İSTANBUL TİCARET ÜNİVERSİTESİ
FEN BİLİMLERİ DERGİSİ

İstanbul Commerce University Journal of Science

http://dergipark.org.tr/ticaretfbd

Research Article / Araştırma Makalesi

SUGGESTIONS FOR SOLUTIONS TO URBAN TRANSPORTATION PROBLEMS WITH INTELLIGENT TRANSPORTATION SYSTEMS: THE CASE OF KARABÜK

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https://doi.org/10.55071/ticaretfbd.1527794

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Received (Geliş Tarihi)	***Revised (Revizyon Tarihi)***	***Accepted (Kabul Tarihi)***
04.08.2024	*21.04.2025*	*22.04.2025*

Abstract

Transportation problems, irregular urbanisation, inadequate transportation infrastructure, and unplanned urbanisation in our country are growing daily. The fact that the Karabük city centre is an old settlement unsuitable for creating alternative roads is a problem. This study aims to identify and prioritise Intelligent Transportation Systems (ITS) strategies for the city of Karabük using the Best Worst Method (BWM), a multi-criteria decision-making technique. Ten experts from Karabük Municipality and related departments participated in pairwise comparisons of ITS-related action items outlined in the 2020 National ITS Strategy Document by the Ministry of Transport and Infrastructure. The consistency ratios of their responses confirmed data reliability. Results indicate that traffic safety, environmental ımpacts, and real-time traffic ınformation are the most important criteria. These findings underline the importance of promoting public transportation and effective passenger information systems. Furthermore, the results provide insights into improving municipalities' range and quality of services.

Keywords: Urban transportation, transportation analysis, public transport, intelligent transportation systems, best-worst method.

Öz

Ülkemizde yaşanan ulaşım sorunları, düzensiz şehirleşme, ulaşım alt yapısının yetersiz oluşu ve plansız şehirleşme her geçen gün büyümektedir. Karabük şehir merkezinin eski bir yerleşim olması ve alternatif yollar oluşturmada elverişsiz olması başlı başına bir sorundur. Bu çalışma, Karabük ili için Akıllı Ulaşım Sistemleri (AUS) stratejilerini belirlemek ve önceliklendirmek amacıyla çok kriterli karar verme tekniklerinden biri olan En İyi-En Kötü Yöntemi (BWM) kullanılarak gerçekleştirilmiştir. Karabük Belediyesi ve ilgili kurumlardan on uzman, Ulaştırma ve Altyapı Bakanlığı tarafından 2020 yılında yayımlanan Ulusal AUS Strateji Belgesi'nde yer alan eylem maddelerine yönelik ikili karşılaştırmalar yapmıştır. Uzman görüşlerinden elde edilen tutarlılık oranları verilerin güvenilir olduğunu göstermiştir. Çalışma sonuçlarına göre; trafik güvenliği, çevresel etkiler ve gerçek zamanlı trafik bilgisi en önemli kriterler olarak belirlenmiştir. Bu bulgular, toplu taşıma sistemlerinin teşvik edilmesinin ve yolcu bilgilendirme sistemlerinin etkinliğinin artırılmasının önemine dikkat çekmektedir. Ayrıca, belediyeler tarafından sunulan hizmetlerin çeşitliliğini geliştirme konusunda da yol gösterici bilgiler sunmaktadır.

Anahtar Kelimeler: Kent içi ulaşım, ulaşım analizi, toplu taşıma, akıllı ulaşım sistemleri, best worst method.

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1. INTRODUCTION

With the rise in population, socio-economic development, and the rapid expansion of the automotive industry, the number of privately owned vehicles in Turkey has been steadily increasing (Şenbil & Yetişkul Şenbil, 2020). However, this surge has not been matched by a corresponding improvement in the urban transportation infrastructure of Karabük. One of the primary reasons for this mismatch lies in the city's topographical limitations; Karabük is an old and rugged settlement where urban growth is largely restricted to a confined mountainous area. Historically, transportation and traffic issues in the city have been either overlooked or addressed with superficial and short-term measures, which have exacerbated congestion within the transportation network. Although awareness of these issues has increased in recent years, the response has been delayed and fragmented, complicating efforts to resolve the underlying problems.

Moreover, the existing infrastructure, including roads, intersections, and parking areas, remains insufficient to meet current demand. In addition to the general problem of irregular parking, public vehicles like buses and minibuses lack defined roadside loading and unloading zones, further impedes traffic flow. The increase in traffic accidents is largely caused by behavioural issues, such as drivers' and pedestrians' disregard for traffic laws, and physical infrastructure flaws (Selimoğlu, 2014).

