Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

2024-2025

PROJECT TITLE
Mobility Hub Center Site Selection by Pythagorean Fuzzy SWARA Integrated ARTASI
PROJECT ADVISOR
Rüçhan DENİZ ÖZGEN
TEAM MEMBERS
Eylül ERDEM (Team Representative) Muhammed Enes ALBAYRAK Sevilay IŞIK Ahmet Yiğit YILMAZ

Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

Project Code:r341371
Project Title: Mobility Hub Center Site Selection by Pythagorean Fuzzy SWARA Integrated ARTASI
Project Advisor: Rüçhan DENİZ ÖZGEN
Project Team Members: Eylül ERDEM (Team Representative) Muhammed Enes ALBAYRAK Sevilay IŞIK Ahmet Yiğit YILMAZ
Sponsor Company (if any): N/A

BUDGET (TL)	PROPOSED	CONSENTED
IMU FUNDING		
SPONSOR COMPANY FUNDING		
TOTAL		

PROJECT PLAN	PROPOSED	CONSENTED
PROJECT PLAN Duration in Weeks	28 Weeks	28 Weeks
STARTING DATE	10.10.2024	30.06.2025

Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

PROJECT ADVISOR	DEPARTMENT CHAIR
Name: Ruchan DENİZ ÖZGEN	**Name:** Assoc. Prof. Dr. Melis Almula Karadayı
Contact Information: Tel : 0216 681 2149 E-mail : ruchan.deniz@medipol.edu.tr	**Contact Information:** Tel : E-mail : makaradayi@medipol.edu.tr
Signature:	**Signature:**

TEAM MEMBER	TEAM MEMBER
Name: Eylül ERDEM (Team Representative)	**Name: Ahmet Yiğit YILMAZ**
Contact Information: Tel E-mail : eylul.erdem@std.medipol.edu.tr	**Contact Information:** Tel E-mail : ahmet.yilmaz7@std.medipol.edu.tr
Signature:	**Signature:**

Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

TEAM MEMBER	Sponsor Company
Name: Enes ALBAYRAK	**Name:** N/A
Contact Information: Tel E-mail : muhammed.albayrak@std.medipol.edu.tr	**Contact Information:** Tel : N/A E-mail : N/A
Signature:	**Signature:**

TEAM MEMBER
Name: Sevilay IŞIK
Contact Information: Tel E-mail : sevilay.isik@std.medipol.edu.tr
Signature: 

Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

Project Title: Mobility Hub Center Site Selection by Pythagorean Fuzzy SWARA Integrated ARTASI	
Project Advisor: Rüçhan DENİZ ÖZGEN	
Team Members: Eylül ERDEM (Team Representative) Muhammed Enes ALBAYRAK Sevilay IŞIK Ahmet Yiğit YILMAZ	
Project Group Title:	

Istanbul Medipol University

School of Engineering and Natural Sciences

Graduation Project

PROJECT OVERVIEW/SUMMARY/ABSTRACT

This study presents a strategic approach that aims to reduce private vehicle dependency and increase sustainability in urban transportation by establishing mobility centers at points with high public transportation access on the Anatolian Side of Istanbul. Mobility centers will allow individuals to park their private vehicles in a safe common area and provide fast and easy access to public transportation vehicles. Thus, a positive transformation in urban transportation is aimed by providing benefits such as reducing traffic congestion, environmental sustainability, increasing road safety and reducing transportation costs of individuals. A new methodology that hybridizes SWARA (Step-Wise Weight Assessment Ratio Analysis) and ARTASI multi-criteria decision-making methods in a Pythagorean fuzzy environment will be proposed for the placement of mobility centers in the most suitable locations. While the SWARA technique determines the weights of the criteria in line with expert opinions, Pythagorean fuzzy sets provide more precise and reliable results by taking into account the uncertainties inherent in the problem and expert evaluations. Thus, with the integration of Pythagorean fuzzy SWARA and ARTASI methods, a comprehensive assessment will be made in line with criteria such as public transportation accessibility, transportation diversity, infrastructure adequacy, environmental impacts and economic benefits, and the most appropriate alternatives for the selection of mobility center locations will be determined.

A strategic and systematic approach will be adopted in project management, and cooperation will be made with stakeholders such as local governments, transportation planning experts and public transportation organizations. Pilot applications will be carried out in the light of the analysis made on the selection and applicability of the locations where mobility centers will be established, and regular evaluations will be made in accordance with the project objectives. With the feedback obtained from the pilot applications, decision-making processes will be updated, and the effectiveness of the application will be increased. Project management will be carried out with the participation of stakeholders and the aim will be for mobility centers to work in an integrated manner with public transportation.

The aim of this project is to provide a safe center where individuals can park their vehicles and continue their transportation or switch to public transportation in order to provide sustainable transportation opportunities for the public on the Anatolian Side of Istanbul. This system will provide savings in fuel and maintenance costs for individuals and contribute to the public transportation sector, thus benefiting the economy. Moreover, by using public transportation, traffic will be reduced, roads will be safer, the time it takes for people to get from point A to point B will decrease, and the psychological distress caused by traffic will decrease, and then people's quality of life will improve. As environmental factors, the city's air quality will improve and carbon emissions will decrease, reducing the carbon footprint.

Keywords: Mobility hub selection, multi-criteria decision making, Pythagorean fuzzy, SWARA, ARTASI

1. OBJECTIVE OF THE PROJECT

The aim of this project is to improve people's experience of public transportation and to reduce the traffic problem on the Asian side of Istanbul by integrating various transportation vehicles such as metrobus, bus, metro, marmaray, train, tram, bicycle, scooter and shared vehicles into a single center. These centers aim to facilitate transportation throughout the city faster and more smoothly, to enable people to use public transportation resources efficiently, to save time and to ensure that their transportation is not complicated, to reduce the traffic problem by reducing the use of public transportation and to encourage people who start their transportation with their private vehicles to use public transportation through systems such as "Park and Ride". People who are far from mobility centers can come to these centers with their cars and park, then continue on their way with environmentally friendly alternatives. In the centers where sustainability is prioritized, there will be electric vehicle charging stations, renewable energy systems, bicycle and scooter parking areas and green areas to increase environmental sustainability and reduce emissions, and also an environment that people will enjoy will be created with waiting areas, restaurants, cafes and green areas. With the unification of transportation systems, urban complexity will be reduced, intra-city travel will be simplified, and the local economy will be revitalized by establishing new workplaces and businesses in these centers, supporting social welfare. In addition, with the use of technology and digital infrastructure, these centers will enhance the travel experience with mobile applications, digital information systems and transportation-specific notification systems, and will enable real-time service monitoring that increases comfort, safety and efficiency. These centers will not only be for public transportation but will also serve as entertainment and social areas. While contributing to the livability of the city, a sustainable and future-ready city will be created for Istanbul [1]-[4].

2. LITERATURE REVIEW

Sustainable Transportation

Today, cities can become smarter and more sustainable for their residents by utilizing renewable energy, other technologies, and information and communication technologies (ICT) through the efforts of governments and municipalities. Smart and sustainable cities aim to meet the economic, social, environmental and cultural needs of current and future generations by using information and communication technologies (ICT). These cities also improve the quality of life, increase the efficiency of urban services and operations, and strengthen the competitiveness of cities. With these features, they play an important role in combating climate change, one of the biggest problems we face on a global scale.

Sustainable and smart cities create a multi-dimensional system with the integration of new technologies, comprehensive urban planning, and environmentally friendly transportation solutions. One of the most important components of this structure is sustainable transportation. This transportation approach aims to meet the mobility needs of society and minimize the negative impacts on the environment.

The benefits offered to society by sustainable transportation systems include savings in fuel costs, reduction of carbon emissions, improvement of air quality and healthier and more practical mobility thanks to transportation vehicles operating with sustainable energy. In this direction, minimizing environmental pollution, reducing the use of natural resources, and reducing air pollution are the main objectives.

As long as sustainability principles are adhered to, both today's and tomorrow's societies will be able to live in a cleaner and more livable environment [5]-[7].

Mobility Hubs

In this context, mobility hubs play a vital role in sustainable and smart transportation systems. Aiming to make public transportation systems more effective and widespread, these centers aim to reduce traffic congestion by reducing individual vehicle use. They both save time and minimize environmental impacts by offering easy transitions between different transportation modes. The contributions of mobility hubs are not limited to easing traffic; they also reduce emissions and air pollution caused by private vehicles by encouraging public transportation habits. Energy efficiency is also significantly increased by integrating renewable energy sources into the public transportation infrastructure. These hubs are one of the fundamental elements that shape urban planning according to their location. A mobility hub that connects transportation vehicles such as buses, trams, metros, electric bicycles and scooters in an integrated manner offers maximum efficiency and sustainability.

Urban planners turn to mobility hubs to implement a more integrated transportation system. For example, in the Drenthe-Groningen region of the Netherlands, mobility hubs are integrated with the country's widely used bicycle-based transit services. This approach is vital in creating a flexible transportation network, even in low-populated areas. Mobility hubs simplify transportation and support businesses by increasing human activity in communal spaces. Cafes, restaurants, and shopping centers around these hubs provide venues where people can conveniently travel while enjoying quality leisure time [8]-[9].

Mobility Hubs for Istanbul’s Asian Side

Mobility hubs can serve as a solution to minimize the severe air pollution, traffic congestion, and economic losses caused by the excessive use of private cars on Istanbul’s Asian Side. Within the framework of sustainable smart cities, the establishment of mobility hubs at key locations on Istanbul's Asian side—one of Turkey's largest metropolitan areas—can significantly address public transportation needs through well-organized planning. These hubs can enable faster and more sustainable transportation options.

In this context, the current study aims to identify and rank the most suitable alternatives for mobility hub placement on Istanbul's Asian side. By implementing these hubs, public transit can be optimized, making it more accessible and effective while contributing to a cleaner, more efficient transportation system [10]-[11].

3. ORIGINALITY

The project stands out in the field of mobility center planning by focusing on the Anatolian side of Istanbul, a region that has been largely ignored in previous studies. While most existing studies focus on general city centers and generally the European side, a significant gap is identified in understanding the unique transportation dynamics of the Anatolian side. By addressing this gap, our project not only contributes to the existing knowledge, but also aims to address a real-world issue that has not yet been adequately addressed.

One of the most striking features of our project is the methodology used to identify potential locations for mobility centers, which is multi-criteria decision-making methods such as Pythagorean Fuzzy Logic and Step-by-Step Weighted Assessment Ratio Analysis (SWARA). Unlike most previous projects, which usually rely on basic or singular assessment criteria such as cost or distance, our approach combines multiple dimensions such as public transport accessibility, environmental impact, user convenience, and economic viability. This comprehensive assessment distinguishes the proposed locations not only in terms of practicality, but also in terms of sustainability and closer alignment with the needs of the region. In addition, while most studies focus on optimizing transportation networks in densely populated areas, our project addresses the scattered population structure, mixed land use, and unique transportation challenges of the Anatolian side, among many other details. These factors require specific solutions that our innovative methodological framework effectively addresses.

