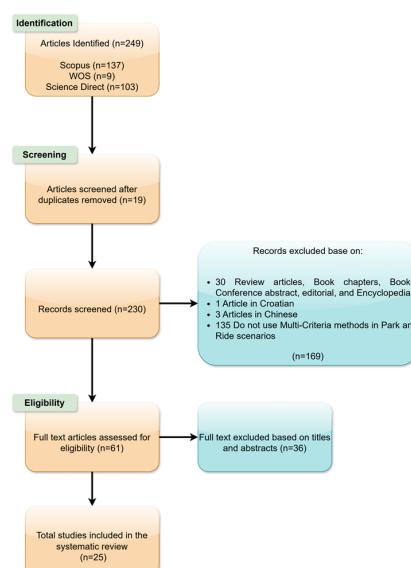**Figure 1.** PRISMA protocol flow diagram.

2.3. Eligibility Criteria

Research articles containing any multi-criteria methods applied to P&R were considered eligible. Figure 1 shows that full texts were excluded (*n* = 36) based on titles and

abstracts. Although some articles referred to implementing multi-criteria methods, their application was not related to the main area of study, P&R. The same happened the inverse way, where there was research dedicated to Park and Ride. However, it omitted or did not establish the use of multi-criteria methods as a methodology.

2.4. Study Selection

In total, 249 articles were deemed suitable based on these criteria. A total of 19 articles were removed because they were found to be duplicates. After carefully examining the records, a total of 169 items were eliminated due to the presence of elements that fulfilled the exclusion criteria. After excluding 36 publications based on evaluating their titles and abstracts, 25 papers that satisfied the inclusion criteria were chosen and incorporated into the systematic review.

In order to establish the criteria for both inclusion and exclusion, Table 2 summarizes the main points to be taken into account for this systematic review.

Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Articles written in the English language.	Articles not written in English.
The source type is an article within a database (Scopus, Science Direct, and WOS).	Duplicate articles.
Multi-criteria methods applied to P&R scenarios.	Review articles, book chapters, books, conference abstracts, editorials, and encyclopedias.

3. Results

This section describes the 25 articles included in the systematic review. First, the articles are distributed over time, i.e., an overview of the years with the most publications on multi-criteria methods applied to deterrent parking scenarios. Second, the distribution of articles by author, journal, and conference proceedings is elaborated, and a breakdown of the indexing is presented. Finally, the distribution of articles by type of multi-criteria method used is shown.

3.1. Articles over Time

Table 3 presents a summary of the number of articles published per year. The results show that the year with the most studies on multi-criteria methods applied to P&R scenarios is 2023, with six articles, followed by 2022, 2020, and 2014, with three articles each. In third place are 2024, 2021, 2016, and 2015, with two articles each. In fourth place, 2019, 2028, 2026, and 2015 have only one article each. Finally, the year 2017 has zero articles.

Table 3. Analysis of articles by year of publication.

No. of Articles	Year	Percentage%
2	2024	8.00%
6	2023	24.00%
3	2022	12.00%
2	2021	8.00%
3	2020	12.00%
1	2019	4.00%
1	2018	4.00%
0	2017	0.00%
2	2016	8.00%
2	2015	8.00%
3	2014	12.00%
Total 25		100%

3.2. Distribution of Articles by Author, Journal, and Conference Proceedings

The 25 articles in the systematic review were distributed among authors, journals, and conference proceedings. Table 4 shows the first distribution, consisting of 19 authors, where the author Ortega, Jairo has the authorship of six articles, while Abdeen, Mohammad A R has two articles. The rest of the authors have published only one article concerning implementing multi-criteria methods applied to P&R scenarios.

Table 4. Distribution of articles by author.