A thorough urban transportation strategy needs to be created and implemented to address these issues. This plan should maintain the historic urban fabric, encourage the efficient use of local resources, and put people before cars. Furthermore, it should incorporate Intelligent transit Systems (ITS), promote environmentally friendly mobility solutions, promote the use of public transit, and offer affordable, secure, and sustainable transportation options. ITS is a collection of tools, applications, and systems that use contemporary information systems and technology to improve transportation infrastructure's sustainability, safety, and efficiency. Road safety, efficiency, ecologically friendly transportation, and traffic management are all greatly enhanced with ITS. These systems' primary goals are to streamline transportation procedures and lessen urban traffic congestion.

This study uses the Best Worst Method (BWM), a multi-criteria decision-making technique, to determine and rank the ITS options for Karabük. Ten experts from Karabük Municipality and related departments participated in pairwise comparisons of ITS-related action items outlined in the 2020 National ITS Strategy Document by the Ministry of Transport and Infrastructure. The results obtained were interpreted by comparing them with the current transportation situation of Karabük province.

2. INTELLIGENT TRANSPORTATION SYSTEMS

ITS is a comprehensive transportation management and service system that aims to provide innovative services for different transportation management modes (Lin et al., 2017). Tektaş et al. (2016) define ITS as "systems that include monitoring, measuring, analysing and controlling with multi-way data exchange between user-vehicle-infrastructure-center developed for purposes such as reducing travel times, increasing traffic safety, optimum use of existing road capacities, increasing mobility, contributing to the country's economy by providing energy efficiency and reducing environmental damage.” The most basic feature of ITS is that it combines high technology and developments in information systems, communication, sensors, controllers, and advanced mathematical methods with the traditional transportation infrastructure world (Sussman, 2005a). When these technologies are integrated into the infrastructure of the transportation system and the vehicles themselves, they eliminate traffic congestion and increase safety and productivity (Yan et al., 2012).

ITS can be defined as using information and communication technologies, including monitoring, measurement, analysis, and control mechanisms, to ensure interoperability in transportation-related applications and solutions. Therefore, ITS includes various interdisciplinary intersections, including computer science and informatics, telecommunications, communications, transportation engineering, sensors and control, finance, e-commerce, and automobile manufacturing. ITS can be considered a tool to provide innovative mobility solutions in all modes of transportation. Various technologies such as sensors, wireless, infrared communication, data analytics, artificial intelligence, and machine learning are among the tools used in ITS applications.

Intelligent transportation uses modern technologies to enable quicker visibility and notifications of problems, making travel safer and more comfortable, and giving communities and people inexpensive options (Mazur, 2020; Peak, 2020). Furthermore, the primary advantages of intelligent transportation are its efficiency, safety, and environmental aspects (Mazur, 2020). Additionally, cutting-edge driver assistance technologies are being created to stop collisions and guarantee passenger safety. Furthermore, connected, collaborative, and autonomous mobility (CCAM) will be made possible by vehicle-to-passenger (V2P), vehicle-to-infrastructure (V2I), vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and in-vehicle mobility (In-V) (Gajewska, 2017).

The Republic of Turkey's Ministry of Transport and Infrastructure (2020) defines ITS as information communication-based systems that include monitoring, measurement, analysis, control mechanisms, and multidirectional data exchange between users, infrastructure, vehicles, and centres. These systems were created to accomplish objectives like making the best use of the road's current capacity, reducing travel times, improving traffic safety and mobility, using energy efficiently, and reducing environmental degradation. Three key ITS application areas, mobility, safety, and the environment, are currently receiving attention (Khan et al., 2017). Human errors in all forms of transportation can be reduced with the help of solutions that use ITS technologies, which are still being developed and used today. At the same time, traffic-related delays, fatal and serious injury accidents, material losses, air pollution, and many other undesirable circumstances can be avoided.

Population expansion, demographic shifts, urbanisation, and climate change are all significant issues for medium-, large, and mega-sized cities worldwide, particularly regarding sustainability. The following five trends are defined by Deloitte (2022) as addressing the issues facing the transportation industry: 1) Creating sustainable financing methods for transportation, 2) Addressing the issue of electric vehicles and infrastructure for charging them, 3) Modernizing transportation systems fairly and inclusively, 4) Increasing the sustainability of transportation networks, and 5) Quickening the pace of technological and digital advancement (Deloitte, 2022). In addition to these difficulties, 193 member nations, including ours, have proposed the Sustainable Development Goals, which focus on resolving current crises and boosting prosperity for 2015–2030. With the help of the Paris Agreement, these objectives aim to turn the battle against climate change into a socially and economically inclusive model.

2.1 Advantages of Intelligent Transportation Systems

The benefits of ITS applications, which have become widespread with technology development, are detailed below.