Another aspect of our project is the integration of stakeholder engagement and local insights. While similar projects often rely on quantitative data alone, our approach also considers qualitative data by combining field observations, user surveys, and community workshops to gain holistic insights into user preferences and local needs.

Finally, our project combines real-time transportation data and predictive analytics, an area often overlooked in similar studies. It optimizes mobility hub locations under changing conditions, ensuring future project adaptability.

A detailed literature review found that there are very few articles on Mobility Hub Location Selection. Wassim Hached, Alain L'Hostis, Albert Gragera (Wassim et al.) studied environmental impacts and user behavior in the planning of sustainable mobility centers in Europe using multi-criteria decision-making methods. However, since it focuses on European cities, its framework is less adaptable to cities with high population density and unique infrastructure dynamics, such as Istanbul. In addition, it prioritizes general sustainability metrics over region-specific criteria such as public transport accessibility. Our project offers a more localized solution by considering the demographic and geographic characteristics of the Anatolian side of Istanbul [12], and the location of mobility centers is determined by using Geographic Information Systems (GIS) focusing on criteria such as distance, population density and the status of existing infrastructure. However, we conclude that it does not use fuzzy logic or SWARA methods, relying on rigid and one-dimensional criteria. Furthermore, it does not adopt a participatory approach or evaluate user preferences. Our project offers a more innovative approach with a broader set of evaluation criteria and a regional participation strategy [15]. take it It used multi-criteria decision-making methods to determine the location of mobility centers in urban areas, focusing on criteria such as cost, distance, and public transport integration. However, it approached the subject from a general city center perspective and did not take into account regional differences. It did not focus on transportation challenges specific to the Anatolian side of Istanbul or use methodologies such as Pythagorean Fuzzy Logic or SWARA [13].
It assessed the accessibility of the transportation network throughout Istanbul and analyzed public transport data to determine transportation centers. The study considered Istanbul as a whole and did not address the specific challenges faced by the Anatolian side. The data used was based on the existing transportation infrastructure, excluding potential future developments. In contrast, our project focuses only on the Anatolian side and includes multi-dimensional analyses with community participation [14].

In summary, what makes our project unique is its focus on the local area, the use of advanced methods (Pythagorean Fuzzy Logic and SWARA), comprehensive evaluation standards, community-centered approach, and use of advanced data analysis. While previous projects often proposed generalized solutions or ignored local contexts, our project offers an innovative approach specifically tailored to the Anatolian side. This approach makes our project both unique and an important contribution to transportation planning and urban development.

4. SCOPE OF THE PROJECT AND EXPERIMENTS/METHODS

The goal of this project is to identify the best sites for mobility hubs on Istanbul's Asian side using a multi-criteria decision-making method. By decreasing reliance on private vehicles, the project seeks to boost the sustainability of urban transportation and encourage the use of public transportation. The study's main findings include improved accessibility, less traffic, and environmental advantages. To accomplish project objectives, this activity integrates technical analysis, stakeholder interaction, and pilot testing. Specifically:

Geographic Scope: Only the Asian side of Istanbul is evaluated.

Criteria: Cost-effectiveness, environmental sustainability, transit accessibility, and interoperability with current infrastructure.

Methods: We use the SWARA and ARTASI decision-making procedures in a Pythagorean fuzzy setting.

Resources: collaboration with local authorities, for example, IETT, and access to institutional facilities (survey tools, GIS, software like AnyLogic, and GPS trackers) [16].

4.1 Work Package 1: Preparatory Studies [17].

• Data Collection: Collect traffic density maps, air quality reports, and infrastructure data. Furthermore, conduct surveys with key stakeholders (for example, transportation planners and academicians).

• Selection of Criteria: Determine decision-making criteria based on literature and stakeholder feedback.

4.2 Work Package 2: Criteria Weight Determination and Methodology Development [18].

• SWARA Weight Assignment: Use expert opinions to assign weight to criteria in a fuzzy Pythagorean environment.

• Integration with ARTASI: Develop a ranking model for location alternatives using weighted criteria.4.3 Work Package 3: Evaluation and Analysis [19].

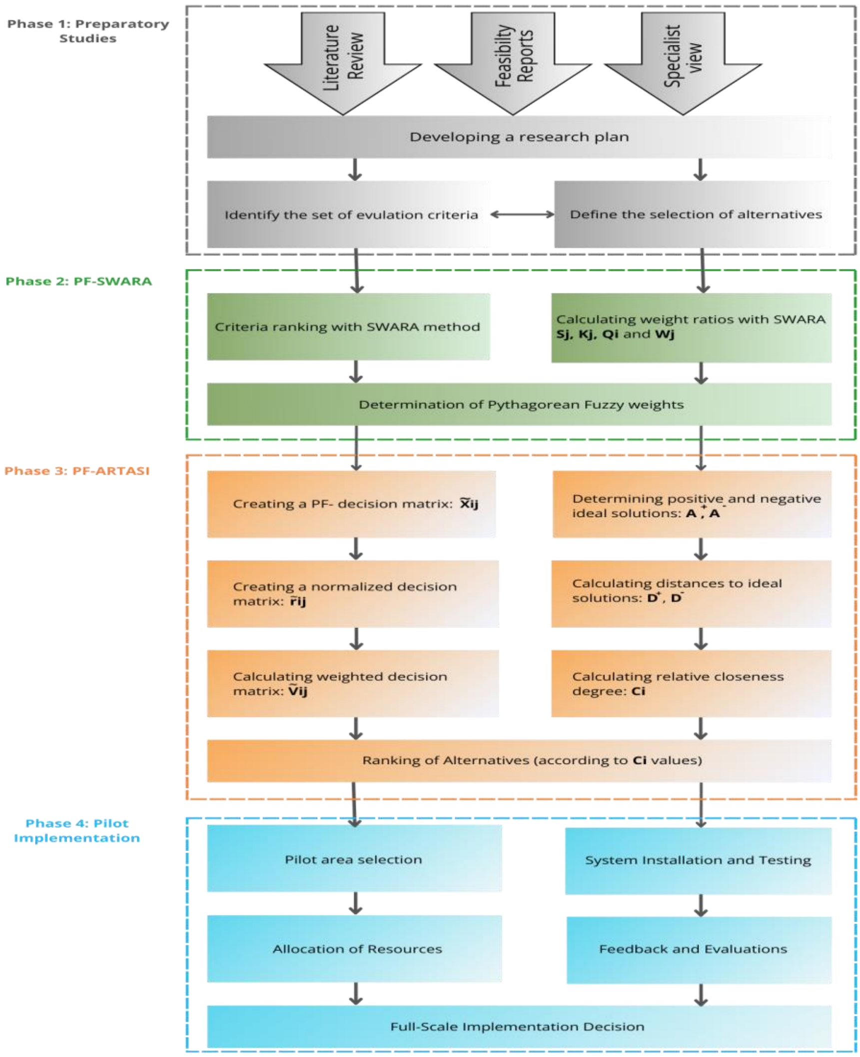
• Alternative Locations: Identify and evaluate potential mobility center areas: Kadıköy, Üsküdar, Kartal, Ümraniye, Beykoz.

• Scenario Testing: Simulate different transportation scenarios to predict center activity.

4.4 Work Package 4: Pilot Implementation [20].

• Prototype Testing: Develop a small-scale application in a high-priority area. Furthermore, collect performance metrics (for example, utilization rates, feedback from passengers).

• Iterative Analysis: Improve the criteria and methodologies according to the pilot results.



Steps of SWARA Method

1. Ranking the Criteria:

Decision-makers rank the criteria in descending order of importance.
In the case of multiple decision-makers, each ranks the criteria individually.
The geometric mean of all individual rankings determines the general ranking for group decision-making.

2. **Comparison of Criteria:**
Based on the general ranking, criteria are compared starting from the second criterion with the previous one.
Each decision-maker performs these comparisons independently.

3. **Calculation of Weights:**
After the comparisons, the weights of the criteria are determined using the SWARA method. This results in as many priority vectors as the number of decision-makers.

4. **Determination of Final General Priority Values:**
The geometric mean of the priority values of each criterion is calculated to obtain the final general priority values.

Advantages of the SWARA Method

Compared to other methods, SWARA requires significantly fewer comparisons. This allows participants to provide more accurate and consistent responses. Moreover, participants can freely evaluate the criteria without using any predefined scales [21].

Steps of ARTASI Method

1. Decision Matrix and Criteria Weights

Alternatives ($A_1, A_2, ..., A_n$) and criteria ($C_1, C_2, ..., C_m$) are determined. A decision matrix is created with the evaluations received from experts. This matrix is usually created with Pythagorean Fuzzy numbers. Criteria weights are determined

2. Normalized Decision Matrix (N)

The decision matrix is normalized, thus eliminating the measurement units of the criteria. Appropriate normalization formulas are used according to the maximization and minimization type criteria.

3. Weighted Normalized Decision Matrix (V)

Each normalized value is multiplied by the weight of the corresponding criterion

4. Determine Ideal (PIS) and Negative Ideal (NIS) Solutions

For each criterion, the best values (Positive Ideal Solution, PIS) and the worst values (Negative Ideal Solution, NIS) are determined:

5. Calculate Using Advanced Similarity Measures

Calculate the degree of positive and negative similarity for each alternative.

6. Calculate Net Similarity Value with Score Function

A total success score is determined for each alternative according to the similarity values obtained. This score is calculated by taking into account both the proximity of the alternative to good and its distance from bad.

7. Alternatives are listed

The alternative with the highest score is the most suitable one. Other alternatives are ranked according to their scores.

Advantages of ARTASI Method

The ARTASI method is a decision-making technique that takes multiple criteria into account, allowing for a more realistic ranking of alternatives by comparing them to an ideal solution. It's designed to handle uncertainty and deliver effective outcomes, particularly when using advanced fuzzy numbers like Pythagorean fuzzy. It provides a balance in the evaluation process by considering how close each option is to the best option and how far it is from the worst option. It also has a user-friendly, flexible structure that can be applied in various fields.

1. Geographical and Physical Criteria

a. Accessibility of Location

The location is evaluated in terms of its proximity to the city center, important points (airport, train stations, business centers, etc.) and areas with large population densities. The ease of accessibility of the location is critical to the use and attractiveness of the mobility center [21].

b. Land Size and Suitability

The selected location must be of a suitable size for the project. Sufficient space should allow for the establishment of all infrastructure such as terminal buildings, parking lots, bus stops, and bicycle parking areas. In addition, the possibility of expansion should be evaluated. (Expert Opinion)

c. Topographic Conditions

The physical structure of the land should be analyzed. For example, sloping and rocky lands may increase construction costs. Flat and solid ground are more advantageous in terms of cost. (Expert Opinion)

d. Climatic Conditions

Seasonal effects in the region should be evaluated. While water drainage systems gain importance in regions with heavy rainfall, shading and cooling systems may be required for passenger comfort in scorching regions. Climate may affect infrastructure and material selection [22].

