

Which Bus Corridors Should Receive Dedicated Bus Lanes? A Multi-Objective Decision Intelligence Approach for Istanbul

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ARTICLE INFO	ABSTRACT
Article history: Received 3 May 2026 Received in revised form 16 July 2026 Accepted 19 August 2026 Available online 31 August 2026 Keywords: Dedicated Bus Lanes; Decision Intelligence; Multi-objective Decision-making; Corridor Prioritisation; Public Transport Planning; Istanbul.	Urban road space is a scarce resource, and dedicated bus lanes cannot be implemented across all corridors in large metropolitan areas. Consequently, transport authorities must determine where road-space reallocation will generate the greatest public transport benefits. This study develops a multi-objective decision intelligence framework for prioritising dedicated bus-lane implementation in Istanbul by integrating four assessment dimensions: feasibility, operational need, strategic importance, and road-space impact. Candidate corridors are identified and evaluated using publicly available transport, traffic, and spatial datasets, including GTFS service information, congestion conditions, network connectivity, accessibility, and implementation constraints. A multi-objective decision model is then applied to generate a transparent corridor-priority ranking. The analysis identifies four Tier 1 corridors as the strongest candidates for dedicated bus-lane implementation: Altunizade-Ümraniye, Kadıköy-Kozyatağı-Ataşehir, Mecidiyeköy-Levent-Maslak, and Avcılar-Esenyurt-Beylikdüzü. The findings demonstrate that corridor prioritisation is influenced not only by congestion levels but also by service intensity, multimodal connectivity, strategic network function, and implementation feasibility. By incorporating explainable evaluation mechanisms, the framework provides transparent justification for corridor selection and supports evidence-based road-space allocation decisions. The proposed methodology offers a practical and transferable decision-support tool for prioritising bus-priority investments under constrained urban road-space conditions.

1. Introduction

Urban transport systems worldwide face increasing challenges arising from rapid urbanisation, population growth, rising travel demand, and limited road-space availability [1, 2]. In many large metropolitan areas, traffic congestion has become a persistent obstacle to efficient and sustainable mobility [3], reducing the attractiveness and effectiveness of public transport services. Buses are particularly vulnerable to congestion because they typically operate within mixed traffic conditions [4], where delays experienced by general traffic are directly transferred to public transport operations. As a result, congestion reduces bus operating speeds, weakens service reliability, increases operating costs, and negatively affects passenger experience [5].

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Improving bus performance has therefore become a major policy objective for transport authorities seeking to promote sustainable mobility while maximising the efficiency of existing infrastructure [6]. Compared with major infrastructure investments such as metro systems or new highway construction, bus-priority measures are generally less costly and can be implemented relatively quickly [7]. Among these measures, dedicated bus lanes have emerged as one of the most widely adopted interventions for improving public transport performance in urban environments [8]. By allocating exclusive road space to buses, dedicated bus lanes reduce interactions with general traffic, allowing bus services to operate more efficiently and reliably [9]. Numerous studies have reported improvements in operating speed, travel-time reliability, service regularity, and passenger satisfaction following the implementation of bus-priority facilities [10].

Despite their well-documented benefits, dedicated bus lanes are not without trade-offs. In most urban environments, road space is a scarce resource that must accommodate multiple and often competing demands, including general traffic movements, parking, freight activity, pedestrian facilities, cycling infrastructure, and public transport services [11]. Establishing a dedicated bus lane frequently requires reallocating road space from one or more of these functions. Consequently, transport authorities rarely possess sufficient physical, financial, or political capacity to implement dedicated bus lanes throughout an entire network [12]. Instead, decision-makers must determine where limited road space should be reallocated in order to generate the greatest overall benefits for passengers and the transport system.

This challenge is particularly relevant in Istanbul, one of Europe's largest metropolitan regions and home to a highly complex and heavily utilised public transport network [13]. The city experiences severe congestion levels and substantial daily travel demand across both the European and Asian sides of the metropolitan area [14]. Although Istanbul has invested heavily in rail transit systems and the Metrobus Bus Rapid Transit network, conventional bus services continue to play a critical role in providing accessibility and network connectivity across the city [15]. Many corridors experience chronic delays, low operating speeds, and unreliable journey times, particularly during peak periods. At the same time, the city's dense urban fabric and constrained road network limit opportunities for large-scale bus-lane implementation. Under such conditions, determining which corridors should receive dedicated bus lanes becomes a significant strategic planning problem.

Traditionally, transport planning decisions have relied on engineering assessments, cost-benefit analyses, or performance indicators focusing on individual dimensions of transport systems [16]. More recently, Multi-Criteria Decision-Making (MCDM) methods have been increasingly applied to support complex transport-planning decisions involving multiple objectives and conflicting stakeholder priorities [17]. Techniques such as the Analytic Hierarchy Process (AHP), TOPSIS, ELECTRE, PROMETHEE, and related approaches have been widely used to evaluate transport investments, infrastructure alternatives, accessibility initiatives, and mobility strategies [18]. While these methods provide useful decision-support capabilities, many corridor-prioritisation studies primarily evaluate existing conditions such as congestion severity, infrastructure deficiencies, or operational performance. Consequently, they often identify corridors with poor performance rather than corridors where intervention would generate the greatest overall benefit.