1. Improved traffic efficiency

The capacity of ITS to enhance traffic flow and lessen traffic congestion is among its most significant advantages. Traffic signals can be controlled by identifying areas of congestion and rerouting traffic to less congested routes using real-time data from cameras, GPS, and traffic sensors. Adaptive signal management systems, for instance, adjust signal timing based on the situation to reduce waiting times at junctions. This results in better traffic flow, shorter travel times, and more seamless traffic movement, particularly during rush hour.

2. Improved road safety

ITS increases road safety for bicycles, pedestrians, drivers, and passengers. ITS helps reduce accidents by utilising technology like speed monitoring systems, real-time hazard warnings, and object identification. Additionally, ITS facilitates quicker arrival at the site and early intervention through applications created in response to traffic accidents. For instance, collision avoidance systems and Electronic Stability Control (ESC) assist drivers by informing them of potentially hazardous circumstances. Automatic speed control systems and red-light cameras are examples of traffic enforcement techniques that can identify reckless driving and promote safer driving practices.

3. Environmental benefits

Because ITS optimises traffic flow, it also lessens stop-and-go situations. As a result, vehicles use less fuel and emit fewer emissions. Carbon dioxide and other air pollutants can be considerably reduced by reducing waiting periods at junctions and in traffic. By offering real-time monitoring, intelligent routing, and convenient access to trip information, ITS also facilitates the integration of eco-friendly transportation solutions like electric cars and public transportation networks. Additionally, it encourages commuters to choose more environmentally friendly modes of transportation.

4. Encouraging public transport use and user experience

ITS improves public transport systems by providing real-time information on bus or train arrivals, delays, and route changes, increasing the convenience and reliability of public transport services. Passengers can plan their journeys more efficiently using mobile applications and digital screens at stops. ITS can also help public transport agencies optimise applications and improve service delivery by supporting smart cards, electronic fare collection, and passenger counting features. For passengers, this means a smoother, more predictable, more accessible, and more enjoyable travel experience.

2.2. Disadvantages of Intelligent Transportation Systems

Despite the numerous advantages, Intelligent Transportation Systems have some disadvantages. They are explained in detail below.

1. High implementation and maintenance costs:

One of the main disadvantages of ITS is the significant financial investment required for implementation. The development of an ITS application involves the integration of advanced technologies such as sensors, communication networks, GPS, traffic cameras, integration software, data analysis systems, and communication network installation. The installation costs cover infrastructure applications such as electricity lines, data centres, and communication network setup. These parts are expensive up front and must be updated and maintained frequently to be safe and functional while the application runs. A yearly budget is also necessary after the system is deployed. The size and technological sophistication of the system determine the costs of things like staff training, technical support, cybersecurity precautions, data backup, software upgrades, license fees, routine maintenance and troubleshooting. This may significantly hamper adoption in poorer nations with tight funds. Additionally, installing, running, and debugging these systems calls for qualified staff, which raises continuing operating costs.

2. Data security and privacy issues:

ITS gathers and sends traffic, driver behaviour, and vehicle location data. Concerns regarding safeguarding personal privacy may surface throughout the storage, tracking, and analysis of this data. Unauthorised people can access or misuse sensitive information if it is improperly maintained. Data theft, control problems, or misuse of personal information may result from this. Additionally, cyberattacks using internet-based technologies are becoming more and more likely to target ITS.

3. Technological and infrastructure challenges

Technology compatibility and the current infrastructure are major factors in the effectiveness of ITS. The performance of ITS is greatly impacted by poor road conditions, systems that are incompatible with modern technology, and systems that are not accessible from all regions. Interoperability issues, such as ineffective communication between systems from different manufacturers or geographical locations, can also arise when integrating ITS with legacy systems or multiple applications. ITS programs must be updated frequently to keep up with technological advancements, which disrupt services and may raise long-term expenses.

4. Social and behavioural aspects

Notwithstanding its advantages, ITS may encounter prejudice from system engineers and users due to shifting customs or a lack of faith in technology. For fear of losing control or being secretly monitored, drivers may hesitate to trust traffic management or control-based application systems. Additionally, employing ITS capabilities may come with a learning curve, particularly for users not accustomed to digital technology or older populations. If ITS implementation is not adequately explained and supported, it may result in misunderstandings, annoyance, or even decreased adherence to traffic laws.

Although there are many prospects in the transportation sector with Intelligent Transportation Systems, their implementation calls for careful planning, funding, and social adjustment. The early identification and suitable resolution of issues, including excessive costs, insufficient infrastructure, data security threats, and user approach, strongly impact the success of ITS projects. Furthermore, ITS applications can become expensive and time-consuming undertakings if not properly designed. As a result, every project should start with well-defined objectives, thorough budget projections, and a workable, realistic timeframe. Planning adaptable time and cost management frameworks also lessens the impact of potential project delays or cost increases.