Author	No. of Articles	Percentage%
Ortega, Jairo	6	24.00%
Pitale, Aditya Manish	2	8.00%
Abdeen, Mohammad A R	1	4.00%
Bakioglu, Gozde	1	4.00%
Barauskas, Andrius	1	4.00%
Blad, Koen	1	4.00%
Cai, Mingming	1	4.00%
Chen, Zhirong	1	4.00%
Fierek, Szymon	1	4.00%
Ignaccolo, Matteo	1	4.00%
Moslem, Sarbast	1	4.00%
Namdeo, A	1	4.00%
Novak, David C	1	4.00%
Palevicius, Vytautas	1	4.00%
Putro, Heru Purboyo Hidayat	1	4.00%
Salavati, Alireza	1	4.00%
Shi, Feng	1	4.00%
Yaliniz, Polat	1	4.00%
Żak, Jacek	1	4.00%
Total	25	100%

Journals and conference proceedings constitute the second distribution (see Table 5); of the 100% of published articles concerning multi-criteria methods in P&R scenarios, 8.70% belong to the journals *Journal of Urban Planning and Development*, *Sustainability*, *Technological Forecasting and Social Change*, and *Transportation Research Part C: Emerging Technologies*. The remaining journals have only one publication, resulting in only 4.35% of the published articles. Regarding conference proceedings, *Transportation Research Procedia* has two publications. Therefore, it has 100% of the published articles since it is the only conference proceedings.

Table 5. Distribution of papers by journal.

Distribution of Papers by Journal			
Name of the Journal	Database	Number of Publications	Percentage
Multimodal Transportation	Scopus	1	4.35%
Gradjevinar	Scopus	1	4.35%
Transportation Research Procedia	Scopus	1	4.35%
Urban, Planning and Transport Research	Scopus	1	4.35%
Transport Policy	Scopus and WOS	1	4.35%
Algorithms	Scopus and WOS	1	4.35%
Arabian Journal for Science and Engineering	Scopus and WOS	1	4.35%
Case Studies on Transport Policy	Scopus and WOS	1	4.35%

Table 5. *Cont.*

Distribution of Papers by Journal			
Name of the Journal	**Database**	**Number of Publications**	**Percentage**
CITIES	Scopus and WOS	1	4.35%
IEEE Access	Scopus and WOS	1	4.35%
Journal of Public Transportation	Scopus and WOS	1	4.35%
Journal of Urban Mobility	Scopus and WOS	1	4.35%
PROMET-TRAFFIC\& TRANSPORTATION	Scopus and WOS	1	4.35%
Research in Transportation Business & Management	Scopus and WOS	1	4.35%
Symmetry	Scopus and WOS	1	4.35%
Journal of Urban Planning and Development	Scopus and WOS	2	8.70%
Sustainability	Scopus and WOS	2	8.70%
Technological Forecasting and Social Change	Scopus and WOS	2	8.70%
Transportation Research Part C: Emerging Technologies	Scopus and WOS	2	8.70%
Total		23	100%
Total index in Scopus		23	
Total index in WOS		19	

Concerning the database, it was identified that most journals are indexed in Scopus and WOS. In contrast, only four journals (*Transportation Research Procedia*; *Urban, Planning and Transport Research*; *Gradjevinar*; and *Multimodal Transportation*) are just indexed to Scopus. Likewise, the *Transportation Research Procedia* conference proceedings are only indexed in Scopus (See Tables 5 and 6).

Table 6. Distribution of papers by conference proceedings.

Conference Proceedings			
Name of the Journal	**Database**	**Number of Publications**	**Percentage**
Transportation Research Procedia	Scopus	2	100%
Total		2	100%
Total index in Scopus		2	
Total index in WOS		0	

3.3. Distribution Articles by Multi-Criteria Methods

Table 7 presents the different methods used for multi-criteria in P&R scenarios. The results show that the Analytic Hierarchy Process (AHP) is the most used methodology, with a contribution of 26.9%, while the combination of AHP and Best Worst Method (BWM) is the second approach most used by the researchers, with 7.7%. The other methods are used only once.

The reason for using the AHP method is its versatility in helping solve decision-making problems. An example is when selecting alternatives based on a series of criteria or selection variables, usually hierarchical, that often conflict with each other. Several authors have also seen an advantage in using AHP with other methods such as Analytic Network Process (ANP), ELimination Et Choix Traduisant la REalité (ELECTRE), Weighted Average (WA), and Geographic Information Systems/Multi-Criteria Decision-Making (GIS-MCDM).