From a policy perspective, however, the question facing transport authorities is not simply which corridor performs poorly, but rather which corridor should be prioritised for intervention under limited resource conditions. A corridor experiencing severe congestion may face substantial physical constraints that make dedicated bus-lane implementation impractical. Conversely, another corridor with slightly better performance may provide significantly larger passenger benefits, stronger network impacts, or lower implementation costs if road space were reallocated. Therefore, the

prioritisation of dedicated bus lanes should be viewed as a multi-objective decision problem that simultaneously considers operational need, strategic importance, implementation feasibility, and potential opportunity costs associated with road-space reallocation.

Recent developments in decision intelligence provide an opportunity to address this challenge more effectively [19]. Decision intelligence extends traditional decision-support approaches by integrating data analytics, domain expertise, explainable modelling, and structured decision-making processes to support complex policy decisions [20]. Rather than simply producing rankings, decision-intelligence frameworks seek to provide transparent and actionable recommendations that explain why particular alternatives should be prioritised. Such capabilities are particularly important in transport planning, where infrastructure decisions often involve substantial investment costs, political implications, and competing stakeholder interests.

A review of the existing literature reveals an important research gap. Numerous studies have examined the impacts of dedicated bus lanes on operational performance and passenger outcomes [7, 8]. Evidence from implementation studies has also demonstrated improvements in reliability, travel times, and passenger experience [9, 10], while other studies have investigated the use of MCDM methods for transport infrastructure prioritisation [17, 18]. However, relatively limited attention has been devoted to the development of explainable decision-support frameworks specifically designed to identify which corridors should receive dedicated bus lanes under constrained urban road-space conditions. Existing research frequently treats corridor prioritisation as a ranking exercise, with limited consideration of implementation feasibility, road-space trade-offs, and transparent decision support. Furthermore, there remains a need for practical methodologies that can be implemented using publicly available transport and mobility datasets.

Addressing this gap is important because transport authorities increasingly require evidence-based frameworks for allocating scarce road space among competing uses while maximising the benefits delivered by public transport systems. Therefore, this study develops a multi-objective decision intelligence framework for prioritising dedicated bus-lane implementation in Istanbul. The proposed framework integrates four complementary dimensions: implementation feasibility, operational need, strategic importance, and road-space impact. Using publicly available transport, traffic, and spatial data, the framework evaluates candidate bus corridors and produces an explainable priority ranking to support policy decision-making.

The study is guided by the following research question:

Which bus corridors should be prioritised for dedicated bus-lane implementation in order to maximise passenger and network benefits under constrained urban road-space conditions?

To answer this question, the study pursues three objectives: (i) to identify corridors where dedicated bus lanes are feasible to implement; (ii) to evaluate and prioritise feasible corridors using a multi-objective decision framework; and (iii) to provide transparent explanations of the factors driving corridor prioritisation. The study contributes to both the decision-intelligence and transport-planning literature by introducing an explainable methodology for allocating scarce road space to public transport investments.

The remainder of this paper is organised as follows. Section 2 reviews the literature on dedicated bus lanes, transport corridor prioritisation, multi-criteria decision-making, and decision intelligence. Section 3 presents the proposed methodological framework, including corridor identification, feasibility assessment, indicator selection, weighting procedures, and the decision-support model. Section 4 describes the Istanbul case study and the publicly available datasets used in the analysis. Section 5 presents the results of the corridor evaluation and prioritisation process and discusses their

implications for transport planning and policy. Finally, Section 6 summarises the main conclusions, outlines the contributions of the study, and identifies opportunities for future research.

2. Literature Review

Dedicated bus lanes are widely recognised as an effective measure for improving bus performance in congested urban environments [6]. By separating buses from mixed traffic, they can increase operating speeds, improve reliability, reduce travel times, and enhance the attractiveness of public transport [7, 9]. Consequently, many cities have adopted bus-priority measures as a cost-effective alternative to major infrastructure investments. However, the effectiveness of dedicated bus lanes varies across corridors depending on traffic conditions, passenger demand, roadway characteristics, and network context [10].

Most existing research has focused on evaluating the impacts of bus lanes after implementation, examining outcomes such as speed improvements, reliability gains, and passenger benefits [9, 10]. While this body of work provides valuable evidence regarding the effectiveness of bus-priority measures, it offers limited guidance on a more fundamental planning question: where should dedicated bus lanes be implemented in the first place? As a result, transport authorities often lack systematic frameworks for prioritising candidate corridors under constrained financial and road-space conditions.

The issue of road-space allocation has become increasingly important as cities pursue sustainable mobility goals [11]. Urban road space is a scarce resource that must accommodate multiple competing functions, including public transport, private vehicles, freight activity, cycling infrastructure, pedestrian movement, and parking. Reallocating road space to public transport can improve the overall efficiency of urban mobility by increasing the number of people moved within a corridor [21]. Nevertheless, such decisions involve significant trade-offs and therefore require a structured and transparent decision-making process [12].

To address complex transport-planning problems, researchers have increasingly adopted Multi-Criteria Decision-Making (MCDM) methods [16, 17]. Techniques such as AHP, TOPSIS, PROMETHEE, ELECTRE, and the Best-Worst Method (BWM) allow multiple objectives and stakeholder preferences to be considered simultaneously [18, 22, 23]. These approaches have been widely applied to transport project evaluation, infrastructure prioritisation, route selection, accessibility assessment, and sustainability analysis. Their popularity stems from their ability to support decisions where no single criterion is sufficient for evaluating alternatives.