2. Transportation and Accessibility Criteria

a. Public Transportation Connections

It is crucial that the chosen site be connected to public transit routes. Centrally feeding transportation networks like the metro, bus, tram, and train increase the efficiency of the mobility center. Additionally, users' accessibility is facilitated by being near these lines [23].

b. Road Connections

The area's proximity to major thoroughfares, highways, intercity and metropolitan roads is assessed. The transportation center's convenient entrance and exit enhance user experience and prevent traffic congestion [24].

c. Bicycle and Pedestrian Paths

Bicycle paths and pedestrian access opportunities are important criteria in terms of supporting sustainable transportation types. The mobility center becomes more useful with bicycle parking areas and safe pedestrian crossings [25].

d. Parking Area Opportunity

We evaluate the location to determine its suitability for parking. We should provide sufficient parking space, particularly for passengers using vehicles. It should also be able to meet modern needs such as electric vehicle charging stations [26].

3. Economic Criteria

a. Cost

- Long-term sustainable cost analyses should be conducted by considering the cost of purchasing or renting land, construction and infrastructure development costs, and operating and maintenance expenses [27].

b. Return on Investment (ROI)

- The time it will take to return on investments made in the project should be calculated, and as a result, elements such as income generation potential, passenger number estimates, and service pricing emerge in this analysis [28].

c. Economic Activity

- The economic potential of the selected region should be evaluated. For example, being close to commercial centers or being in regions with economic growth potential can increase the contribution of the mobility center to the region [29].

4. Social and Environmental Criteria

a. Environmental Sustainability

- The environmental impact of the project should be evaluated. The analysis should include factors such as loss of green space, increased carbon emissions, noise, and air pollution. Sustainable energy solutions (e.g., solar panels) and green infrastructure projects gain importance [30].

b. Population Density

- The population density that the mobility center will serve should be taken into account. For example, being close to densely populated areas increases passenger traffic. In addition, demographic data (e.g. age groups) should be analyzed to determine target users. (Expert Opinion)

c. Social Acceptance

- The support of local residents and stakeholders for the project is important. The social benefit of the project should be evaluated through participatory meetings and feedback mechanisms. (Expert Opinion)

d. Noise and Air Pollution Impact

- The potential negative impacts of the mobility center on the quality of life in the region should be evaluated. Necessary measures should be planned to reduce noise levels and emissions [31].

5. Technological and Innovative Criteria

a. Infrastructure Technologies

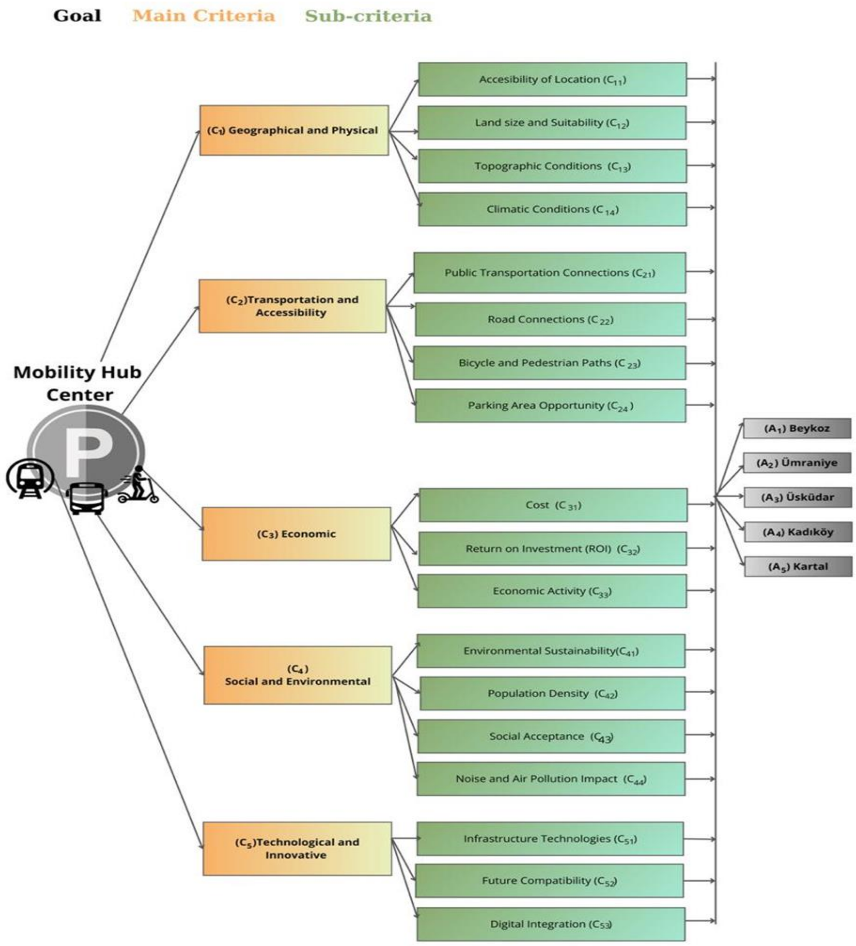
- The suitability of the location for modern infrastructure systems should be evaluated. For example, technological infrastructure needs such as electric vehicle charging stations, smart traffic systems, and internet connection should be taken into account [32].

b. Future Compatibility

- The selected location should be compatible with future transportation trends and technologies [32].

c. Digital Integration

- Integration with digital platforms and applications increases the user experience. For example, features such as parking reservations, trip planning, or payment systems via mobile applications will make users' lives easier and increase efficiency [32].



SUB-CRITERIA	DESCRIPTIONS
Accessibility of Location C1	Proximity to city centers, airports, train stations, and densely populated areas is evaluated.
Land Size and Suitability C2	The selected location must allow the establishment of all infrastructure, such as terminal buildings, parking lots, and bus stops, with expansion potential.
Topographic Conditions C3	Sloping or rocky lands may increase construction costs. Flat and solid ground are more advantageous than ground.
Climatic Conditions C4	Drainage systems are critical in rainy regions; shading and cooling systems are important in hot regions.
Public Transportation C5	Connections to central transportation networks increase accessibility and efficiency.

Road Connections C6	Easy access to major roads enhances user experience and reduces traffic congestion.
Bicycle and Pedestrian Paths C7	Bike parking and pedestrian crossings improve usability.
Parking Area Opportunity C8	Adequate parking, including facilities for electric vehicles, should be ensured.
Cost C9	Conducting a long-term sustainable cost analysis is necessary.
Return on Investment (ROI) C10	Passenger number estimates and pricing help calculate investment payback time.
Economic Activity C11	Proximity to commercial centers or economically growing regions increases regional contribution.
Environmental Sustainability C12	Factors like loss of green spaces, increased emissions, and noise should be analyzed.
Population Density C13	Proximity to densely populated areas increases passenger traffic. Demographics help identify target users.
Social Acceptance C14	Social benefits should be evaluated via participatory meetings and feedback.
Noise and Air Pollution Impact C15	Necessary measures should be planned to mitigate noise and emissions.
Infrastructure Technologies C16	Modern needs like EV charging stations, smart systems, and internet connectivity should be assessed.
Future Compatibility C17	The location must align with future transportation technologies.
Digital Integration C18	Features like mobile reservations, trip planning, and payments enhance efficiency.

5. PROJECT TARGETS AND SUCCESS CRITERIA

The aim of this project is to select a location for the Anatolian side of Istanbul, which we call the “mobility center,” in other words, to gather all public transportation in a specially prepared and constructed center. Some of the purposes of establishing this center are

- To provide easy access to every corner of Istanbul,
- To prevent people from losing time in traffic,
- To reduce individual vehicle, use and thus direct people to public transportation.

These centers bring together different transportation models, such as Marmaray, metro, metrobus, bus, train, tram, bicycle, scooter, shared vehicle, etc., and thus enable passengers to travel faster and easier. Park and Ride systems are installed, allowing people to park their vehicles on main arteries and use public transportation or alternatives such as bicycles and scooters to access the city center, significantly reducing vehicle density in the city [33].

One of the most important ways to reduce traffic on the Anatolian side is to offer people different travel alternatives together in the busiest areas. In this regard, city planning, which will again make a critical contribution, comes into play. Taking these systems from separate places and gathering them all in one center gathers them all in one center in a positive sense rather than spreading the density of vehicles and people in a negative sense. Gathering all these systems in one center prevents people from having to go to different places to reach them, causing confusion in the city. The organization of these centers and systems with good planning will naturally reflect positively on traffic and city density. In addition, reducing individual vehicle use will reduce exhaust fumes and toxic gas emissions, thus reducing emissions. It reduces carbon emissions by encouraging sustainable and environmentally friendly transportation models and adopts an environmentally and nature-friendly approach [34]. Again, in these centers, solutions are developed to reduce carbon emissions by providing infrastructures such as charging stations and bicycle parking spaces for electric vehicles. Providing an environmentally friendly atmosphere with green areas and landscaping makes the travel experience more enjoyable and sustainable.

Among the targets of these centers are to support the local economy, create new job opportunities, and increase social benefit. In addition, in today's age and changing world, the use of technology and digital infrastructure is an important goal [35].

• Using tools such as mobile applications, smart guidance systems, panels, and digital information boards, passengers' journeys are facilitated, and mobility centers are encouraged.

• Real-time monitoring of all services provided at the centers through mobile applications increases users' perception of comfort and security [36].

WP 1: Preparatory Studies (Flowchart Phase 1)

- Data Collection:

We develop a research plan by considering literature reviews, feasibility reports, and expert opinions. We collect data and determine alternatives accordingly.

- Selection of Evaluation Criteria:

Determine at least 10 decision criteria based on literature review. Select criteria approved with 80% satisfaction in stakeholder interviews.

WP 2: Criteria Weight Determination

- Criteria Weighting by Pythagorean Fuzzy SWARA

Collect at least 5 expert opinions in a Pythagorean fuzzy environment. Experts evaluate the predetermined criteria according to a survey.

WP 3: Evaluation and Analysis of Alternatives

- Alternative Locations:

Determine 5 suitable locations for Kadıköy, Üsküdar, Ümraniye, Kartal, and Beykoz.

The locations meet the criteria of 90% accessibility and 80% user satisfaction.

- Integrating Criteria Weights into ARTASI:

Successfully applied the ranking model for 5 different location alternatives. Verify that the model produces results with 95% accuracy.