Many authors employ the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) because it is based on the principle that a specific alternative should be situated at the minimum distance from a positive ideal solution and at the maximum distance from a negative ideal solution. Combining TOPSIS with other methodologies, such as Grey Relational Analysis (GRA), Relative to an Identified Distribution Integral

Transformation (RIDIT), Simple Additive Weighting (SAW), and Complex Proportional Assessment (COPRAS), highlights its versatility and effectiveness.

Geographic Information Systems (GISs) are distinguished by their flexibility and capacity to use spatial analysis and decision assistance to combine and visually show results.

Table 7. Articles distributed by multi-criteria method.

Multi-Criteria Method	Number of Publications	Percentage%
AHP	7	28%
AHP and BWM	2	8%
AHP and ANP	1	4%
AHP and ELECTRE	1	4%
AHP and WA	1	4%
Bi-level programming model	1	4%
Delphi	1	4%
Evaluation based on Distance from Average Solution (EDAS)	1	4%
Full Consistency Method (FUCOM)	1	4%
Geographic Information Systems-Multi-Actor Multi-Criteria Analysis (GIS-MAMCA)	1	4%
GIS-MCDM and AHP	1	4%
(GRA, RIDIT, and TOPSIS)	1	4%
Hierarchical Optimal Routing and Parking Algorithm (HORPA)	1	4%
Multi-Criteria Analysis (MCA)	1	4%
Multi-criteria assessment framework	1	4%
(SAW, COPRAS, TOPSIS)	1	4%
Stepwise Weight Assessment Ratio Analysis (SWARA)	1	4%
The paper utilizes a Weighted Linear Combination (WLC)	1	4%
Total	25	100%

4. Discussion

This section presents an overview of the different multi-criteria methods applied in P&R localization. Each method provides a comprehensive insight into the theoretical implications and applications that other researchers have used.

This section is divided into several subsections. First of all, there is the section called Overview of Multi-Criteria Methods Applied in P&R Locations, where an overview of the different methods used for P&R locations is given. Each method also shows the studies that have used the multi-criteria method and the results obtained. Secondly, the Comparative Analysis Method subsection presents the strengths and limitations of each method used in the literature. In order to show specific cases of the use of the multi-criteria methods, in the section called Case Studies, a specific description of several case studies where the most used multi-criteria methodology was applied is given. Finally, in the last section, future works and limitations are presented based on the results obtained.

4.1. Overview of Multi-Criteria Methods Applied in P&R Locations

Park-and-ride facilities have grown rapidly and significantly in recent times. Studies have incorporated various methodologies to expand the supply of park-and-ride facilities. The following is a discussion of different methods employed in this field. An evaluation of each approach is also included.

- Analytic Hierarchy Process (AHP): The AHP is a method based on the estimation and knowledge of the decision-makers. This method allows appropriate decisions to solve complex problems. Thus, several studies have used this multi-criteria method as a reference in methodology. In the studies developed by Ortega et al. [90–93], the AHP method was used to evaluate and analyze the problems with the location of P&R and

establish a P&R system. The author highlights that accessibility to public transport is the most crucial factor in establishing a P&R system. This means that for a P&R system to be effective, it must be strategically located near efficient public transport connections, making it easy for users to transition between their private vehicle and public transport modes. The AHP method was also utilized to create a location-based service (LBS) designed to help P&R users [94]. Ignaccolo et al. [95] introduced a multi-criteria approach (AHP) that involves citizens in selecting transportation choices related to the connectivity between a subway station and a park-and-ride location. The study carried out by Salavati et al. [96] focused on establishing suitable criteria for a systematic evaluation and prioritization of several potential corridors for public transport investment. Applying the AHP method revealed that P&R infrastructures prioritized improving the state of essential corridors. The range of applications of AHP is noticeable in its integration with various multi-criteria methodologies, including BWM, ANP, ELECTRE, WA, and GIS-MCDM GIS-MCDM [97–105]. The widespread use of the AHP in conjunction with other methods demonstrates its superiority in studies related to P&R scenarios.

- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS): A prominent multi-criteria method in P&R scenarios is the use of TOPSIS, as demonstrated by the studies by Pitale et al., 2023. [102] and Palevicius et al., 2016. [103]. This method selects alternatives that are the minimum distance from the positive ideal solution and the maximum distance from the negative ideal solution.
- Geographic Information Systems (GISs): The use of Geographic Information Systems (GISs) in multi-criteria analysis provides an advantage in terms of data visualization. Through spatial analysis and decision support tools, it is possible to explicitly visualize the results of P&R implementation. The consideration of various criteria, such as accessibility, user demand, and connectivity to public transport, facilitates the identification of optimal locations for P&R and public transport facilities, as evidenced in various specialized studies in urban planning and transport [101,106].
- Bi-level programming model: The methodology used in the studies by Barauskas et al. [107] shows how the integration of the b of the bi-level programming model technique decreases overburden flow and increases customer surplus, consequently, via artificially optimizing the elastic demand and P&R selection.
- Delphi: By combining the thoughts of specialists from different domains in P&R topics, Delphi is an efficient and economical way to assess pertinent indicators [108–111].
- Evaluation based on Distance from Average Solution (EDAS): The EDAS method may be used to analyze and determine the essential criteria that support the efficient operation of private and public transportation systems. This method also helps in categorizing these conceptual locations as implementing P&S lots [109,110].
- Full Consistency Method (FUCOM): FUCOM was the strategy that Moslem et al. [108] utilized in order to understand which criteria are the most significant for the placement of a P&R system in Cuenca, Ecuador.
- Hierarchical Optimal Routing and Parking Algorithm (HORPA): The study conducted by Abdeen et al. [109] employed HORPA to address routing and parking issues to mitigate traffic congestion and minimize trip time [111].
- Multi-Criteria Analysis (MCA): As an effective multi-criteria tool, MCA can support decision-making for multi-faceted policy decisions involving many stakeholders with different objectives and priorities. Such is the case for an innovative change in a state transportation project prioritization process such as P&R [112].
- Multi-criteria assessment framework: Developing a methodological approach for multi-dimensional spatial analysis that addresses the possibilities of deploying public access charging opportunities for Plug-in Electric Vehicle (PEV) users is necessary. This approach can be developed using a multi-criteria assessment framework, focused on the development of public charging infrastructure, both for the provision of charging

facilities on-street and in residential areas, as well as the implementation of fast charging stations in parking centers (P&R) [113].

- Stepwise Weight Assessment Ratio Analysis (SWARA): A novel multi-criteria method, SWARA, is proposed to select and prioritize sustainable transport strategies. Through SWARA, the relative importance of criteria can be quantified, and decision-makers opinions can be integrated to specify initial priorities and relative importance based on their judgments [112,114].
- Weighted Linear Combination (WLC): In the study carried out by Chen et al. [115], WLC was used to determine the best station for the P&R user output.

It is interesting to note that when using different multi-criteria methods on the location of a P&R system, they can vary in their ranking [116]. Table 8 shows how a set of criteria for P&R location varies depending on the method used [90–93,97,108].

Table 8. Weighted scores of the P&R facilities using different multi-criteria methods.

Criteria	Description	AHP Rank	F-AHP Rank	BWM Rank	G-AHP Rank	FUCOM Rank
C1	Distance	5	5	5	4	5
C2	Conditions of traffic along the route (origin-destination)	6	6	6	5	6
C3	Accessibility of public transport	1	1	1	1	1
C4	Transport aspects	3	3	3	3	3
C5	Economic aspects	4	2	4	6	4
C6	Environmental aspects	2	4	2	2	2

The studies by Ortega et al. [90–93,97] and Moslem et al. [108] presented in Table 8 identify six main criteria for the location of a P&R system. By applying different multi-criteria methods to determine which criterion is the most relevant, it was found that, regardless of the method used, criterion C3, 'Accessibility to public transport', is always the most important. This indicates that accessibility to public transport should be a priority consideration when selecting the location of a P&R system.

Furthermore, Table 8 shows that the second most crucial criterion is usually 'Environmental aspects' in almost all multi-criteria methods, except when the F-AHP method is applied, where it ranks fourth in relevance. This analysis is interesting, as the criteria ranking varies according to the multi-criteria method used, except for the main criterion, which always remains the most important.

4.2. Comparative Analysis Method

Multi-criteria methodologies, being methodologies widely used in various areas, also have limitations. Especially when it comes to the localization of P&Rs. Table 9 presents the main strengths and limitations of the methods used in the literature.