However, existing corridor-prioritisation studies exhibit several limitations [24]. Many focus on identifying locations with poor performance, high congestion, or infrastructure deficiencies. While these analyses help diagnose transport problems, they do not necessarily identify where a dedicated bus lane would generate the greatest overall benefit. A corridor experiencing severe congestion may face physical constraints that limit implementation opportunities, whereas another corridor may deliver greater passenger and network benefits despite exhibiting less severe operational problems. Therefore, intervention prioritisation requires a broader perspective than performance assessment alone [25].

Another limitation concerns implementation feasibility [25]. Many evaluation frameworks implicitly assume that all candidate corridors are equally suitable for intervention. In practice, factors such as lane configuration, roadway width, land-use characteristics, intersection density, and operational requirements can substantially affect implementation potential. Ignoring such constraints may produce recommendations that are analytically attractive but practically unrealistic.

Recent advances in decision intelligence offer opportunities to overcome these limitations [19, 20]. Decision intelligence combines data analytics, domain expertise, and structured decision-making

methods to support complex policy decisions. A central feature of this approach is explainability [26]. Rather than merely producing rankings, decision-intelligence frameworks seek to explain why alternatives are prioritised [27], thereby increasing transparency, stakeholder confidence, and policy legitimacy. Such explainability is particularly important for road-space allocation decisions, which frequently involve competing interests and public scrutiny.

The growing availability of transport-related open data further supports the development of more sophisticated decision-support systems. Publicly available datasets relating to transit operations, network characteristics, and traffic conditions allow researchers to evaluate performance, connectivity, and accessibility at increasingly detailed levels. Istanbul represents a particularly relevant context because it combines severe congestion, extensive bus operations, constrained road space, and an expanding open-data ecosystem [13–15].

Despite significant research on bus-priority measures, MCDM applications, and transport analytics, an important gap remains. Existing studies rarely integrate feasibility assessment, operational need, strategic network importance, and road-space considerations within a single explainable framework for bus-lane prioritisation. Furthermore, limited research has explored how openly available mobility data can support such decision-making processes. Addressing these gaps, this study proposes a multi-objective decision intelligence framework for prioritising dedicated bus-lane implementation in Istanbul. The framework moves beyond identifying problematic corridors and instead focuses on determining where scarce road space should be allocated to maximise passenger and network benefits.

3. Methodology

This study develops a multi-objective decision intelligence framework to identify and prioritise bus corridors for dedicated bus-lane implementation in Istanbul. The framework is designed to support road-space allocation decisions under physical, operational, and financial constraints. Unlike conventional corridor-ranking approaches that focus primarily on congestion or operational performance, the proposed framework integrates implementation feasibility, operational need, strategic importance, and road-space impacts within a structured decision-support process. The outcome is an explainable prioritisation of candidate corridors that can assist transport planners in identifying locations where dedicated bus lanes are most likely to generate substantial passenger and network benefits.

The methodology consists of six sequential stages. First, candidate bus corridors are identified from the Istanbul bus network. Second, a feasibility screening process is undertaken to exclude corridors where dedicated bus-lane implementation is unlikely to be practical. Third, the operational need for intervention is assessed using performance-related indicators. Fourth, the strategic importance of each corridor within the wider transport network is evaluated. Fifth, potential road-space impacts associated with implementation are examined. Finally, these dimensions are combined through a multi-objective decision model to generate corridor-priority rankings and explainable policy recommendations.

The analysis begins with the identification of candidate bus corridors across the Istanbul bus network. Candidate corridors are defined as major roadway sections supporting significant bus operations and performing an important role within the public transport network [3]. Since transport interventions are implemented at corridor level rather than route level, overlapping bus routes operating on the same roadway are aggregated into common corridor segments. This approach enables individual bus services to be evaluated within a broader network context while establishing the corridor as the primary decision-making unit.

A feasibility screening stage is then undertaken because poor operational performance alone does not necessarily indicate suitability for dedicated bus-lane implementation [28]. International guidance on bus-priority design and corridor suitability also informed the feasibility assessment criteria [29]. Some corridors may experience severe congestion yet face physical or operational constraints that make implementation impractical. To address this issue, the framework evaluates three aspects of feasibility: physical feasibility, operational feasibility, and network feasibility. Physical feasibility relates to roadway width, lane availability, median configuration, and geometric constraints. Operational feasibility considers intersection density, turning movements, freight activity, and traffic-management requirements. Network feasibility evaluates the corridor's role within the road hierarchy, the availability of alternative routes, and potential impacts on wider network operations. Based on these criteria, corridors are classified as feasible, conditionally feasible, or not feasible. Corridors classified as not feasible are excluded from subsequent analysis.

For feasible corridors, the framework evaluates the operational need for bus-priority intervention. The objective is not merely to identify congested locations but to determine where bus services are most adversely affected by traffic conditions. Four indicators are proposed for this purpose: average bus operating speed, corridor delay level, travel-time reliability, and congestion exposure. Corridors exhibiting low operating speeds, high delays, unreliable travel times, and significant congestion exposure receive higher need scores. These indicators are standardised to permit comparisons across corridors with differing physical and operational characteristics. The overall need score for corridor i is represented as:

$$N_i = f(S_i, D_i, R_i, C_i) \quad (1)$$

where S_i denotes average bus speed, D_i represents delay level, R_i denotes reliability, and C_i captures congestion exposure. Higher values of N_i indicate a stronger operational need for intervention.