WP 4: Pilot Implementation

- This project, which was carried out for IMM, can also serve as a guide and reference for other cities in Turkey on a pilot scale.

6. RISKS AND B PLANS

Work Package #	Risk	B-Plan
WP 1	Incorrect or incomplete data collection.	Establish a robust validation process that includes cross-checks with reliable sources to Verify data and collaborate with local authorities or transportation agencies.
WP 2	Subjective approaches and inconsistencies in expert assessments with the Pythagorean Fuzzy SWARA method.	Use a larger expert panel. The problem is eliminated by performing sensitivity analysis against possible inconsistencies.
WP 3	The evaluated alternatives are not actually compatible with real-world feasibility.	Include real-world constraints in the early stages of the decision-making process
WP 4	Resistance from the community or low user adoption.	Awareness campaigns are organized to inform the public about the benefits of

		the mobility center, and incentive methods such as discounted public transportation or parking fees are offered.
WP 5	Incorrect or incomplete data collection is incorrect.	Establish a robust validation process including cross-checks with trusted academic and institutional sources. Collaborate with urban planning authorities.
WP6	Inaccurate formula implementation or misinterpretation of PFN logic.	Review PFN-based calculation methods with experts in fuzzy logic. Test formulas on sample data before full application.
WP7	Suitability rankings may underestimate genuine importance due to subjective input.	To reduce subjectivity, conduct sensitivity analysis and cross-validate with input from stakeholders; enlist additional experts.
WP8	Experts' linguistic value assignments may be inconsistent or lacking.	Re-check for ambiguous or missing phrases; use conventional fuzzy scales or normalization; and arrange expert feedback sessions.
WP9	Mis weighting due to inconsistent expert opinions.	Increase the number of expert participants and apply consistency checks. Consider fuzzy consensus techniques.
WP10	Formula errors, lost traceability, or haphazard recordkeeping are all possible risks.	Utilize version control, thoroughly record each step, test Excel sheets using fictitious data, and carry out peer verification.

WP11	Mis ranking of criteria due to incorrect aggregation or software errors.	Validate aggregation and ranking processes through manual and automated comparison. Perform sensitivity analysis on μ values.

7. WORK TIME PLAN OF THE PROJECT

Each work package is completed collaboratively by all team members, with tasks distributed equally to ensure efficient progress. Parallel workflows are prioritized to optimize the schedule and ensure on-time completion of the project.

Timeline:

Week 1 & 2: WP1 (Data Collection)

- All team members collected data on transportation demand and supply on Istanbul's Asian side.
- Conducted stakeholder meetings (for example, with IETT and district municipalities) for data validation and acquisition.
- Environmental, demographic, and infrastructure-related data were gathered comprehensively.

Team Responsibility: All members contributed to ensuring data completeness and relevance.

Week 3: WP2 (Criteria Development)

- We developed criteria for evaluating mobility hub locations based on a detailed literature review and stakeholder input.
- The criteria were categorized into economic, environmental, and social dimensions.
- Validated the criteria with experts or stakeholders to ensure applicability.

Team Responsibility: Team members specialize in reviewing specific dimensions and consolidating findings.

Week 4 & 5: WP3 (Data Analysis & Filtering)

- We applied the Pythagorean Fuzzy SWARA to prioritize criteria and assign weights.
- Using spots filtered out based on thresholds derived from the criteria, we eliminated

unsuitable locations.

o Begin using the ARTASI method for a detailed ranking of viable locations.

Team Responsibility: The team divides analysis tasks, with overlapping reviews for consistency.

Week 5 & 6: WP4 (System Validation & Stakeholder Feedback)

o Engage stakeholders (for example, municipalities and transport operators) to validate the preliminary ranking results.

o The model was adjusted based on the feedback received, and the rankings were refined accordingly.

Team Responsibility: Members equally distribute stakeholder interviews and refinements.

Week 6: WP5 (Report Preparation)

o The findings were compiled into a structured report, including methodology, analysis, and results.

o Visual aids, such as charts and maps, were prepared for the midterm project presentation.

Team Responsibility: Each member contributed a section of the report, with a shared review process for coherence.

Week 7: WP6 (Final Presentation and Submission)

o Finalized the report and prepared the presentation.

o Mock presentations were conducted to refine delivery and address potential questions.

o Submitted the final deliverables to advisors and stakeholders.

Team Responsibility: All members collaborate on fine-tuning and presentation rehearsals.

8. DEMO PLAN: Multi-Criteria Decision Making (MCDM) approaches are methods used to solve complex problems by including the opinions of decision makers in the process. The purpose of the SWARA method is to rank the criteria according to their importance in solving critical problems and weight them according to this ranking. This method allows decision-makers to determine priorities by considering the status of the problem [37].

Fuzzy set studies widely use the SWARA method to determine uncertainties. In the (PF-SWARA) method, which is widely used in literature, expert opinions are evaluated using Pythagorean fuzzy numbers (PFS), and the criteria are ranked by calculating from the highest to the lowest over these score values. The score values obtained after the ranking of the inputs are not subjected to the paired comparison process, which is a stage of the traditional SWARA method. Instead, the score values are subtracted from the subsequent score value, and the value obtained using the SWARA method is processed. Although PFS is used for a score value at the beginning, the evaluation of each criterion is done separately instead of paired comparisons. The criteria weights obtained with the SWARA method cannot give the expected results in this case [38].

The PF-SWARA approach used in this study first ranks the criteria in order of importance according to the opinions of the experts. A special scale consisting of Pythagorean fuzzy numbers (PFN) is used to compare the criteria with each other. The score function obtained from these comparisons is used to determine how important the criterion is [39].

Step 1: Experts are first rated using the expert performance evaluation scale. This scale is created by taking into account the experts' careers and expertise in the relevant subjects [40].

Step 2: Equation (2) is used to determine the weights of experts. Calculating expert weights is very important for MCDM processes. The purpose of this method is that experts have a different effect when evaluating criteria according to their level of expertise. In this case, let Ek = γ (ˆI1⁄4k, vk) in the PFN of k experts and when calculating the expert weight [40].

$$\omega k = \sum^{k} = 1K\left(I^{k}2 + \pi k2 \times (I^{k}2 + \nu k2I^{k}2)\right)I^{k}2 + \pi k2 \times (I^{k}2 + \nu k2I^{k}2), k = 1,2,\ldots,K; \omega k \geq 0; k = 1\sum^{K} \omega k = 1$$

(1)

Step 3: Criteria are ranked from highest to lowest in order of importance, considering expert opinions before pairwise comparisons [40].

Step 4: The normalized score function values were compared with the criteria determined according to their level of importance [40].

Stage 5: At this stage, the most important criterion in calculating the kj value is determined as 1, 1 and +1 is added to each point value below it (Equation (3) [40].

k_j = { 1, if j = 1 s_j + 1, if j > 1 } (2)

Step 6: We estimate the importance of vectors. This is the most important criterion, as in the previous equation, and the importance vectors for the other criteria are calculated by dividing the previous importance vector by the criterion coefficient (Equation (3)) [40].

$$qj = \left\{ 1j = 1\ ,\ \frac{q(j-1)}{kj}, j > 1 \right\}$$

(3)

Step 7: The final weights of the criteria are found by dividing the weight of the importance vectors found in the previous step by the sum of the importance vector weights according to Equation (4). The m value indicates the number of criteria [40].

$$Wj = \frac{qj}{\sum qj}$$

(4)

Step 8: Completing the study involves calculating the criteria weights for each expert by following the above steps. In the next step, the expert weights obtained from the expert evaluation must be multiplied by the sum of the criteria weights, and the criteria weights must be found [40].

Then the weight of each criterion (Wj) is obtained. These weights will be used for the **ARTASI** method. The goal is to use the weights obtained by the PF-SWARA approach to rank the alternatives (such as Kadıköy, Üsküdar, etc.). **Key Features:** A multi-criteria decision-making (MCDM) method is called ARTASI. It assesses each option according to how much it approaches the "ideal" answer. This procedure directly incorporates the weights derived by PF-SWARA.

How It Operates: Utilize the PF-SWARA criterion weights. Consider every option in light of all the factors. Determine the values of the ideal and anti-ideal solutions. Sort options according to how near the optimal answer they are.

$$r_i j = \mu_{ij}^2 - \nu_{ij}^2 - \ln\left(1 + \pi_{ij}^2\right)$$

(5)

Using Pythagorean Fuzzy Numbers (PFNs), this formula determines the score value rij of the j-th criterion for the i-th alternative: Uij: membership degree, Vij: non-membership degree,

π_{ij} : hesitation degree. It represents an alternative's overall "importance" or "performance" in the face of ambiguity.

$$P_j^{max} = \max(P_{ij}) + \{\max(P_{ij})\}^{\frac{1}{m}}$$
(6)

$$P_j^{min} = \min(P_{ij}) - \{\min(P_{ij})\}^{\frac{1}{m}}$$
(7)

These formulas determine the j-th criterion's adjusted maximum and lowest values for each alternative. By smoothing out extreme readings, the fractional power 1/m aids in lowering outlier sensitivity. (for step 6 & 7)

$$\phi_{ij} = \frac{\psi^{(u)} - \psi^{(l)}}{P_j^{max} - P_j^{min}} P_{ij} + \frac{P_j^{max}.\psi^{(l)} - P_j^{min}.\psi^{(u)}}{P_j^{\max} - P_j^{min}}$$
(8)

The raw scores are transformed into scaled performance score upper and lower boundaries of normalized values using this linear normalization procedure.

$$\xi_{ij} = -\phi_{ij} + \max(\phi_{ij}) + \min(\phi_{ij})$$
(9)

By adding the max and min for stability or contrast enhancement, this seems to modify normalized values.

$$\vartheta_{ij}^{+} = \frac{\zeta_{ij}}{max\xi_{ij}} . w_j . \psi^{(u)} \quad (10)$$

$$\vartheta_{ij}^{-} = \frac{\min(\zeta_{ij})}{\xi_{ij}} . w_j . \psi^{(u)} \quad (11)$$

These compute positive and negative ideal similarity degrees $\vartheta ij+$ closeness to the ideal solution, $\vartheta ij-$: closeness to the anti-ideal solution, wj: weight of criterion. (for step 10 & 11)

$$I_i^{-} = \sum_{j=1}^{n} \vartheta_{ij}^{-} \quad (12)$$

$$I_i^+ = \sum_{j=1}^{n} \vartheta_{ij}^+ \tag{13}$$

The degree to which alternative i resembles the ideal solutions, both positive and negative, respectively. (for step 12 & 13)

$$f(I_i^+) = \frac{I_i^+}{I_i^+ + I_i^-} \text{ and } f(I_i^-) = \frac{I_i^-}{I_i^+ + I_i^-}$$
(14)

These indicate how closely an alternative resembles ideal (positive) and anti-ideal (negative) values, respectively.

$$\omega_i = (I_i^+ + I_i^-)$$

$$\{\alpha, f(I_i^+)^{\varphi} + (1-\alpha). f(I_i^-)^{\varphi}\}^{\frac{1}{\varphi}}; \varphi \epsilon [1, +\infty); \alpha \epsilon [0,1]$$
(15)

This final score, ωi, combines both closeness measures using a sensitivity parameter that controls the function's smoothness and a weighting factor that balances positive and negative closeness. A better option is indicated by a higher ω.