The systematic review revealed that the Analytic Hierarchy Process (AHP) method provides functions that allow appropriate decisions to resolve a complex problem. Although AHP has limitations, it allows stakeholders to create and determine several projects and thus generate development according to the needs of the analyzed areas. The flexibility of the AHP method allows the development of hybrid methods. Hybrid methods, such as AHP and BWM, ANP, or ELECTRE, offer advantages of global analysis and ranking in decision-making compared to non-combined methods [67].

Table 9. Multi-criteria methods strengths and limitations.

Multi-Criteria Method	Strengths	Limitations
AHP	• Facilitates direct prioritizing by stakeholders. • Versatile across many urban situations.	• Personal, affected by the opinions of those making the decisions. • Possibility of discrepancy between contexts.
GIS	• Allows for real-time spatial insights. • Great for visualizing and analyzing spatial data.	• Big on data, needs a lot of input, and does not work well with non-spatial criteria.
TOPSIS	• An approach that uses closeness to an ideal answer as its guiding principle. • Optimal for accurate quantitative ranking.	• Insufficient for use with subjective and qualitative evaluations. • Risks oversimplifying complex situations.
FUCOM	• Consistently assigns weights to criteria. • Trusted for making decisions requiring pinpoint accuracy.	• Inflexible, having little room for adjustment to other standards. • Complex integration with more adaptable systems.
BWM	• Generates accurate weight calculations using a few pairwise comparisons • Lessens the likelihood of inconsistent weighing of criterion.	• Judgment is heavily needed to determine which criteria are the "best" and which are the "worst." • Possibility of oversimplifying complex issues.
ELECTRE	• Useful in cases when requirements are incompatible. • Intended for use in evaluating options with complicated interrelationships.	• Adding criteria and options makes things more complicated. • Making decisions based on interpretations might be difficult.
Delphi	• Makes complicated decisions by relying on expert agreement. • Helpful in finding appropriate criterion indicators.	• Complex, time-consuming, and subject-matter expert availability is key • Restricted to standards set by experts, which can leave out essential considerations.
EDAS	• Simple and effective for arranging choices • Regardless of the size of the city, it is suitable for different P&R location evaluations.	• Constraints on how criteria and subjective judgments may be combined • Situations requiring geographical analysis are when they fall short.
WLC	• Easy to use and understand when comparing options • Compatible with a variety of additional MCDM techniques.	• Not very good at managing complicated connections between criteria. • Without extensive modification, the criterion weights are assumed to be equivalent.

4.3. Case of Studies

The AHP method, as shown in the previous section, is the most widely used multi-criteria method for solving complex decision problems. Several cities around the world have implemented this method, an example of which is cities such as Cuenca, Ecuador, where P&R locations were evaluated based on accessibility, environmental impact, and cost. The data indicated a 20% increase in the use of public transport among P&R users, accompanied by a 15% decrease in urban congestion near the facility locations [93]. Another example is Budapest, Hungary, where, through the AHP method, experts agreed that by implementing P&R near public transport, vehicle traffic would be reduced by 30% [58].

4.4. Future Works and Limitations

In general, the overall use of this method is more holistic and compatible with other multi-criteria methods due to its versatility compared to other methods.

Future studies should explore the integration and combination of more multi-criteria methods in order to encompass the integration of more points of view and thus effectively take into account the opinions of experts from various fields in P&R areas. It is also

recommended that rigorous tests be carried out to evaluate the safety of the methods in real-world conditions.

One of the issues faced throughout the development of this study was the process of selecting articles based on the PRISMA criteria. Furthermore, the assessment and examination of articles using specific search terms might influence the accuracy of the review article. An investigation into methods for overcoming these limitations may be a captivating extension of this study.

5. Conclusions

In the P&R system, its location was studied as the success of the system depends on it. The multi-criteria method provides a combination of criteria and sub-criteria to guide researchers and transport officials in their optimal siting. To better understand the implementation and use of multi-criteria methods, this study focused on the various multi-criteria methods applied through a systematic review.