2.3. Environmental and Sustainable Impacts of Intelligent Transportation Systems

Intelligent transportation systems are strategic tools that safeguard the environment and promote sustainable urban living, as well as technical solutions that control traffic. They have a beneficial impact on several things, including lowering carbon emissions, conserving energy, lowering air pollution, and encouraging a sustainable mobility culture.

1. Reducing carbon emissions

Smart transportation systems minimise stop-and-go driving and needless waiting by maximising traffic flow. As a result, automobiles use less gasoline, and carbon emissions are greatly decreased. Smart signalling systems, for instance, guarantee that cars wait less at red lights. Vehicles spend less time in traffic when guided to the best path by real-time traffic control applications. Both individual automobile use and overall carbon emissions are decreased by incorporating public transit options. Therefore, ITS applications are crucial for regulating greenhouse gas emissions and lowering the carbon footprint of cities.

2. Energy efficiency and resource savings

ITS applications enable more efficient use of energy in transportation systems. For example, the infrastructure of smart charging stations for electric vehicles contributes to the balanced use of the electricity grid. Integrated with public transportation systems, ITS makes public transportation more attractive. Thus, more passengers can be transported with less energy. As traffic density decreases, resource consumption, such as fuel and tire wear. This provides both economic savings and enables more sustainable use of natural resources.

3. Reducing air and noise pollution

Traffic density and irregular vehicle movements in traffic are the main factors that increase air and noise pollution in cities. ITS can provide direct solutions to these problems: With ITS applications, heavy traffic can be reduced, and fewer exhaust gases can be released. Less stop-and-go of vehicles reduces engine noise and brake sounds. Encouraging public transportation and reducing the number of individual vehicles can also reduce noise pollution caused by urban traffic. In this way, a more livable and healthy environment can be created in cities.

4. Increasing the culture of sustainable transportation

ITS not only improves existing transportation but also encourages the adoption of more sustainable transportation habits. Systems integrated with bicycle paths and pedestrian crossings support existing transportation. Mobile access to public transportation information and ease of use make it easier for individuals to choose public transportation instead of private vehicles. E-scooters and micro-mobility systems provide transportation for those with fewer resources. In the long term, these systems will contribute to sustainable city life by spreading environmentally friendly transportation models.

3. KARABÜK PROVINCE TRANSPORTATION CURRENT STATUS

3.1. Highway Transportation

Karabük is connected to the Black Sea highway, the TEM highway and the E-5 Highway from the south. It neighbours Bartın in the northeast and Kastamonu in the southeast. In addition, connection work to Zonguldak continues with the road that follows the Yenice Stream valley from the west and is under construction.

There is a total of 385 km of road network in Karabük. 48% (185 km) of this road network consists of state roads, and 52% (200 km) of provincial roads (Table 1). When we look at the type of road surface, there are 2 km of parquet, stabilised, and dirt roads and 115 km of bituminous hot-coated roads. In addition, there are 268 km of surface paved roads, 30% of which are bituminous hot pavement (Figure 1).

Table 1. Current State and Provincial Road Length in Karabük Province as of July 2024 (km) (General Directorate of Highways [KGM], 2024)

City	State highway	City Highway	Total
Karabuk	185	200	385

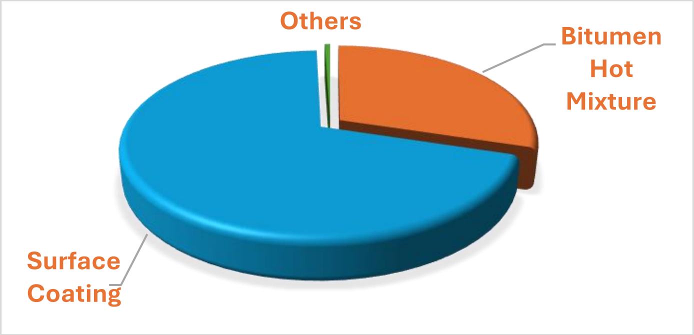

Figure 1. Road Network Surface Types in Karabük Province

The public transportation options available in Karabük are private and municipal public buses, minibuses, and taxis. While there is a high demand for public buses to transport people to the city centre, there are inadequacies in the number and frequency of trips. Long waiting times at the stops, buses waiting for short periods due to the absence or insufficient pockets in the road superstructure design, and bus stops when it approaches the stop while continuing in the current traffic, especially in the city centre, stop the traffic. There is frequent congestion due to the number of vehicles parked on the roadside, insufficient parking, and irregularity. This density negatively affects pedestrians and people who want to park their vehicles. Pedestrian traffic cannot cross the street safely due to the long queues created by vehicles and the incorrect positions of pedestrian crossings. This problem occurs frequently on weekdays and weekends, especially on the main street where Kares Shopping Centre is in the city centre.