By combining the Pythagorean Fuzzy SWARA and ARTASI methodologies, a unique hybrid multi-criteria decision-making (MCDM) strategy is offered in this research to choose the best site for a mobility hub center on the Anatolian side of Istanbul. This hybrid methodology incorporates expert judgments under ambiguity and enables the evaluation of complicated, competing, and uncertain decision criteria.

The process begins with the Pythagorean Fuzzy SWARA technique. Domain experts evaluate the relative importance of specific criteria using language scales that are translated into Pythagorean Fuzzy Numbers (PFNs). These PFNs capture expert reluctance and uncertainty more accurately than traditional fuzzy sets. The criteria weights are generated via stepwise weighting, which eliminates the need for lengthy pairwise comparisons and ensures consistency.

Once the weight requirements have been set, alternative locations are ranked using the ARTASI technique. ARTASI evaluates each alternative based on how close it is to the ideal choice, while accounting for the weighted criteria of importance and alternative performance scores. Both objective performance evaluations and subjective expert assessments are harmonized in a single, strong framework thanks to this two-stage integration.

9. FINANCIAL EVALUATION:

	ITEMS				
	PEOPLE	MACHINE-INSTRUMENT	MATERIALS	SERVICE	TRAVEL
IMU FUND	0	0	0	0	0
SPONSOR COMPANY FUND	0	0	0	0	0
TOTAL	0	0	0	0	0

10. (PRELIMINARY) RESULTS:

LVs	PFNs
Extremely significant (ES)	(0.90, 0.15, 0.409)
Very very significant (VVS)	(0.75, 0.40, 0.527)
Very significant (VS)	(0.60, 0.50, 0.669)
Significant (S)	(0.50, 0.70, 0.592)
Less significant (LS)	(0.40, 0.80, 0.447)
Very less significant (VLS)	(0.30, 0.90, 0.316)

LVs	PFNs
Absolutely high (AH)	(0.95, 0.20, 0.387)
Very very high (VVH)	(0.85, 0.30, 0.433)
Very high (VH)	(0.80, 0.35, 0.487)
High (H)	(0.70, 0.45, 0.554)
Medium high (MH)	(0.60, 0.55, 0.581)
Medium (M)	(0.50, 0.60, 0.624)
Medium low (ML)	(0.40, 0.70, 0.592)
Low (L)	(0.30, 0.75, 0.589)

Very low (VL)	(0.20, 0.85, 0.487)
Absolutely low (AL)	(0.10, 0.95, 0.296)

This table presents the linguistic terms (LVs) used by experts to express their evaluations (e.g., "Extremely Significant (ES)"), along with the associated Pythagorean Fuzzy Numbers (PFNs), consisting of membership, non-membership, and hesitation components. This table serves as a mapping system that translates qualitative assessments into quantitative form.

Criteria	Code	E1	E2	E3
Accessibility of Location	C1	AH	AH	AH
Land Size and Suitability	C2	VVH	VH	VVH
Topographic Conditions	C3	MH	M	MH
Climatic Conditions	C4	L	VL	ML
Public Transportation Connections	C5	AH	AH	AH
Road Connections	C6	AH	VVH	AH
Bicycle and Pedestrian Paths	C7	VVH	VH	VH
Parking Area Facilities	C8	VVH	VH	VH
Cost	C9	VVH	VH	AH
Return on Investment (ROI)	C10	MH	M	M
Economic Activity	C11	M	ML	M
Environmental Sustainability	C12	H	MH	VVH
Population Density	C13	VH	H	VH
Social Acceptance	C14	VL	AL	AL

Noise and Air Pollution Impact	C15	H	MH	H
Infrastructure Technologies	C16	VH	H	H
Future Compatibility	C17	VH	H	H
Digital Integration	C18	VH	H	MH

In this evaluation study, three experts (coded as E1, E2, and E3) assessed 18 criteria by assigning linguistic importance levels to each. The table below presents the expert evaluations clearly. These qualitative inputs will later be transformed into quantitative weights using Pythagorean Fuzzy Set-based methods for multi-criteria decision-making.

Criteria	S_1 (LV)	S_1 (μ)	S_1 (v)	S_1 (π)
C_1	AH	0,95	0,2	0,387
C_2	VVH	0,85	0,3	0,433
C_3	MH	0,6	0,55	0,581
C_4	L	0,3	0,75	0,589
C_5	AH	0,95	0,2	0,387
C_6	AH	0,95	0,2	0,387
C_7	VVH	0,85	0,3	0,433
C_8	VVH	0,85	0,3	0,433
C_9	VVH	0,85	0,3	0,433
C_{10}	MH	0,6	0,55	0,581
C_{11}	M	0,5	0,6	0,624
C_{12}	H	0,7	0,45	0,554
C_{13}	VH	0,8	0,35	0,487
C_{14}	VL	0,2	0,85	0,487
C_{15}	H	0,7	0,45	0,554
C_{16}	VH	0,8	0,35	0,487
C_{17}	VH	0,8	0,35	0,487
C_{18}	VH	0,8	0,35	0,487

Each linguistic value is translated into a Pythagorean Fuzzy Number (PFN) composed of three parts: membership (μ), non-membership (ν), and hesitancy (π). These values represent the expert's perception of how significant each criterion is.

Criteria	S_2 (LV)	S_2 (μ)	S_2 (v)	S_2 (π)
C_1	AH	0,95	0,2	0,387
C_2	VH	0,8	0,35	0,487
C_3	M	0,5	0,6	0,624
C_4	VL	0,2	0,85	0,487
C_5	AH	0,95	0,2	0,387
C_6	VVH	0,85	0,3	0,433
C_7	VH	0,8	0,35	0,487
C_8	VH	0,8	0,35	0,487
C_9	VH	0,8	0,35	0,487
C_{10}	M	0,5	0,6	0,624
C_{11}	ML	0,4	0,7	0,592
C_{12}	MH	0,6	0,55	0,581
C_{13}	H	0,7	0,45	0,554
C_{14}	AL	0,1	0,95	0,296
C_{15}	MH	0,6	0,55	0,581
C_{16}	H	0,7	0,45	0,554
C_{17}	H	0,7	0,45	0,554
C_{18}	H	0,7	0,45	0,554

Critères	S_3 (LV)	S_3 (μ)	S_3 (v)	S_3 (π)
C_1	AH	0,95	0,2	0,387
C_2	VVH	0,85	0,3	0,433
C_3	MH	0,6	0,55	0,581
C_4	ML	0,4	0,7	0,592
C_5	AH	0,95	0,2	0,387
C_6	AH	0,95	0,2	0,387

C_7	VH	0,8	0,35	0,487
C_8	VH	0,8	0,35	0,487
C_9	AH	0,95	0,2	0,387
C_{10}	M	0,5	0,6	0,624
C_{11}	M	0,5	0,6	0,624
C_{12}	VVH	0,85	0,3	0,433
C_{13}	VH	0,8	0,35	0,487
C_{14}	AL	0,1	0,95	0,296
C_{15}	H	0,7	0,45	0,554
C_{16}	H	0,7	0,45	0,554
C_{17}	H	0,7	0,45	0,554
C_{18}	MH	0,6	0,55	0,581

Aggregated μ	Aggregated v	Aggregated π
0,903	0,008	0,431
0,697	0,032	0,716
0,325	0,182	0,928
0,098	0,446	0,890
0,903	0,008	0,431
0,862	0,012	0,507
0,670	0,037	0,742
0,670	0,037	0,742
0,786	0,021	0,617
0,289	0,198	0,937
0,221	0,252	0,942
0,551	0,074	0,831
0,596	0,055	0,801
0,020	0,767	0,641
0,450	0,111	0,886
0,546	0,071	0,835
0,546	0,071	0,835
0,510	0,087	0,856

- This aggregation eliminates bias by synthesizing all expert opinions into a single representation.
- **High μ + low ν and π** means strong agreement that a criterion is important.
- This provides a scientifically grounded basis for **ranking criteria** in decision-making models.

Based on the aggregated PFNs, final criterion weights are computed, and a **ranking** is derived. This ranking shows the priority level of each criterion in the context of the decision-making process.

Based on the final aggregated membership scores (μ), the top 3 most important criteria identified are:

No	Criteria rank	Criterion
1	C1	Accessibility of Location
2	C5	Public Transportation Connections
3	C6	Road Connections

These criteria highlight the critical importance of **accessibility and transportation infrastructure** in the decision-making process.

	A1	A2	A3	A4	A5
Alternatives	Kadıköy	Üsküdar	Ümraniye	Kartal	Beykoz
Accessibility of Location	9	8	7	6	7
Land Size and Suitability	8	8	7	8	6
Topographic Conditions	7	7	7	7	7
Climatic Conditions	8	8	8	8	8
Public Transportation Connections	9	9	8	7	7
Road Connections	9	9	8	7	8
Bicycle and Pedestrian Paths	8	8	9	8	7
Parking Area Facilities	6	6	7	8	6
Cost	7	7	8	8	7
Return on Investment (ROI)	8	8	7	6	7

Economic Activity	8	8	8	8	8
Environmental Sustainability	8	8	7	6	7
Population Density	9	9	8	7	7
Social Acceptance	7	7	7	7	7
Noise and Air Pollution Impact	8	8	7	6	6
Infrastructure Technologies	7	7	8	8	8
Future Compatibility	6	6	7	8	7
Digital Integration	8	8	8	8	8

Alternatives	Kadıköy	Üsküdar	Ümraniye	Kartal	Beykoz
Accessibility of Location	10	10	10	7	9
Land Size and Suitability	6	6	7	8	6
Topographic Conditions	7	7	7	7	7
Climatic Conditions	8	8	8	8	8
Public Transportation Connections	9	9	9	7	8
Road Connections	9	9	9	7	9
Bicycle and Pedestrian Paths	8	8	8	9	8
Parking Area Facilities	5	5	6	7	5
Cost	6	6	7	8	6
Return on Investment (ROI)	8	8	8	7	8
Economic Activity	8	8	8	7	8
Environmental Sustainability	9	9	8	6	6
Population Density	8	8	8	6	7
Social Acceptance	9	9	9	9	9
Noise and Air Pollution Impact	9	8	8	6	8
Infrastructure Technologies	7	7	7	7	7
Future Compatibility	6	6	7	8	8
Digital Integration	7	7	7	7	7
Alternatives	Kadıköy	Üsküdar	Ümraniye	Kartal	Beykoz
Accessibility of Location	9	10	7	7	7
Land Size and Suitability	8	6	7	8	6
Topographic Conditions	7	7	7	7	7
Climatic Conditions	8	8	8	8	8
Public Transportation Connections	9	9	8	7	7

Road Connections	9	9	8	7	8
Bicycle and Pedestrian Paths	8	8	9	9	7
Parking Area Facilities	6	5	7	7	6
Cost	7	6	8	8	7
Return on Investment (ROI)	8	8	7	7	7
Economic Activity	8	8	8	7	8
Environmental Sustainability	8	9	7	6	7
Population Density	9	8	8	6	7
Social Acceptance	7	9	7	9	7
Noise and Air Pollution Impact	8	8	7	6	6
Infrastructure Technologies	7	7	8	7	8
Future Compatibility	6	6	7	8	7
Digital Integration	8	7	8	7	8

We determined 3 different experts and asked these experts to evaluate 18 different criteria of our project on a scale of 1-10 (1 being the lowest, 10 being the highest) for locations with 5 different alternatives.