This study allowed the development of a PRISMA protocol to identify the multi-criteria methods used to evaluate the location of P&R systems. This systematic approach is crucial as it provides a consistent and uniform framework for examining and contrasting various methodologies used in different articles. This is especially important in the context of multi-criteria methods, where multiple factors and variables must be considered, such as accessibility, cost, environmental impact, and user demand. The results revealed a remarkable trend in P&R location research between 2014–2024, showing a growing interest of researchers and underlining the relevance of P&R systems in the field of mobility. A variety of methods used to establish localization were also observed, with the AHP method standing out as the most widely used due to its flexibility, adaptability, accuracy, efficiency, and simplicity.

The research conducted in this article on the location of a P&R system in an urban environment underlines that the primary factor for establishing a P&R system in an urban environment is accessibility to public transport. Studies that have implemented multi-criteria methods identify public transport as the most significant element, with sub-criteria such as frequency of service. In contrast, the lowest priority criterion is the location of the system.

However, other multi-criteria methods have not yet been used and should be explored to continue advancing research on the location of P&R systems in urban environments. In this sense, this research has provided new perspectives by applying multi-criteria methods in this context.

This study contributes to a better understanding of the various methods and systems used in the siting of a P&R system. By providing a comprehensive analysis of existing approaches, it establishes a solid foundation for future research. Subsequent studies can build on this work, refining and extending the multi-criteria methods used to identify, explore, and analyze optimal locations for P&R systems. This groundwork will not only facilitate more effective site selection strategies but will also encourage the development of innovative techniques to meet the evolving challenges of urban transport planning. The majority of the research results found that public transport is the most essential factor in setting up a P&R system. Future work should be conducted on the study of public transport as an integrated system that should include the P&R system.

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Appendix A

Table A1. Research articles about multi-criteria in park-and-ride (P&R) scenarios.

Author and Year	Article	Research Focus	Findings	Multi-Criteria Method
Ortega et al., 2023 [90]	A two-phase decision making based on the grey analytic hierarchy process for evaluating the issue of park-and-ride facility location	This study proposes a two-level scale approach using the analytical hierarchy process to prioritize P&R location criteria, building on previous research using multi-criteria methods.	The efficacy and usefulness of the proposed multi-criteria method to determine the hierarchy of criteria from most to least important for P&R system location.	AHP
Ortega et al., 2023 [91]	An Integrated Approach of the AHP and Spherical Fuzzy Sets for Analyzing a Park-and-Ride Facility Location Problem Example by Heterogeneous Experts	Apply the AHP method to a P&R system location problem to evaluate the results of participating transportation experts from various backgrounds.	The results provide urban transport planners with a clear directive that the installation of the P&R system should occur simultaneously with the optimization of public transport.	AHP
Ortega et al., 2023 [92]	Decision support system for evaluating park & ride system using the analytic hierarchy process (AHP) method	Initially, it identifies the most prominent attributes of the P&R system. Furthermore, it is important to construct a set of criteria from a fresh scientific standpoint. Finally, a multi-criteria technique like the Analytic Hierarchy Process (AHP) can be used to precisely determine the location of the P&R system from a methodological perspective.	Transportation planners consider public transportation accessibility the most crucial condition for building a P&R system.	AHP
Putro et al., 2021 [94]	Development of multi-actor multi-criteria analysis based on the weight of stakeholder involvement in the assessment of natural-cultural tourism area transportation policies	Establish a multi-actor, multi-criteria analysis method that weighs stakeholder involvement when making transportation policy decisions for sustainable mobility in protected natural–culture tourism areas.	The results show that the weighting of stakeholders with the AHP method produced smaller standard deviations, i.e., the assessments are more consistent and coherent among stakeholders.	AHP
Ortega et al., 2020 [93]	An Integrated Approach of Analytic Hierarchy Process and Triangular Fuzzy Sets for Analyzing the Park-and-Ride Facility Location Problem	It is proposed that a multi-criteria decision-making methodology (MCDM) be integrated to evaluate the location of P&R system facilities.	By incorporating expert opinions and a fuzzy environment, the methodology generates better flexibility and accurate evaluation compared to the traditional AHP method.	AHP
Ignaccolo et al., 2019 [95]	Public Engagement for Designing New Transport Services: Investigating Citizen Preferences from a Multiple Criteria Perspective	Examine public preferences using a multi-criteria approach to gather data that will help build a transportation service that is both technically sound and widely accepted.	Identification of citizens' perceptions in order to design a new transportation service and have a global vision of their preferences.	AHP