3.2. Railway Transportation

Railway transportation is also available in Karabük. Karabük has a railway connection to Zonguldak and Ankara via Çankırı. Passenger transportation is carried out between Ankara and Zonguldak with Karaelmas Express. In addition, passenger transportation, mainly for workers, is carried out between Karabuk and Zonguldak. The raw material needs of Kardemir Iron and Steel Enterprises are met via the existing railway line and are used for product transportation.

Trains travel from Karabük to sea level at an altitude of 258 m. Due to uphill travel, the Turkish National Railway System (TCDD) has defined the average cruising speeds on the line as 70 km/h towards Zonguldak and 60 km/h towards Karabük. However, due to the line renewal works completed in 2018, it takes time for the line to be put into place, and trains have been instructed to travel slowly and carefully. For this reason, trains remain far from planned speeds. When the train travel times on the railway track between Karabük and Zonguldak are compared, an average travel time of 168.5 minutes emerges in the current situation. During this period, trains travel at an average speed of 43,03 km/h. This speed is 59% lower than the mediocre 60 km/h (Akay & Aygun, 2022).

3.3. Airway Transportation

Among the closest airports providing transportation to Karabük, Ankara Esenboga Airport is 240 km away. Additionally, Zonguldak Airport is 97,6 km away, and Kastamonu Airport is 136,4 km away. Ankara Esenboğa Airport hosts national and international flights due to its distance from Karabük and the capital's central location, Ankara. This airport is generally a preferred option for transportation to Karabük.

Although Zonguldak Airport is closer to Karabük, flight options are more limited since it is a smaller airport. Kastamonu Airport can also be an alternative option for transportation to Karabük. However, it is less preferred since it is farther away than other airports. Zonguldak Airport serves the province of Zonguldak, which is located close to Karabük, but it is a smaller airport. The airport is generally used for domestic flights, which are generally directed to Istanbul. Flights from Zonguldak Airport to Istanbul are generally organised on certain days of the week.

3.4. Karabük Province Traffic Accident Statistics

Every year in our country, thousands of people are injured, disabled, or lose their lives due to traffic accidents. As a result of traffic accidents, serious damage may occur to both your physical integrity and your property. While injuries can cause short or long-term health problems, in severe cases, permanent disabilities may also occur. Additionally, accidents can cause property damage, causing damage to your vehicles and other belongings that need to be repaired or replaced. This situation causes great costs and losses individually and socially, and creates an economic burden. To prevent traffic accidents and mitigate their consequences, it is vital to comply with traffic rules, adopt safe driving techniques, and take necessary emergency precautions.

Statistics on traffic accidents in Karabük in 2023 show serious traffic safety problems in the city. Three thousand one hundred ninety-three traffic accidents occurred, and 761 were recorded as fatal and injured (Table 2). As a result of these accidents, 48 people lost their lives, and 1203 people were injured. The total number of motor vehicles in Karabük is 73,886, and the number of accidents is quite high compared to this vehicle density (TUIK, n.d.).

Table 2. Karabük Province 2023 Traffic Accident Statistics

City	Total number of accidents	Total Number of Motor Vehicles	Number of Accidents with Fatal Injury	Number of Deaths	Number of Injured
Karabuk	3193	73 886	761	48	1203

Especially considering the number of fatal and injured accidents, it is understood that traffic inspections and driver training are insufficient. The high rate of accidents shows that various measures must be taken to increase compliance with traffic rules and make drivers more conscious. Reviewing and improving the city's road infrastructure and traffic signs can also reduce accidents. Loss of life and injuries caused by traffic accidents negatively affect not only individuals and families but also the general well-being of society.

3.5. Karabük Province 2050 Population and Vehicle Situation Analysis

3.5.1. 2050 Population Projection

Population projection is making predictions about the population based on future trends of birth, death, and migration data, as well as some assumptions. Population projections are used in many areas. The institution from which we can obtain this data in our country is the Turkish Statistical Institute (TUIK)

Table 3. Population Values of Karabük Province Between 1955 and 2023 (TUIK, n.d.).

Year	Karabük Population
1955	49.654
1960	66.246
1965	84.457
1970	103.767
1975	116.088
1980	131.349
1985	142.569
1990	123.381
2000	116.804
2005	200.084
2010	227.61
2015	236.978
2020	243.458
2023	255.242

The arithmetic Increase Method was used in the 2035 population projection calculation.

$$N_g = N_s + k_a(t_g - t_s) \quad (1)$$

$$k_a = (N_y - N_e)/(t_y - t_e) \quad (2)$$

N_g : Estimated future population
N_s: Latest census (most current population data)
k_a : Arithmetic coefficient of increase rate
t_g : Year corresponding to the next year (the future in which the population estimate will be made)
t_s : Year corresponding to the last census

N_y :New census
N_e : Old census
t_y : New year corresponding to the new census
t_e: Old year corresponding to the old census

k_a= (255242-49654) / (2023-1955) = 3023,35
N_{2025} = 49654 + 3023,35*(2025-1955) = 261.289 person

The results of the above data are shown in Table 4. Considering the 2050 provincial population in the table, it is seen that the provincial population will increase by approximately 32% compared to 2023 in an average period of 25 years. In other words, the provincial population is expected to increase by an average of 32% in 2050. Inevitably, this significant increase will also bring transportation problems. Therefore, it is important to make effective plans to solve transportation problems that may arise in the future.