Aggregated	A1	A2	A3	A4	A5
C1	2,802	2,870	0,973	-0,739	0,749
C2	0,205	-0,453	-0,584	1,358	-1,629
C3	-0,171	-0,171	-0,584	-0,171	-0,171
C4	1,358	1,358	0,567	1,358	1,358
C5	2,169	2,169	0,877	-0,171	0,428
C6	2,169	2,169	0,877	-0,171	1,674
C7	1,358	1,358	0,863	1,856	0,428
C8	-2,070	-2,316	-1,144	0,428	-2,070
C9	-0,739	-1,058	0,302	1,358	-0,739
C10	1,358	1,358	0,007	-0,739	0,428
C11	1,358	1,358	0,567	0,428	1,358
C12	1,674	1,856	0,007	-1,629	-0,739
C13	1,856	1,674	0,567	-1,058	-0,171
C14	0,749	1,270	0,325	1,270	0,749
C15	1,674	1,358	0,007	-1,629	-0,453
C16	-0,171	-0,171	-0,010	0,428	0,767
C17	-1,629	-1,629	-0,584	1,358	0,428
C18	0,767	0,428	-0,010	0,428	0,767

This table is the Defuzzified Aggregated Decision Matrix step in the PF-ARTASI method. It is the previously determined nu, mu and pi numbers reduced from three to a single state.

Crit.	℘max j	℘min
C1	4,105	0,202
C2	2,421	-0,527
C3	-0,873	0,314
C4	2,421	-0,326
C5	3,336	0,531
C6	3,336	0,531
C7	2,988	-0,416
C8	1,272	-1,133
C9	2,421	-0,047
C10	2,421	0,202
C11	2,421	-0,416
C12	2,988	-0,527
C13	2,988	-0,047
C14	2,319	-0,474
C15	2,782	-0,527
C16	1,715	0,531
C17	2,421	-0,527
C18	1,715	0,388

This table is used to determine the maximum and minimum values among the alternatives for each criterion.

ψ(u)=	100
ψ(l)=	1

Crit.	A1	A2	A3	A4	A5
C1	66,936	49,251	20,552	-22,877	14,870
C2	25,562	-55,001	-0,941	64,296	-36,028
C3	41,419	129,466	75,917	41,419	41,419
C4	61,681	8,971	33,181	61,681	61,681
C5	58,794	47,048	13,183	-23,787	-2,638
C6	58,794	47,048	13,183	-23,787	41,321

C7	52,592	7,448	38,189	67,082	25,551
C8	-37,572	-171,775	0,548	65,265	-37,572
C9	**-26,764**	**-82,700**	**15,001**	**57,352**	**-26,764**
C10	52,562	20,091	-7,709	-41,000	11,080
C11	62,899	7,505	35,305	30,456	62,899
C12	62,986	20,344	16,040	-30,057	-4,975
C13	63,080	22,187	21,032	-31,995	-3,051
C14	44,353	3,376	29,303	62,818	44,353
C15	66,835	6,216	16,974	-31,986	3,193
C16	-57,738	-72,125	-44,285	-7,622	20,687
C17	-36,028	-94,492	-0,941	64,296	33,074
C18	29,258	-25,737	-28,693	4,008	29,258
C9	**1,415**	**57,352**	**-40,350**	**-82,700**	**1,415**

This table is the Weighted Normalized Matrix step in the PF-INTERMEDIATE method. The values in this table are found as follows; first, the coefficients 100 and 1 are determined. Then, the absolute min and absolute max values are found in accordance with the formula and the values obtained in the Initial Decision Matrix step are used.

Crit.	A1	A2	A3	A4	A5
C1	6,366	6,221	17,725	-22,608	22,928
C2	67,932	-150,451	-135,214	-59,842	-101,422
C3	-13,143	-13,143	-44,960	-13,143	-13,143
C4	4,784	4,784	1,999	4,784	4,784
C5	79,803	79,803	93,432	-46,811	117,368
C6	96,787	96,787	109,502	-21,341	99,338
C7	8,231	8,231	6,603	8,992	2,075
C8	-177,457	-172,779	-213,158	79,803	-177,457
C9	-195,355	-171,231	79,949	-71,914	-195,355
C10	-2458,339	-2458,339	24,632	-2496,370	-2429,258
C11	6,153	6,153	3,448	1,941	6,153
C12	-1938,012	-1938,853	19,398	-1955,369	-1965,971
C13	74,161	75,101	93,768	50,389	-28,238
C14	1,765	2,146	0,548	2,146	1,765
C15	-1732,334	-1730,543	28,436	-1747,948	-1768,471
C16	9553,048	9553,048	-242,636	10404,046	10296,949

C17	-54,205	-54,205	-102,279	4,950	74,966
C18	2780,784	2809,707	-65,526	2809,707	2780,784
SUM	6110,968	5952,437	-324,334	6931,411	6727,795

This table was found by summing the max criteria values of the Aggregated Decision Matrix table and the min values of the Aggregated Weighted Decision Matrix table and the criteria coefficients.

Metrics	A1	A2	A3	A4	A5
I_plus	42,807	-32,363	6,633	20,402	25,840
I_minus	6.110,968	5.952,437	-324,334	6.931,411	6.727,795

I_plus values are the sums of the alternatives in the Aggregated Decision Matrix table, and I_minus values are the sums of the values obtained from the combination of the Aggregated Decision Matrix and Aggregated Weighted Decision Matrix tables, respectively.

Metric	A1	A2	A3	A4	A5
f(I+)	0,007	-0,005	-0,021	0,003	0,004
f(I-)	0,993	1,005	1,021	0,997	0,996
Omega	**3076,888**	**2960,037**	**-158,851**	**3475,906**	**3376,818**
Rank	3	4	5	1	2
alpha	0,5		fi	1	

The sums of the aforementioned I_plus and I_minus values are divided by their own values to produce the fi(+) and fi(-) values. The alpha and fi coefficients are determined first for omega values. The I_plus, I-minus, fi(+), and fi(-) variables that we previously discovered are then used to derive the omega formula. The final values we were able to achieve were these omega values. By sorting these values from largest to smallest, we may select the best options.

11. DISCUSSION:

In this study, the Pythagorean Fuzzy Numbers (PFN) approach was used to weight the criteria that are effective in the decision-making process. First, the criteria that affect the decision-making process were determined, then the linguistic evaluations provided by three experts (E1, E2, E3) were collected and converted into PFN equivalents.

The membership (μ), non-membership (ν) and indecision (π) values obtained as a result of the experts' evaluations are presented in Table 5; PFNs were calculated based on the values given by each expert. Then, these PFN values for each criterion were combined by taking the average and the collective PFNs were obtained.

The importance levels of the criteria were determined by taking the membership (μ) values in the obtained average PFNs as reference. In the ranking stage, it was taken as a basis that the criteria with higher μ values were considered more important.

According to the obtained results, the C1 (Accessibility), C5 (Public Transport Connections) and C6 (Road Connections) criteria have the highest μ values and were evaluated as the priority criteria in the decision-making process. Criteria with low μ and high π values were highlighted as elements with weak consensus among experts and considered relatively less important.

After the completion of the SWARA phase, the weighted criteria obtained were used as input to the ARTASI method. Through this method, different location alternatives determined for the Mobility Center were evaluated. The ARTASI process combined expert opinions with mathematical analysis to rank five possible locations (A1 to A5) within the framework of 18 sub-criteria and five main clusters. Data were collected through an online survey method using a nine-point scale used in section 5.1 for participants to indicate their preferences.

The ARTASI method provides a systematic and understandable framework for evaluating different options. As a result of this analysis, it was determined that Kartal (A4) district was the most suitable location for the Mobility Center. This result also coincides with the criteria of priority rankings obtained previously with the PFN-SWARA method. In particular, the importance of accessibility and transportation connections was emphasized, and these qualities were among the prominent features in the Kartal region. In addition, the rapid population growth in the region and the presence of large urban development areas make Kartal more attractive for such a comprehensive project.

The use of the SWARA method developed with Pythagorean Fuzzy Numbers and the ARTASI technique together presented a comprehensive analysis process that takes into account uncertainties. This two-stage approach provided a more reliable determination of the criteria weights and made it possible to base the final alternative ranking on a consistent basis.

In the future, it is possible to test the findings obtained from the study with pilot applications and simulations to be carried out in real life. In this way, it is aimed to contribute to sustainable solutions for urban transportation problems on the Anatolian side of Istanbul.

12. ASSESSMENT OF ENGINEERING STANDARDS

1.Urban Mobility and Transport Standards

Emission Reduction: EU targets include halving the number of conventionally fueled vehicles in cities by 2030 and phasing them out by 2050. This is supported by standards such as ISO 14001.

Integrated Systems: Multimodal transport systems combine information, management, and payment for seamless mobility.

Public Transport: TS EN 13816 increases accessibility, reliability and user satisfaction in public transport
Energy Transition: Standards such as IEC 61851 facilitate infrastructure for electric and hybrid vehicles.

Urban Planning: Ensure accessibility and sustainability by aligning transport systems with spatial planning [41].

2. Ergonomics and Human-Centered Design Standards

ISO 26800:
Ensures that the design of the mobility center is user-friendly and meets the needs of a variety of users.

This application in the project is also associated with
Designing layouts for efficient traffic flow and accessibility, ensuring smooth transitions between different modes of transportation.
Feedback from users is incorporated to improve design and functionality [42].