Table A1. *Cont.*

Author and Year	Article	Research Focus	Findings	Multi-Criteria Method
Salavati et al., 2016 [96]	Applying AHP and Clustering Approaches for Public Transportation Decisionmaking: A Case Study of Isfahan City	Establish suitable standards for a methodical process to assess and rank several public transportation routes concurrently in order to satisfy travel demand while accounting for the availability of the current public transportation system and the state of the road network.	The comprehensive assessment of corridors that are suitable for implementing each policy as a practical alternative. Essentially, each corridor may be an ideal location for implementing certain guidelines. These guidelines should be thoroughly analyzed regarding technical and economic feasibility at the installation and performance levels.	AHP
Yaliniz et al., 2022 [52]	Evaluation of Park-and-Ride Application with AHP and ANP Methods for the City of Eskisehir, Turkey	Perform a multi-criteria evaluation using methods such as AHP and ANP to apply park-and-ride facilities.	The park-and-ride application ensured a clear superiority compared with other alternatives.	AHP and ANP
Ortega et al., 2021 [98]	An Integrated Multi Criteria Decision Making Model for Evaluating Park-and-Ride Facility Location Issue: A Case Study for Cuenca City in Ecuador	Implement a combined model of the Analytic Hierarchy Process (AHP) and the Best Worst Method (BWM) to evaluate the most critical factors associated with the location of a park-and-ride facility.	The outcome indicates that using multi-criteria methods is a planning instrument for professionals when developing a P&R system.	AHP and BWM
Ortega et al., 2020 [97]	Using Best Worst Method for Sustainable Park and Ride Facility Location	Assess the issue of the P&R system's facility location from the perspective of the experts.	The findings indicated that the most critical factor in the issue of the location of P&R facilities is the "accessibility of public transportation".	AHP and BWM
Żak et al., 2015 [99]	Application of AHP and ELECTRE III/IV Methods to Multiple Level, Multiple Criteria Evaluation of Urban Transportation Projects	Evaluate urban transportation projects using multi-criteria decision-making methods.	The Analytic Hierarchy Process (AHP) and ELimination Et Choix Traduisant la REalité (ELECTRE) methods are successfully applied to analyze and rank 18 transportation projects.	AHP and ELECTRE
Fierek et al., 2020 [116]	Multiple criteria evaluation of P&R lots location	This article concentrates on substantiating the P&R car park location employed by the transport system authorities in Bydgoszcz, Poland.	A solution to the P&R localization problem is presented.	AHP and WA
Shi et al., 2014 [105]	Optimization method of alternate traffic restriction scheme based on elastic demand and mode choice behavior	Develop a bi-level programming model for optimizing alternate traffic restriction (ATR) schemes considering the proportion of restricted automobiles and the restriction districts.	Develop an optimization method for Alternative Traffic Constraint (ATC) schemes.	Bi-level programming model
Cai et al., 2023 [106]	Developing a multi-criteria prioritization tool to catalyze TOD on publicly owned land areas	Created a multi-criteria prioritization technique to identify attractive transit-oriented development (TOD) sites and tested it at three Washington State Department of Transportation park-and-ride sites.	Using the suitability scores calculated through the Delphi method, potential TOD sites can be prioritized for further review.	Delphi
Barauskas et al., 2018 [107]	Ranking conceptual locations for a park-and-ride parking lot using EDAS method	This study aims to determine the essential factors contributing to the efficient operation of private and public transportation systems. These factors will be ranked using the Evaluation based on the Distance from Average Solution (EDAS) method, a multiple-criteria decision-making approach.	The results suggest that this method (EDAD) for developing P&R parking lots is easy to accomplish, requires little data, and can be used to various cities regardless of size, sprawl, population, or transport networks.	EDAS
Moslem et al., 2024 [108]	Optimizing park-and-ride location selection using the novel parsimonious full consistency method: Insights from Cuenca, Ecuador	Use multi-criteria methods to understand which criteria are most important for P&R location.	Using FUCOM improves the efficiency and precision of P&R system placement criteria.	FUCOM