Operational need alone is insufficient to determine implementation priority because some corridors play a more significant role within the transport network than others. Accordingly, the framework incorporates a strategic importance assessment that evaluates each corridor's contribution to public transport accessibility and network performance. Four dimensions are considered: passenger demand, network connectivity, accessibility contribution, and service importance. Passenger demand reflects the scale of potential beneficiaries. Network connectivity captures interchange opportunities with other public transport modes and routes. Accessibility contribution measures the corridor's role in connecting residents with employment, education, and key urban activities. Service importance reflects the corridor's position within the wider bus network. The strategic importance score for corridor i is expressed as:

$$SI_i = f(P_i, NC_i, A_i, SV_i) \quad (2)$$

where P_i represents passenger demand, NC_i denotes network connectivity, A_i measures accessibility contribution, and SV_i represents service importance. Higher values indicate greater strategic significance.

Since dedicated bus lanes require the reallocation of scarce urban road space, implementation benefits must also be considered alongside associated costs and constraints. To address this issue, the framework incorporates a road-space impact assessment. This dimension considers the number of traffic lanes affected, potential parking loss, impacts on kerbside activities, and implementation complexity. The objective is to identify corridors where substantial passenger and network benefits can be achieved without excessive disruption to other roadway functions. The road-space impact score for corridor i is represented as:

$$RS_i = f(L_i, PK_i, K_i, IC_i) \quad (3)$$

where L_i denotes lane reallocation requirements, PK_i represents parking impacts, K_i captures kerbside effects, and IC_i reflects implementation complexity. Lower values indicate fewer implementation constraints.

Following indicator calculation, corridor prioritisation is performed using a multi-objective decision model. The model integrates the three principal evaluation dimensions: operational need, strategic importance, and road-space impact. A weighted aggregation approach is employed to calculate an overall priority score for each corridor. The priority score for corridor i is calculated as:

$$PS_i = w_N N_i + w_{SI} SI_i - w_{RS} RS_i \quad (4)$$

where PS_i denotes the overall priority score, w_N is the weight assigned to operational need, w_{SI} is the weight assigned to strategic importance, and w_{RS} is the weight assigned to road-space impact. Given the exploratory nature of the study and the absence of an established weighting scheme for bus-lane prioritisation in Istanbul, equal weights were assigned to the Operational Need, Strategic Importance, and Road-Space Impact dimensions for this study.

To ensure consistency across multiple evaluation criteria, all indicators were transformed onto a common standardised scale prior to aggregation. Since the selected indicators are measured in different units and originate from different data sources, direct comparison is not possible without normalisation. Therefore, a min-max normalisation procedure was applied to convert all indicator values to a dimensionless range between 0 and 1.

For benefit indicators, where higher values indicate more desirable conditions, the normalised score was calculated as:

$$X_i^* = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (5)$$

For cost indicators, where lower values indicate more desirable conditions, the normalised score was calculated as:

$$X_i^* = \frac{X_{max} - X_i}{X_{max} - X_{min}} \quad (6)$$

where X_i represents the observed value for corridor i , and X_{max} and X_{min} represent the maximum and minimum values observed across all candidate corridors.

Following normalisation, dimension scores were calculated as the arithmetic mean of the indicators belonging to each evaluation category. The Operational Need score was derived from average operating speed, delay level, travel-time reliability, and congestion exposure. The Strategic Importance score was derived from passenger demand, network connectivity, accessibility contribution, and service importance. The Road-Space Impact score was derived from lane-reallocation requirements, parking impacts, kerbside effects, and implementation complexity.

Because detailed passenger-count and operational datasets were not available for all corridors, several indicators were estimated using proxy measures derived from publicly available GTFS, traffic, and spatial datasets. Consistent with the exploratory nature of the study, all indicators within a given dimension were assigned equal importance.

The overall priority score for each corridor was then calculated using the weighted aggregation model whereby equal weights were assigned to the three principal evaluation dimensions:

$$w_N = w_{SI} = w_{RS} = \frac{1}{3} \quad (7)$$

This approach reflects the assumption that operational need, strategic importance, and road-space impacts are equally important considerations when prioritising dedicated bus-lane investments.

To facilitate interpretation and presentation of results, continuous scores were converted into qualitative categories. Corridor scores were classified according to quartile-based thresholds:

- i. Very High: top 25% of scores

- ii. High: 50th - 75th percentile
- iii. Medium: 25th - 50th percentile
- iv. Low: bottom 25% of scores

These categories were used in Tables 2, 3, 4 and 5 to provide an intuitive representation of corridor performance across the different evaluation dimensions while preserving the underlying quantitative assessment.

A central feature of the proposed framework is explainability. Rather than providing only a final ranking, the model identifies the factors that most strongly influence the position of each corridor. For every prioritised corridor, the framework reports the relative contributions of operational need, strategic importance, and road-space considerations. This enables planners and decision-makers to understand not only which corridors are recommended for intervention but also why they are ranked highly. The final results are grouped into three implementation tiers. Tier 1 consists of immediate candidates exhibiting high need, strong strategic importance, and acceptable implementation constraints. Tier 2 comprises secondary candidates that offer significant benefits but involve greater trade-offs or uncertainty. Tier 3 includes lower-priority corridors where expected benefits are comparatively limited or implementation challenges are substantial.