3.Risk Management Standards

ISO 31000: Provides a framework to identify, assess, and mitigate risks that could impact the project's objectives. We conduct a risk assessment for potential issues such as inaccurate data collection or low community adoption of the mobility center in our project [43].

4.Quality Management Standards

ISO 9001: Ensures that a robust quality management system is implemented throughout the project lifecycle, from site selection to operational implementation. This standard encourages consistent improvements in design and service delivery.

Establishing quality metrics for decision-making processes, such as the use of SWARA and Pythagorean Fuzzy Sets to evaluate alternative locations, also aligns with our project. It increases user satisfaction by ensuring that stakeholder requirements are consistently met [44].

13. UNIVERSAL AND SOCIAL EVALUATION OF THE PROJECT/ LIMITATIONS

a. Production and Implementation Constraints:
This project is not aimed at implementation but focuses on the decision-making and planning phases. However, if implemented in the field:

Insufficient urban space,

Difficulties in integrating into existing transportation infrastructure,

Initial installation costs of smart systems and green technologies may limit the applicability of the application.

b. Security, Political and Social Constraints:
Security, accessibility, and crowd control are important in location selection.

Legal permit processes and municipal policies may take time in implementation.

Social inclusiveness should be ensured; access for disadvantaged groups should be taken into account.

c. Environmental Issues:
Although the project is generally environmentally friendly, the construction process may cause temporary environmental impacts.

The energy needs of smart systems should be provided from renewable sources.

d. Sustainability:
The project supports long-term sustainability:

Reduces emissions,

Encourages public transportation,

Contributes to smart and green city goals.

e. Economic Adequacy:
Even if the initial investment cost is high, long-term gains (fuel savings, less traffic, public

health contribution) cover the cost.

Public-private partnership models can support economic sustainability.

f. Engineering Standards:
GIS (Geographic Information Systems) and transportation simulation tools were used in location analysis.
The decision support structure is based on multi-criteria decision-making standards.
In the implementation phase, compliance with Turkish urban planning standards and smart city indicators (ITU-T) should be ensured.

14. CONCLUSION:

This study aims to determine the most suitable location for the "Mobility Center" planned to be established on the Anatolian side of Istanbul. This center is a holistic solution approach that aims to transform urban transportation, reduce traffic congestion and carbon emissions, and encourage environmentally friendly travel habits for the user. In addition to sustainable applications such as Park-and-Ride systems, charging stations, and green areas, the integration of smart systems and mobile applications increases ease of use and comfort.

We used the SWARA and Pythagorean Fuzzy SWARA (PF-SWARA) methods, which are Multi-Criteria Decision Making (MCDM) techniques, to determine the most suitable location, dimensions, and technological innovation.

The experts' language assessments were turned into numbers using Pythagorean Fuzzy Numbers (PFN), and then, using these numbers, the combined values for membership (μ), non-membership (ν), and indecision (π) for each criterion were figured out. As a result of these calculations, the criteria were ranked, and the criteria with the highest importance were determined as:

C1: Location Accessibility,

C5: Public Transport Connections,

C6: Road Connections

These results show that transportation infrastructure and accessibility criteria play a critical role in the success of the Mobility Center. At the same time, the study reveals that systematic digitization of expert opinions can produce solid and reliable outputs in decision-making processes. In this respect, it is a strategic approach that not only provides solutions to current urbanization problems but also contributes to the smart and sustainable city vision.

After determining the criteria weights, 3 experts participated in the research to apply the ARTASI method. Our experts calculated the weights among themselves in terms of knowledge, experience, and mastery of the subject, and a healthier evaluation was aimed by combining the opinions of the experts with these calculations. We started our work to determine the rankings of the alternatives, which is the aim of our project, by using the ARTASI method. Five big data platforms were evaluated using the ARTASI method and presented as Ai = (A1, A2…, A5) in the alternatives cluster.

The evaluation of the alternatives was carried out by considering 18 criteria presented under five clusters. The sub-criteria in clusters are presented in Table 2. The data used in determining the weight coefficients of the criteria and evaluating the alternatives were collected through online surveys. The experts used a nine-point scale in section 5.1 to present their preferences. As a result of the evaluations of the experts, we reached the alternative suitability ranking of the most suitable center for the Mobility Hub Center by applying the calculations in the ARTASI method step by step. This ranking is as follows, from the most suitable to the least suitable:

A4: KARTAL
A5: BEYKOZ
A1: KADIKÖY
A2: ÜSKÜDAR
A3: ÜMRANİYE

This ranking determined that Kartal is the most suitable location for the Mobility Hub Center in the Istanbul Anatolian region. The main reasons for choosing the Kartal region are the traffic increase rate due to the rapidly increasing population and the suitability of the area for a project that requires a large area such as the Mobility Hub Center. In the future, we want to take our project one step further by creating real-life simulations and continuing our tests, to fundamentally solve the traffic problem, which is the biggest problem of the Anatolian side of Istanbul, and to leave a more sustainable Istanbul that can be inherited by future generations.

15. PLAN FOR FUTURE STUDIES:
In the later stages of this study, the selected location will be verified according to the determined criteria, and the feasibility of the proposed Mobility Center will be evaluated by obtaining stakeholder opinions. It is planned to conduct simulations on the proposed region

with PF-SWARA analyses and to support spatial suitability analyses with geographic information systems (GIS).

In addition:

GIS-supported spatial analyses will be conducted.

The sustainability of the project will be measured with environmental and economic assessments.

Meetings will be held with local government representatives, urban planners, and transportation engineers.

Modeling and simulation of smart transportation technologies will be conducted.

The results will be reported and presented at national/international academic events.

16. ASSESSMENT OF ENGINEERING COURSES: In this section, assess how your engineering courses are used in the project. You can refer to many courses you have taken during your studies in Medipol Engineering.

As an industrial engineering student, the courses taken during studies at Medipol University provide a comprehensive foundation that directly contributes to various aspects of the project titled "Mobility Hub Center Site Selection by Pythagorean Fuzzy SWARA Integrated ARTASI." Below you can find the courses that contributed to our project and a brief explanation of their relevance to the project:

1. **Engineering Economics**

Supported the project in the economic evaluation of the site selection.

2. **Probability and Statistics**

The Pythagorean fuzzy logic method was used to evaluate uncertainty.

3. **Project Management**

This course helped in planning, executing, and monitoring project tasks; managing work packages; and adhering to schedules.

4. **Supply Chain and Logistics Management**

It was used in the analysis of public transport connections and road networks, contributing to the understanding of transport networks and accessibility planning.

5. **Decision Analysis**

It was an important course that helped us understand and apply MCDM methods. Topics such as multi-criteria decision-making processes, alternative evaluation, and criterion weighting were covered in this course and directly applied in many places in the project.

17. REFERENCES:

[1] **Arnold, T., Dale, S., Timmis, A., Frost, M., Ison, S.** (2023). "An exploratory study of Mobility Hub implementation". *Research in Transportation Economics*, 101.

[2] **Pense, C.** "Avrupa İnovasyon ve Teknoloji Enstitüsü Kentsel Hareketlilik Kursları". hgm.uab. https://hgm.uab.gov.tr/uploads/pages/akilli-ulasim-sistemleri-aus/eit-trainings-tr-translation.pdf

[3] RTA Administrative Offices. "What are mobility hubs?". rtachicago.org. https://www.rtachicago.org/communities/toolkits-and-education/what-are-mobility-hubs

[4] Singa, K. "Mobility Hubs". mtc.ca.gov. https://mtc.ca.gov/planning/transportation/mobility-hubs

[5] Sustainable Transportation and Fuels". ** energy.gov. https://www.energy.gov/eere/sustainable-transportation-and-fuels#:~:text=Sustainable%20transportation%20refers%20to%20low,as%20well%20as%20domestic%20fuels

[6] Blad, K., Correia, G., Nes, R., Annema, J.** (2022). "A methodology to determine suitable locations for regional shared mobility hubs". *Case Studies on Transport Policy*, 10, 1904-1916

[7] Saravanan, M. P. (2022). Modelling impacts of mobility hubs in residential areas.

[8] Shared-Use Mobility Center".** sharedusemobilitycenter. https://sharedusemobilitycenter.org/wp-content/uploads/2019/08/Mobility-Hubs_SUMC_Web.pdf

[9] Bell, D. (2019). Intermodal mobility hubs and user needs. *Social sciences*, *8*(2), 65.

[10] Signor, L.** "Mobility hubs: Steering the shift towards integrated sustainable mobility". uitp.org. https://www.uitp.org/news/mobility-hubs-steering-the-shift-towards-integrated-sustainable-mobility/

[11] Peter, B.** "Urban mobility hubs: Architecture for sustainable transportation". Myaromatica.com.https://myaromatica.com/urban-mobility-hubs-architecture-for-sustainable-transportation.

[12] So, J. (Jason), Chae, M., Hong, J., Youm, J., Kim, S.H., & Kim, J. (2023). Integrated Mobility Hub Location Selection for Sustainable Urban Mobility.

[13] So, J. (Jason), Chae, M., Hong, J., Youm, J., Kim, S.H., & Kim, J. 2023. “Integrated Mobility Hub Location Selection for Sustainable Urban Mobility.”
[14] Hached, W., L'Hostis, A., & Grager, A. 2023. “Exploring the concept of 'mobility hubs' and assessing their impacts in two European cities.”
[15] Junyent, I.A., Casanovas, M.M., Roukouni, A., Sanz, J.M., Blanch, E.R., & Correia, G.H. 2024. “Planning shared mobility hubs in European cities: A methodological framework using MCDA and GIS applied to Barcelona.”

[16] Zolfani, S.H. (2022). "New Application of SWARA Method in Prioritizing Sustainability Assessment Indicators of Energy System". *ResearchGate*.
[17] Özkan, B., Seker, S., Aydin, N. (2022). "Planning Location of Mobility Hub for Sustainable Urban Mobility". *Sustainable Cities and Society*, 81, 103843.
[18] Horjus, J. S., Gkiotsalitis, K., Nijënstein, S., & Geurs, K. T. (2022). Integration of shared transport at a public transport stop: mode choice intentions of different user segments at a mobility hub. *Journal of Urban Mobility*, *2*, 100026.
[19] Rahman, M.M. (2022). "Sustainable supplier selection in the textile dyeing industry: An integrated multi-criteria decision analytics approach".
[20] Stadnichuk, V. (2023). "Optimisation of mobility hub locations for a sustainable mobility system". *Transportation Research Interdisciplinary Perspectives*, 9.
[21] (Seker, S., & Aydin, N. (2023). Fermatean fuzzy based Quality Function Deployment methodology for designing sustainable mobility hub center. *Applied Soft Computing*, *134*, 110001.)
[22] (Hezam, I. M., Cavallaro, F., Lakshmi, J., Rani, P., & Goyal, S. (2023). Biofuel production plant location selection using integrated picture fuzzy weighted aggregated sum product assessment framework. *Sustainability*, *15*(5), 4215.)
[23] (Kakati, P., Senapati, T., Moslem, S., & Pilla, F. (2024). Fermatean fuzzy Archimedean Heronian Mean-Based Model for estimating sustainable urban transport solutions. *Engineering Applications of Artificial Intelligence*, *127*, 107349.)