Table 4. Karabük Province's Population Projection for 2050

Year	Population
2025	261.289
2030	276.405
2035	291.522
2040	306.639
2045	321.756
2050	336.872

3.5.2. 2050 Vehicle Projection

The number of motor vehicles in Karabük province between 2019 and 2023 is shown in Table 5.

Table 5. Number of Traffic Vehicles in Karabük According to Years (TUIK, N.D.).

Year	Total Number of Vehicles
2019	66.719
2020	67.165
2021	68.427
2022	69.711
2023	73.886

The arithmetic Increase Method was used in the 2050 traffic vehicle projection calculation.

$$T_g = T_s + k_a(t_g - t_s) \quad (3)$$

$$k_a = (T_y - T_e)/(t_y - t_e) \quad (4)$$

k_a= (73.886-66.719) / (2023-2019) = 1792,75
T_{2025} = 66.719+ 1792,75. (2025-2019) = 77472 vehicle

Table 6. 2050 Traffic Vehicle Projection for Karabük Province

Year	Total Number of Vehicles
2025	77 472
2030	86 433
2035	95 395
2040	104 356
2045	113 318
2050	122 279

According to the data in Table 6, the number of vehicles in the Karabük District is expected to increase steadily between 2025 and 2050. The total number of vehicles, which will be 77,472 in 2025, is expected to reach 122,279 in 2050, with an increase of approximately 9,000 to 10,000 units every five years (TUIK, n.d.). This forecast shows that traffic in Karabük province will intensify in the coming years, and therefore, significant planning needs to be made for infrastructure, road expansion, and traffic management. In addition, sustainable transportation solutions need to be developed by considering the environmental impacts of this increase. It is thought that these data will play an important role in determining the future transportation strategies of Karabük province.

Table 7. Number of Motor Vehicles in Karabük Between 2019 and 2023

Year	Total	Automobile	Minibus	Bus	Pickup truck	Truck	Motorcycle	Special Purpose Vehicles	Tractor
2019	66719	41451	1734	627	9718	3024	4085	240	5840
2020	67165	41255	1684	581	9730	3053	4635	261	5966
2021	68427	41901	1636	561	9836	3106	4986	271	6130
2022	69711	42134	1586	539	9939	3195	5780	290	6248
2023	73886	43376	1597	584	10086	3254	8240	308	6459

It is possible to find the average percentages of vehicles by considering the values in Table 7. Average Automobile Percentage (K_A) can be calculated as follows:

K_A = (41451+41255+41901+42134+4376)100 / (66719+67165+68427+69711+73886): 61%

In Karabük, the highest share of road vehicles was taken by automobiles, with a rate of 61%. The 2050 Karabük province traffic vehicle distribution projection, created because of the above calculations, is shown in Table 8.

Table 8. Traffic Vehicle Distribution Projection for Karabük Province for 2025-2050

Year	Total	Automobile	Minibus	Bus	Pickup truck	Truck	Motorcycle	Special Purpose Vehicles	Tractor
%	100	61	2	1	14	4	8	1	9
2025	77472	47258	1549	775	10846	3099	6198	775	6972
2030	86433	52724	1729	864	12101	3457	6915	864	7779
2035	95395	58191	1908	954	13355	3816	7632	954	8585
2040	104356	63657	2087	1044	14610	4174	8348	1044	9392
2045	113318	69124	2266	1133	15865	4533	9065	1133	10199
2050	122279	74590	2446	1223	17119	4891	9782	1223	11005

4. METHODOLOGY

The National Intelligent Transportation Systems Strategy Document, prepared by UAB in 2020, determined the action plan and national strategies between 2020 and 2023 by determining responsible and collaborative organisations through 5 strategic objectives and 31 action items.

This study evaluated urban transportation in Karabük through action items that directly or indirectly concern municipalities within the scope of UAB's National Intelligent Transportation Systems Strategy Document (Table 9). Pedestrians, cyclists, and private vehicle users living in Karabük were asked to determine the importance of 8 criteria consisting of action items. These articles are considered especially useful in evaluating the diversity of services municipalities offer (Republic of Turkey Ministry of Transport and Infrastructure, 2020).