By integrating feasibility assessment, operational analysis, strategic evaluation, and explainable decision support, the proposed methodology moves beyond traditional corridor-ranking exercises and provides a practical framework for prioritising dedicated bus-lane investments under constrained urban road-space conditions.

4. Case Study and Data

Istanbul was selected as the study area because it presents a highly relevant context for investigating bus-lane prioritisation under constrained urban road-space conditions. As one of the largest metropolitan areas in Europe and the Middle East, Istanbul experiences substantial travel demand, severe congestion, and a heavy dependence on bus-based public transport services. Despite significant investment in rail transit and the Metrobus Bus Rapid Transit (BRT) system, conventional bus services continue to provide critical connectivity across the metropolitan area. Consequently, improving the performance of the bus network remains an important policy objective for transport authorities.

The city also offers a favourable environment for data-driven transport research due to the increasing availability of publicly accessible mobility datasets. The Istanbul Metropolitan Municipality (IMM) Open Data Portal provides a wide range of transport-related datasets, including public transport network information, traffic conditions, and spatial data. In particular, the General Transit Feed Specification (GTFS) dataset published by IETT contains route, stop, trip, and service information describing the structure of the bus network. In addition, traffic-density datasets and related mobility information are available through the IMM open-data ecosystem, creating opportunities to evaluate both public transport operations and prevailing traffic conditions.

The analysis focuses on major bus corridors operating within the Istanbul bus network. Candidate corridors are derived from the aggregation of multiple bus routes that share common roadway segments. This approach ensures that the prioritisation framework evaluates the physical corridors where dedicated bus lanes could be implemented rather than individual bus services. The corridor therefore represents the primary unit of analysis throughout the study.

The proposed framework utilises publicly available data sources to construct the indicators required for feasibility assessment, need assessment, strategic importance assessment, and road-space impact assessment. Table 1 summarises the principal datasets and their intended analytical use.

Table 1

Publicly available datasets used in the study

Dataset	Source	Purpose
GTFS route data	ETT Open Data Portal	Corridor identification and route geometry
GTFS stop data	IETT Open Data Portal	Stop density and network accessibility
GTFS trip data	IETT Open Data Portal	Service frequency and operational importance
Traffic density data	IMM Open Data Portal	Congestion and traffic conditions
Road network data	OpenStreetMap	Lane configuration and roadway characteristics
Population and land-use data	Public spatial datasets	Accessibility and strategic importance
Public transport interchange data	IMM and IETT datasets	Connectivity assessment

Following corridor identification, a series of indicators are calculated to represent the four dimensions of the decision framework. The feasibility assessment considers whether dedicated bus lanes can realistically be implemented within a corridor. Since detailed engineering designs are beyond the scope of this study, a strategic-level screening approach is adopted. Indicators include roadway classification, estimated lane availability, corridor continuity, and network characteristics. The purpose of the screening stage is to eliminate corridors where implementation is clearly impractical and to focus subsequent analysis on realistic candidate locations.

The need assessment evaluates the extent to which a corridor currently suffers from operational problems potentially addressable through bus-priority measures. Four indicators are selected: average operating speed, estimated delay, travel-time reliability, and congestion exposure. Lower speeds and poorer reliability indicate greater operational need for intervention. Because the selected indicators are measured in different units, all values are normalised before aggregation.

Strategic importance is evaluated using indicators that reflect the significance of a corridor within the wider public transport network. These indicators include service frequency, route concentration, connectivity with other public transport modes, and population accessibility. Corridors serving a large number of routes, supporting important interchange functions, or providing access to major activity centres are expected to receive higher strategic scores. This dimension ensures that prioritisation reflects not only operational deficiencies but also broader network objectives.

The road-space impact assessment captures the practical implications of reallocating roadway capacity to buses. Indicators include estimated lane-reallocation requirements, potential kerbside impacts, roadway complexity, and implementation constraints. Incorporating this dimension recognises that dedicated bus lanes are not cost-free interventions and that road-space availability remains a critical determinant of implementation feasibility.

After the indicators have been calculated, a normalisation procedure is applied to transform all variables onto a common scale. Min-max normalisation is adopted because of its simplicity and widespread use in multi-criteria decision analysis. For benefit indicators, higher values correspond to more desirable conditions, whereas cost indicators are transformed so that lower values represent more favourable outcomes. This process ensures comparability across all evaluation criteria.

The resulting indicator matrix is then integrated within the multi-objective decision model described in Section 3. Operational need, strategic importance, and road-space impact scores are computed for each corridor and subsequently combined to generate an overall priority score. The analysis produces a ranked list of candidate corridors together with explanations of the factors contributing to each ranking.

The methodology outlined in Sections 3 and 4 provides a practical and replicable framework for identifying bus corridors where dedicated bus lanes are expected to generate the greatest overall benefits under constrained urban road-space conditions. By relying primarily on publicly available

datasets, the framework is designed to support evidence-based decision-making while remaining transferable to other cities facing similar transport-planning challenges.

Several data limitations should be noted. Publicly available datasets do not provide corridor-level passenger demand, automated vehicle location (AVL) records, or observed bus travel-speed measurements. Consequently, service intensity and observed congestion patterns are used as proxies for corridor importance and operational need.