Table A1. *Cont.*

Author and Year	Article	Research Focus	Findings	Multi-Criteria Method
Blad et al., 2022 [104]	A methodology to determine suitable locations for regional shared mobility hubs	The implemented technique GIS Multi-Criteria Analysis (MCA) is utilized in the Rotterdam region (The Netherlands) to assess the effectiveness of the methodology in facilitating policy implementation.	The methodology is appropriate for addressing the problem of determining location suitability, as it yields intuitive outcomes.	GIS-MAMCA
Pitale et al., 2022 [116]	GIS-MCDM-Based Approach to Determine the Potential Facility Locations for Park-and-Ride Facilities along Transit Corridors	This work introduces a spatial multi-criteria decision-making (MCDM) technique, specifically the GIS-MCDM approach, to determine viable locations for P&R facilities by taking into account various criteria.	The results indicate that the criterion of a P&R facility serving the maximum population had the greatest significance in identifying the potential locations.	GIS-MCDM and AHP
Pitale et al., 2023 [102]	Factors influencing choice riders for using park-and-ride facilities: A case of Delhi	This study seeks to ascertain the significance of various service aspects in motivating choice passengers to choose park and ride (P&R) as a dependable and environmentally friendly means of transportation instead of driving alone.	The findings indicate that cleanliness is the primary element influencing riders' choice, with safety at the park-and-ride facility being the second most important consideration.	GRA, RIDIT, and TOPSIS
Abdeen et al., 2023 [109]	A Hierarchical Algorithm for In-city Parking Allocation Based on Open Street Map and AnyLogic Software	Introduces a hierarchical optimal algorithm, known as HOPRA, which utilizes the concept of multi-criteria decision and historical traffic data to address the routing and parking problem.	The results demonstrate that the HORPA algorithm outperforms at mitigating traffic congestion on roads and minimizing journey driving time.	HORPA
Novak et al., 2015 [110]	Evaluating the outcomes associated with an innovative change in a state-level transportation project prioritization process: A case study of Vermont	Use a mixed methodological approach to empirically evaluate the innovative change's outcomes for three objectives: (1) to make the project prioritization process more transparent, (2) to improve it by incorporating well-defined, objective evaluation criteria into the decision-making process, and (3) to reduce local jurisdictional inequality in transportation project funding.	The novel project prioritizing process improvement met objectives 1 and 2, but not 3.	MCA
Namdeo et al., 2014 [111]	Spatial planning of public charging points using multi-dimensional analysis of early adopters of electric vehicles for a city region	A geospatial modeling approach is introduced to investigate the potential for deploying public access charging opportunities for consumers based on the intensity of plug-in electric vehicle (PEV) adoption and trip characteristics.	Effectively spreading PEVs in urban regions worldwide requires focusing on the latter group's needs and creating a public charging infrastructure for residential street overnight charging and fast charging at P&R facilities.	Multi-Criteria Assessment Framework
Palevicius et al., 2016 [103]	Developmental analysis of park-and-ride facilities in Vilnius	The purpose of this article is to develop a multi-criteria methodology for the selection of P&R lot sites and to conduct a developmental analysis of P&R facilities	Multi-criteria methods have been employed to determine and present the developmental priorities and a strategy for the implementation of the proposed solutions.	SAW, COPRAS, TOPSIS
Bakioglu 2024 [112]	Selection of sustainable transportation strategies for campuses using hybrid decision-making approach under picture fuzzy sets	The research aims to propose a novel hybrid multi-criteria decision-making (MCDM) method that integrates Stepwise Weight Assessment Ratio Analysis (SWARA) in order to select and prioritize sustainable transportation strategies within the campus environment.	The results suggest that short-term strategies, such as reorganizing campus parking and providing facilities for bike commuters, were the most effective due to their immediate feasibility and cost-effectiveness.	SWARA
Chen et al., 2014 [115]	Development of location-based services for recommending departure stations to park and ride users	Establish a location-based service (LBS) application that assists P&R users in selecting the most suitable train station to reach their destination by employing a multi-criteria decision-making model.	The results show the calculation to determine the ability of P&R to be integrated with other criteria to generate optimal stations.	WLC

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