Table 9. Action Items Regarding Municipalities in the Strategy Document

Action 1.4.	Establishing provincial traffic control centres
Action 1.7.	Installation of smart car park applications and electric vehicle charging stations
Action 2.2.	Passenger information systems
Action 4.4.	Establishment of a unit responsible for intelligent transportation systems in local governments
Action 4.5.	Using electric vehicles in public transportation fleets and service vehicles, and encouraging public transportation
Action 4.7.	Expanding the use of bicycles

The best-worst method, one of the multi-criteria decision-making methods, was used in the analysis of the study. Multi-criteria decision-making has proven to be an effective approach for ranking or selecting one or more alternatives from a limited number of alternatives based on multiple, often conflicting, criteria. One of the alternative methods to these methods is the Best-Worst Method (BWM). This method attracts attention due to its effectiveness in reducing pairwise comparison times and its good performance in maintaining consistency between judgments. BWM is a multi-criteria decision-making method that can select the best and worst criteria and compare these criteria with other criteria.

Table 10. Criteria and Practice Codes

Establishing provincial traffic control centres	Criteria 1
Installation of the smart car park application	Criteria 2
Installation of electric vehicle charging stations	Criteria 3
Passenger information systems	Criteria 4
Establishment of a unit responsible for intelligent transportation systems in local governments	Criteria 5
Use of electric vehicles in public transport fleets and service vehicles	Criteria 6
Encouraging public transportation	Criteria 7
Expanding the use of bicycles	Criteria 8

According to BWM, the most important and least important criteria are determined by decision-makers (Rezaei, 2015). Then, each of these most important and least important criteria is evaluated in a pairwise comparison with other criteria. The most effective feature of BWM, compared to existing MCDM methods, is that it has fewer pairwise comparison matrices and provides more consistent evaluations (Rezaei, 2015).

BWM obtains the importance levels of the criteria through an application consisting of six stages.

Step 1: Criteria c_1, c_2 … c_n are determined.

Step 2: Among n criteria, the most and least significant criteria are identified.

Step 3: The importance level of the most important criterion compared to other criteria is obtained by using a scale between 1 and 9 (1: equally important; 9: extremely important). It should be evaluated as 1 when it is equally important and 9 when it is very important. The vector evaluates the most important criterion according to other criteria.

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn}) \quad (5)$$

Step 4: Comparison of other criteria concerning the least important criterion using a scale ranging from 1 to 9. The vector evaluates other criteria according to the least important criterion.

$$A_W = (a_{1W}, a_{2W}, \dots a_{nW})^T \quad (6)$$

Step 5: Optimum weights of the criteria (W_1^* , W_2^* , … W_n^*) are calculated. If the consistency indicator is close to "0", it indicates high consistency.
The model that minimizes the maximum of $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jw}\right|$differences is the model that minimizes the maximum for all j.

$$\begin{cases} minmax_j \left\{\left|\frac{W_B}{W_j} - a_{Bj}\right|, \left|\frac{W_j}{W_W} - a_{jw}\right|\right\} \\ st \\ \sum_j W_j = 1 \\ W_j \geq 0 \, for\ all\ j \end{cases} \tag{7}$$

The equation (7) can be translated into linear form as follows:

$$\begin{gathered} \min\xi \\ \left|\frac{W_B}{W_j} - a_{Bj}\right| \leq \xi \text{ for all } j \\ \left|\frac{W_j}{W_W} - a_{jw}\right| \leq \xi \text{ for all } j \\ \sum_j W_j = 1 \\ W_j \geq 0 \text{ for all } j \end{gathered} \tag{8}$$

Step 6: With the solution of the model, criterion weights and consistency index (ξ) are calculated. In the last stage of the method, the consistency of the evaluations is tested. The consistency ratio is calculated using Eq. 9.

$$\text{Consistency Ratio} = \frac{\xi}{\text{Consistency Index}} \tag{9}$$

Table 11. Consistency Index (CI)

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index	0	0,44	1,00	1,63	2,30	3,00	3,73	4,47	5,23

As the consistency ratio approaches zero, it is concluded that the evaluations are more consistent.

After the criteria in Table 10 were determined, decision-makers made separate evaluations to make calculations with BWM. First, the most important and least important criteria were determined. The evaluations were completed by evaluating the preference levels of the most important criterion compared to other criteria and the preference levels of other criteria compared to the least important criteria, using the evaluation scale between 1 and 9.

After receiving the evaluations of the decision makers, separate linear programming models were established using Equations (5)-(8). These models were solved using the MS Excel solver add-in, and the criterion weights were calculated, as shown in Table 12. The final weights were obtained by averaging the criterion weights calculated separately for 10 decision-makers. In addition, the consistency of all evaluations was tested using Equation (9), and the consistency rates were transferred to the last line of Table 12.