5. Results and Discussion

An initial set of candidate corridors was identified through the aggregation of GTFS bus routes operating along common arterial road segments and serving major transport activity centres. Following the feasibility screening process, the analysis was narrowed to ten strategic corridors that exhibited sufficient potential for dedicated bus-lane implementation while maintaining significance within the wider public transport network. These ten corridors formed the basis for the subsequent operational, strategic, and road-space assessments. As shown in Table 2, the Altunizade-Ümraniye, Kadıköy-Kozyatağı-Ataşehir, Mecidiyeköy-Levent-Maslak, and Avcılar-Esenyurt-Beylikdüzü corridors demonstrated the strongest overall feasibility profiles. These corridors are characterised by relatively continuous arterial roadways, strategic transport functions, and sufficient roadway capacity to support dedicated bus-priority treatments. In contrast, central corridors in areas such as Beşiktaş and the historic core of Kadıköy exhibited lower feasibility due to road-space constraints and intensive competing demands for kerbside activity.

Table 2
Feasibility Assessment of Major Candidate Corridors

Corridor	Physical Feasibility	Operational Feasibility	Network Feasibility	Overall Assessment
Altunizade-Ümraniye	High	High	High	Feasible
Kadıköy-Kozyatağı-Ataşehir	High	High	High	Feasible
Mecidiyeköy-Levent-Maslak	Medium-High	Medium	High	Feasible
Avcılar-Esenyurt-Beylikdüzü	High	High	High	Feasible
Mecidiyeköy-Çağlayan-Kağıthane	Medium-High	Medium	High	Feasible
Kartal-Pendik-Kurtköy	High	Medium	Medium	Feasible
Kartal-Sultanbeyli	Medium-High	Medium	Medium	Feasible
Üsküdar-Altunizade-Bulgurlu	Medium	Medium	High	Feasible
Yenibosna-Basin Ekspres	Medium	Medium	Medium-High	Feasible
Beşiktaş Central Area	Low	Low	Medium	Conditionally Feasible

The operational assessment revealed that bus activity is concentrated on a relatively small number of strategic corridors. Analysis of GTFS routes, trips, and stop-time patterns indicated that the greatest operational challenges occur on corridors serving major interchange centres, employment districts, and high-frequency bus services. These corridors accommodate intensive bus operations while simultaneously experiencing recurring congestion, resulting in increased travel times, reduced reliability, and declining operational efficiency.

The results presented in Table 3 indicate that the Altunizade-Ümraniye corridor and the Kadıköy-Kozyatağı-Ataşehir corridor achieved the highest operational need ratings. Both corridors combine very high service intensity with severe congestion exposure. The Mecidiyeköy-Levent-Maslak corridor also achieved a very high need score due to its role as one of Istanbul's most important business and employment axes. Similarly, the Avcılar-Esenyurt-Beylikdüzü corridor demonstrated

substantial operational need owing to the large concentration of bus-dependent populations and recurring peak-period congestion.

Table 3
Operational Need Assessment

Rank	Corridor	Service Intensity	Congestion Exposure	Operational Need
1	Altunizade-Ümraniye	Very High	Very High	Very High
2	Kadıköy-Kozyatağı-Ataşehir	Very High	Very High	Very High
3	Mecidiyeköy-Levent-Maslak	High	Very High	Very High
4	Avcılar-Esenyurt-Beylikdüzü	Very High	High	High
5	Mecidiyeköy-Çağlayan-Kağıthane	High	High	High
6	Kartal-Pendik-Kurtköy	High	Medium	Medium-High
7	Kartal-Sultanbeyli	Medium	High	Medium-High
8	Üsküdar-Altunizade-Bulgurlu	Medium	Medium-High	Medium
9	Yenibosna-Basın Ekspres	Medium	Medium-High	Medium
10	Beşiktaş Central Area	High	Very High	High

Operational performance alone, however, does not determine intervention priority. Corridors must also be assessed according to their strategic contribution to the public transport system. The strategic evaluation therefore examined corridor connectivity, accessibility functions, and integration with the wider transport network. The highest strategic scores were associated with corridors linking major multimodal interchange locations including Altunizade, Kadıköy, Mecidiyeköy, Avcılar, Kartal, and Pendik.

As shown in Table 4, the Altunizade-Ümraniye, Kadıköy-Kozyatağı-Ataşehir, and Mecidiyeköy-Levent-Maslak corridors all achieved very high strategic importance ratings. These corridors support significant passenger movements, facilitate transfers between multiple public transport modes, and provide access to major employment and residential areas. The Avcılar-Esenyurt-Beylikdüzü corridor also scored highly because of its extensive residential catchment and strong dependence on bus-based mobility.

Table 4
Strategic Importance Assessment

Corridor	Passenger Catchment	Connectivity	Accessibility Contribution	Strategic Importance
Altunizade-Ümraniye	High	Very High	High	Very High
Kadıköy-Kozyatağı-Ataşehir	Very High	High	Very High	Very High
Mecidiyeköy-Levent-Maslak	High	Very High	Very High	Very High
Avcılar-Esenyurt-Beylikdüzü	Very High	Medium	High	High
Mecidiyeköy-Çağlayan-Kağıthane	High	High	High	High
Kartal-Pendik-Kurtköy	High	High	Medium	High
Kartal-Sultanbeyli	Medium	Medium	Medium	Medium
Üsküdar-Altunizade-Bulgurlu	Medium	High	Medium	High
Yenibosna-Basın Ekspres	Medium	Medium-High	High	Medium-High
Beşiktaş Central Area	High	Very High	High	High

The road-space impact assessment introduced an important implementation dimension to the analysis. While operational and strategic considerations identify where benefits may be generated,

implementation constraints determine the practical viability of dedicated bus lanes. Significant variation was observed across the candidate corridors.

As reported in Table 5, corridors such as Avcılar-Esenyurt-Beylikdüzü and Kartal-Sultanbeyli exhibited comparatively favourable road-space conditions, with lower lane-reallocation requirements and fewer kerbside conflicts. Conversely, corridors within more constrained urban environments, particularly the central districts of Beşiktaş and Kadıköy, were associated with substantially higher implementation complexity.

Table 5
Road-Space Impact Assessment

Corridor	Lane Reallocation Difficulty	Kerbside Impacts	Implementation Complexity	Overall Impact
Altunizade-Ümraniye	Medium	Medium	Medium	Medium
Kadıköy-Kozyatağı-Ataşehir	Medium	Medium	Medium	Medium
Mecidiyeköy-Levent-Maslak	Medium	High	Medium	Medium-High
Avcılar-Esenyurt-Beylikdüzü	Low	Low	Medium	Low-Medium
Mecidiyeköy-Çağlayan-Kağıthane	Medium	Medium	Medium	Medium
Kartal-Pendik-Kurtköy	Medium	Medium	Medium	Medium
Kartal-Sultanbeyli	Low	Low	Medium	Low-Medium
Üsküdar-Altunizade-Bulgurlu	Medium	Medium	Medium	Medium
Yenibosna-Basın Ekspres	Medium	Medium	Medium	Medium
Beşiktaş Central Area	High	High	High	High

The integration of operational need, strategic importance, and road-space impacts produced the final corridor prioritisation. The results, presented in Table 6, indicate the emergence of four clear Tier 1 corridors. These corridors consistently achieved strong performance across all evaluation dimensions and therefore represent the most attractive candidates for dedicated bus-lane implementation.

The Altunizade-Ümraniye corridor achieved the highest overall ranking due to its combination of severe operational challenges, exceptional network connectivity, and acceptable implementation conditions. The Kadıköy-Kozyatağı-Ataşehir corridor ranked second and benefited from its strong accessibility function and major employment-related travel demand. The Mecidiyeköy-Levent-Maslak corridor ranked third owing to its strategic role within Istanbul's principal business district, while the Avcılar-Esenyurt-Beylikdüzü corridor completed the top tier because of its large residential catchment, high bus dependency, and comparatively favourable implementation characteristics.

The final rankings shown in Table 6 demonstrate that the most congested corridors are not necessarily the most suitable corridors for dedicated bus-lane implementation. Rather, high-priority corridors are characterised by a balanced combination of operational need, strategic importance, and implementation feasibility. This finding highlights the limitations of prioritisation approaches based exclusively on congestion indicators.

Another notable observation is the prominence of multimodal interchange locations among the highest-ranked corridors. Altunizade, Kadıköy, Mecidiyeköy, Avcılar, and Kartal repeatedly appear within the highest-priority corridors identified by the framework. This suggests that dedicated bus-lane investments targeted at major interchange corridors are likely to generate broader network-wide benefits than interventions focused on isolated routes.

The results also demonstrate the importance of feasibility screening. Had the analysis focused only on operational indicators, several highly constrained central-city corridors would have achieved

substantially higher rankings. By incorporating the feasibility and road-space assessments presented in Tables 2 and 5, the framework generates recommendations that are more realistic from an implementation perspective.

Table 6
Final Corridor Prioritisation

Rank	Corridor	Priority Tier
1	Altunizade-Ümraniye	Tier 1
2	Kadıköy-Kozyatağı-Ataşehir	Tier 1
3	Mecidiyeköy-Levent-Maslak	Tier 1
4	Avcılar-Esenyurt-Beylikdüzü	Tier 1
5	Mecidiyeköy-Çağlayan-Kağıthane	Tier 2
6	Kartal-Pendik-Kurtköy	Tier 2
7	Kartal-Sultanbeyli	Tier 2
8	Üsküdar-Altunizade-Bulgurlu	Tier 2
9	Yenibosna-Basın Ekspres	Tier 2
10	Beşiktaş Central Area	Tier 3

The geographical distribution of the evaluated corridors is illustrated in Figure 1, highlighting the concentration of high-priority corridors around major interchange locations and high-demand travel corridors. The highest-priority corridors are distributed across both the European and Asian sides of Istanbul, indicating that opportunities for dedicated bus-lane implementation are not confined to a single part of the metropolitan area.