Table 12. Calculated Criterion Weights and Consistency Rates

Decision Makers	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9	DM10	Final Weights
Criteria1	0,1032	0,1258	0,1940	0,0937	0,0725	0,1027	0,1293	0,1139	0,0848	0,0873	0,1107
Criteria2	0,0248	0,1887	0,1293	0,0586	0,0286	0,0280	0,1293	0,2807	0,0565	0,0748	0,0999
Criteria3	0,0590	0,0252	0,0970	0,1171	0,0453	0,0587	0,0554	0,0854	0,0848	0,0655	0,0693
Criteria4	0,2064	0,3019	0,0970	0,0586	0,0906	0,2054	0,3104	0,1709	0,3948	0,1310	0,1967
Criteria5	0,1376	0,0629	0,0647	0,0669	0,1812	0,1370	0,1940	0,1709	0,1271	0,3286	0,1471
Criteria6	0,0688	0,0943	0,0554	0,0273	0,0906	0,0822	0,0554	0,0683	0,0401	0,0333	0,0616
Criteria7	0,3178	0,1258	0,3319	0,3436	0,3100	0,3175	0,0970	0,0854	0,0848	0,1048	0,2118
Criteria8	0,0825	0,0755	0,0306	0,2342	0,1812	0,0685	0,0291	0,0244	0,1271	0,1746	0,1028
ξ	0,0949	0,0755	0,0562	0,1249	0,0525	0,0934	0,0776	0,0610	0,1138	0,1953	
Consistency Rates	0,3194	0,2917	0,1528	0,1667	0,1528	0,3571	0,2857	0,2083	0,2500	0,3036	

4. CONCLUSION AND RECOMMENDATIONS

According to the analysis results conducted within the scope of the study, the most important criterion is "Criteria 7-Encouragement of public transportation," with a weight value of 21,18%. This criterion was followed by "Criteria 4-Passenger information systems" and "Criteria 5-Establishment of a unit responsible for smart transportation systems in local governments". On the other hand, the least important criterion was determined as "Criteria 6-Use of electric vehicles in public transportation fleets and service vehicles," with a weight value of 6.16%. In addition to the results, the consistency rates of the evaluations for all decision-makers were calculated. It was seen that all these coefficients were very close to zero, and therefore, quite consistent evaluations were made by the decision-makers.

The results indicate the first three criteria for public and smart transportation systems. It is concluded that the deficiencies in the current public transportation system should be eliminated, passenger information systems should be integrated with smart transportation systems, and a relevant unit should be established within local governments to establish and manage smart transportation systems. Intelligent transportation systems in urban transportation will positively affect many areas. These systems play an important role in reducing the cognitive load on drivers, passengers, and pedestrians using urban transportation and improving transportation's economic, environmental, and social impacts. Moreover, smart transportation systems greatly increase the demand for public transportation. It is also important to remember that systems that improve and encourage bicycle and pedestrian safety should be developed within sustainable mobility and transportation.

Based on all these evaluations, the following suggestions are proposed for improving urban transportation in Karabük province:

1. Encouraging public transportation plays an important role in solving transportation problems. Expanding public transportation lines and increasing their hours can ease traffic by reducing the use of private vehicles. Another important issue in public transportation services is accessibility. Whether the vehicles and stops are disability-friendly should be examined, and necessary improvements should be made. Public vehicles should be integrated with smart transportation systems. Single card usage in public vehicles, displaying card information and balance via the internet or mobile systems, and balance loading systems should also be developed.

2. Existing public transport stops should be transformed into smart stops. Smart stops allow passengers to instantly track their journeys, stop information, make electronic payments, and benefit from wireless internet networks and charging units. These improvements are thought to make the city's transportation system more efficient and user-friendly.

3. Using intelligent transportation systems is one of the most effective methods for managing traffic and directing vehicles. Especially in signalled intersections, intersection management, fixed phase, multi-phase, dynamic intersection, green wave, etc., intersection and corridor management systems should be applied. In this way, traffic flow can be regulated, and density can be reduced. In addition, a more efficient transportation network can be created by adjusting the timing of traffic lights and using real-time traffic data.

4. Due to the inadequacy of safety measures on the superstructure of the roads in and around the city centre, unwanted accidents occur every year for vehicles and pedestrians, causing various injuries and deaths. A comprehensive improvement and renovation work is required to increase road safety and prevent accidents. Measures such as arranging pedestrian crossings, paying attention to traffic signs and signals, implementing speed limits more effectively, and increasing lighting should be included in these studies.

5. Improving urban transportation infrastructure will facilitate daily life and contribute to creating a sustainable transportation system in the long term. In this context, it is recommended that local governments work with relevant stakeholders to develop and implement a comprehensive transportation plan.

Contribution of The Authors
The authors declared that they contributed equally to this paper.

Conflict of Interest
The authors declare that there is no conflict of interest.

Statement of Research and Publication Ethics
Research rules and publication ethics were followed in the study.

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