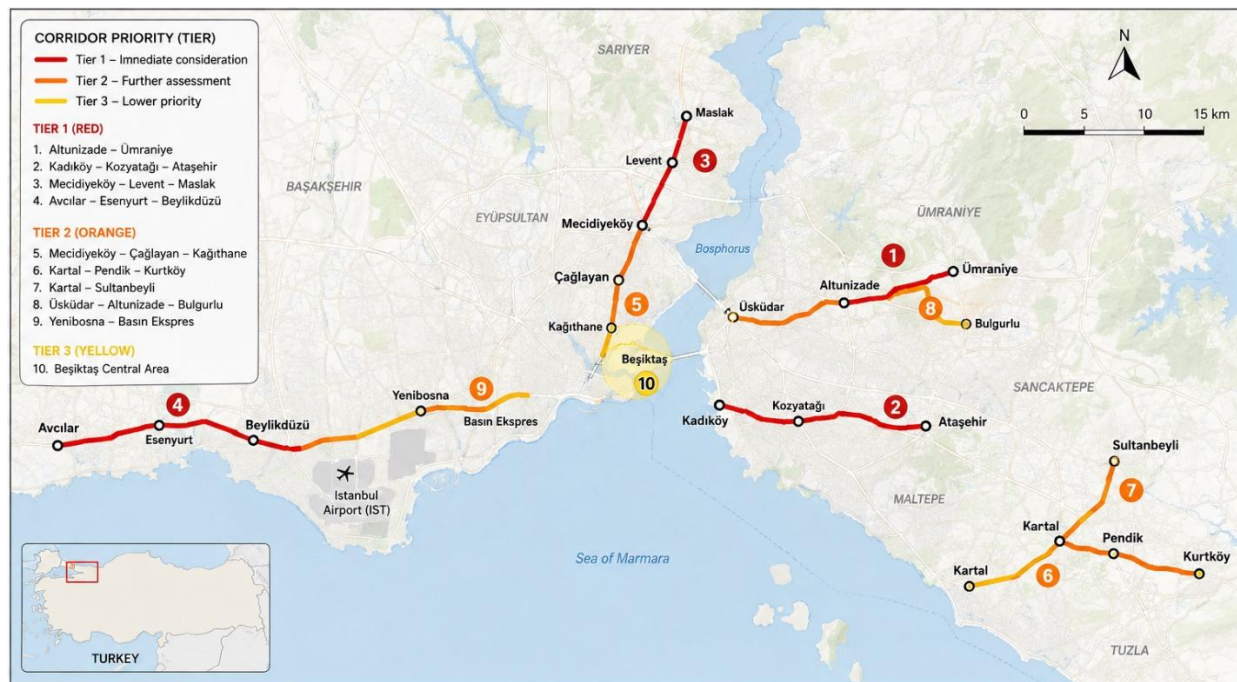


Fig. 1. Priority bus corridors identified for dedicated bus-lane implementation in Istanbul

Overall, the evidence presented in this section indicates that dedicated bus-lane planning should be treated as a strategic road-space allocation problem rather than merely a congestion-management exercise. By combining operational performance, strategic network functions, and implementation considerations within a single explainable decision-support framework, the

proposed methodology provides a practical basis for prioritising bus-priority investments. The findings suggest that interventions focused on major multimodal and high-frequency bus corridors are likely to produce the greatest overall benefits for passengers, operators, and the wider metropolitan public transport system.

6. Conclusions

This study developed a multi-objective decision intelligence framework for prioritising dedicated bus-lane implementation in Istanbul under constrained urban road-space conditions. The framework addresses a key planning question: which bus corridors should receive priority for dedicated bus-lane investment in order to maximise passenger and network benefits while accounting for implementation constraints.

Unlike conventional approaches that focus primarily on congestion or operational deficiencies, the proposed framework integrates feasibility assessment, operational need, strategic importance, and road-space impacts within a single decision-support process. Using publicly available GTFS data, transport network information, and observed congestion conditions, the framework provides a transparent and replicable methodology for corridor prioritisation.

Application of the framework identified clear differences in corridor suitability. The results indicate that the highest-priority corridors are not necessarily those experiencing the greatest congestion, but those that combine strong operational need, strategic network importance, and feasible implementation conditions. The Altunizade-Ümraniye, Kadıköy-Kozyatağı-Ataşehir, Mecidiyeköy-Levent-Maslak, and Avcılar-Esenyurt-Beylikdüzü corridors emerged as the strongest candidates for dedicated bus-lane implementation.

The findings also highlight the importance of multimodal interchange functions. Corridors serving major transfer hubs such as Altunizade, Kadıköy, Mecidiyeköy, Avcılar, and Kartal consistently achieved high scores across multiple evaluation dimensions, suggesting that investments targeted at these corridors are likely to generate wider network benefits beyond individual routes.

From a methodological perspective, the study contributes to the decision-intelligence literature by demonstrating how diverse transport datasets can be integrated into an explainable prioritisation framework. Rather than producing only a ranking, the framework provides transparent justification for corridor selection, supporting evidence-based and accountable decision-making.

The study has practical relevance for transport authorities seeking to allocate scarce road space more effectively. Although developed for Istanbul, the framework is transferable to other metropolitan areas because it relies primarily on widely available transport, traffic, and spatial datasets.

Several limitations should be acknowledged. The analysis did not include passenger boarding and alighting data, automatic vehicle location records, observed bus speeds, or detailed engineering assessments. Consequently, the results should be interpreted as a strategic-level prioritisation rather than a detailed implementation plan.

Future research could incorporate passenger-demand data, observed operational performance measures, and predictive models capable of estimating travel-time savings associated with dedicated bus lanes. The framework could also be extended to evaluate other bus-priority measures, including transit signal priority, queue-jump lanes, and dynamic bus lanes.

Overall, the study demonstrates that dedicated bus-lane planning should be approached as a strategic road-space allocation problem rather than solely a congestion-management exercise. By integrating operational performance, network importance, and implementation considerations within an explainable decision-support framework, the proposed methodology provides a practical basis for prioritising bus-priority investments in large metropolitan transport networks.

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Conflicts of Interest

The authors declare no conflicts of interest.

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