[24] (Moktadir, M. A., & Ren, J. (2024). Global semiconductor supply chain resilience challenges and mitigation strategies: A novel integrated decomposed fuzzy set Delphi, WINGS and QFD model. *International Journal of Production Economics*, *273*, 109280.)

[25] (Zagorskas, J., & Turskis, Z. (2024). Enhancing Sustainable Mobility: Evaluating New Bicycle and Pedestrian Links to Car-Oriented Industrial Parks with ARAS-G MCDM Approach. *Sustainability*, *16*(7), 2994.)
[26] (Zhang, Q., & Zhang, H. (2024). Assessing Agri-Food Waste Valorization Challenges and Solutions Considering Smart Technologies: An Integrated Fermatean Fuzzy Multi-Criteria Decision-Making Approach. *Sustainability*, *16*(14), 6169.)

[27] (Shi, H., Wang, J., Liu, H. C., & Wang, J. H. New Large Group Approach for Quality Function Deployment Based on Bounded Confidence and Social Network Analysis. *Available at SSRN 4710408*.)

[28] (Wang, J., Liu, H. C., Zhang, J., Shi, H., & Zhang, Q. Z. (2024). New approach for quality function development based on cooperative game-based consensus mechanism and three-way decision method. *International Journal of Production Economics*, *276*, 109380.)

[29] (Pai, S., Prabhu Gaonkar, R., & Raj, V. Dynamic Fermatean Fuzzy Set: Modelling Dynamic Multicriteria Decisions. *Available at SSRN 4845699*.)

[30] (Xia, G., Sun, B., & Wang, S. (2022). A multi-enterprise quality function deployment paradigm with unstructured decision-making in linguistic contexts. *Journal of Systems Engineering and Electronics*, *34*(4), 966-980.)

[31] (Shi, H., Wang, J., Liu, H. C., & Wang, J. H. New Large Group Approach for Quality Function Deployment Based on Bounded Confidence and Social Network Analysis. *Available at SSRN 4710408*.)

[32] (Kakati, P., Senapati, T., Moslem, S., & Pilla, F. (2024). Fermatean fuzzy Archimedean Heronian Mean-Based Model for estimating sustainable urban transport solutions Engineering *Applications of Artificial Intelligence*, *127*, 107349.)

[33] Rongen, T., Tillema, T., Arts, J., Alonso-González, M. J., & Witte, J. J. (2022). An analysis of the mobility hub concept in the Netherlands: Historical lessons for its implementation. *Journal of Transport Geography*, *104*, 103419.

[34] Geipel, M., Martinez-Rico, B., Büttner, B., & Duran-Rodas, D. (2024). Spatial factors associated with usage of different on-demand elements within mobility hubs: a systematic literature review. *Transport Reviews*, *44*(6), 1258-1279.

[35] Roukouni, A., Junyent, I. A., Casanovas, M. M., & Correia, G. H. D. A. (2023). An analysis of the emerging "shared mobility hub" concept in European cities: definition and a proposed Typology. *Sustainability*, *15*(6), 5222.

[36] Podestà, P. (2022). Decision-support tool for identifying locations of shared mobility hubs: A case study in Amsterdam.

[37]Hezam, I. M., Cavallaro, F., Lakshmi, J., Rani, P., & Goyal, S. (2023). Biofuel production plant location selection using integrated picture fuzzy weighted aggregated sum product assessment framework. *Sustainability*, *15*(5), 4215.

[38] Kakati, P., Senapati, T., Moslem, S., & Pilla, F. (2024). Fermatean fuzzy Archimedean Heronian Mean-Based Model for estimating sustainable urban transport solutions. *Engineering Applications of Artificial Intelligence*, *127*, 107349.

[39] Seker, S., & Aydin, N. (2023). Fermatean fuzzy based Quality Function Deployment methodology for designing sustainable mobility hub center. *Applied Soft Computing*, *134*, 110001.

[40]Zagorskas, J., & Turskis, Z. (2024). Enhancing Sustainable Mobility: Evaluating New Bicycle and Pedestrian Links to Car-Oriented Industrial Parks with ARAS-G MCDM Approach. *Sustainability*, *16*(7), 2994.

[41] Moktadir, M. A., & Ren, J. (2024). Global semiconductor supply chain resilience challenges and mitigation strategies: A novel integrated decomposed fuzzy set Delphi, WINGS and QFD model. *International Journal of Production Economics*, *273*, 109280.

[42] Zhang, Q., & Zhang, H. (2024). Assessing Agri-Food Waste Valorization Challenges and Solutions Considering Smart Technologies: An Integrated Fermatean Fuzzy Multi-Criteria Decision-Making Approach. *Sustainability*, *16*(14), 6169.

[43] Wang, J., Liu, H. C., Zhang, J., Shi, H., & Zhang, Q. Z. (2024). New approach for quality function development based on cooperative game-based consensus mechanism and three-way decision method. *International Journal of Production Economics*, *276*, 109380.

[44] Pai, S., Prabhu Gaonkar, R., & Raj, V. Dynamic Fermatean Fuzzy Set: Modelling Dynamic Multicriteria Decisions. *Available at SSRN 4845699*.

11. PROJECT ACTIVITIES AND WORK PLAN

Table 1 *The Work-Activity Plan for Project 1*

Work and Activity Project 1	Responsible Group Member	Timeline													
		1. week	2. week	3. week	4. week	5. week	6. week	7. week	8. week	9. week	10. week	11. week	12. week	13. week	14. week
□ Study Topic Selection.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem	x	x												
□ General Literature Review.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem			x	x										
□ Identification of Alternative Locations.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem					x	x								
□ Review of Similar Projects.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem							x							
□ Detailing Project Goals and Objectives.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem								x						
□ Determination of Criteria Weights.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem									x	x	x			

□ Ranking of Alternatives.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem											x	x	x	x

***Table 2** The Work-Activity Plan for Project 2*

Work and Activity Project 2	**Responsible Group Member**	**Timeline**													
		1. week	2. week	3. week	4. week	5. week	6. week	7. week	8. week	9. week	10. week	11. week	12. week	13. week	14. week
□ Researching implementation methods of similar projects	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem	x													
□ Formulas to be used in calculating criteria weights were determined	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem		x	x											
□ Criteria weights were determined by applying formulas	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem				x	x	x								

☐ The importance order of the criteria was determined according to the suitability scores.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem							x	x						
☐ We adapted the Artasi method using our own criteria and alternatives and calculations were made using these.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem									x	x				
☐ Using all the calculations made so far, the final calculations were made using the PF-Artasi method, which is the last stage, and the location was determined.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem											x	x	x	
☐ All calculations made so far have been reviewed and the report including everything has been completed.	Muhammed Enes Albayrak, Sevilay Işık, Ahmet Yiğit Yılmaz, Eylül Erdem														x

16.1 LIST OF WORK PACKAGES

Table 3 *Detailed Definition of Work and Activity*

WP No	Detailed Definition of Work and Activity
1	Preparation and Evaluation
2	Survey with the experts
3	Determination of Criteria Weights
4	Researching implementation methods of similar projects
5	Formulas to be used in calculating criteria weights were determined
6	Criteria weights were determined by applying formulas
7	The importance order of the criteria was determined according to the suitability scores.
8	The opinions (E1, E_2, E3) from the expert opinion surveys were combined into a single unified fuzzy decision matrix. The consistency and complementarity of the linguistic values assigned to each criterion were ensured.
9	Linguistic values (LV) were transformed into Pythagorean Fuzzy Numbers (PFN), normalized weights were calculated and the consistency of the combined weights was checked.
10	The alternatives were ranked according to the calculated criteria weights and suitability scores. A final decision list was created based on the weighted performance of each alternative.
11	All results were added to the report and the most suitable alternative was determined by ranking according to the criteria.

Table 4 *Work package targets, their assessment, and the contribution of each work package to the overall project success.*

Work package	Target	Measurable outcome	Contribution to overall success (%)
1	• Collect and evaluate data to define criteria and alternatives.	Criteria and alternatives have been defined, data collection and evaluation have been completed.	10
2	• Obtain expert opinions to validate and refine criteria.	The criteria were verified and developed by gathering expert opinions.	5

3	• Assign importance levels to criteria using a structured methodology.	The importance levels of the criteria were determined.	10
4	• Researching implementation methods of similar projects	The formulas to be used to calculate the criteria weights were determined.	8
5	• Formulas to be used in calculating criteria weights were determined	The formulas to be used to calculate the criteria weights were determined.	12
6	• Criteria weights were determined by applying formulas	Criteria weights were determined by applying formulas.	10
7	• The importance order of the criteria was determined according to the suitability scores.	The order of importance of the criteria was determined according to their suitability scores.	5
9	• Convert linguistic values to PFNs. • Apply aggregation formulas to calculate normalized weights. • Check consistency of aggregated weights.	Final weights of each criterion with validated PFNs and consistency ratios.	10
10	• Organize all steps and calculations into a structured Excel file. • Ensure traceability and clarity for future evaluation.	Completed Excel file containing expert evaluations, weight calculations, and ranking steps.	10
11	• Rank alternatives using calculated criteria weights. • Generate final decision based on suitability scores.	Ranked list of alternatives based on weighted performance.	10
			Total:100
8	• Consolidate expert inputs (E1, E_2, E3) into a single decision matrix. • Ensure consistency and completeness in linguistic value assignments.	Unified fuzzy decision matrix derived from expert inputs.	10

Table 5 *The work package distribution to project team members: Who works on which work package? Specify the percentage contributions.*

WORK PACKAGE DISTRIBUTION

Project Member	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11
Eylul Erdem	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Muhammed Enes Albayrak	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Ahmet Yiğit Yılmaz	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Sevilay Işık	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Total	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

12. BUDGET

Table 6 *Proposed Budget in TL*

	ITEMS				
	PEOPLE	MACHINE-INSTRUMENT	MATERIALS	SERVICE	TRAVEL

IMU FUND	0	0	0	0	0
SPONSOR COMPANY FUND	0	0	0	0	0
TOTAL	0	0	0	0	0

***Table** 7 Actual Budget in TL (what you spent indeed)*

	ITEMS				
	PEOPLE	MACHINE-INSTRUMENT*	MATERIALS*	SERVICE	TRAVEL
IMU FUND					
SPONSOR COMPANY FUND					
TOTAL					

*Provide proforma invoice for machines and materials to be purchased.
*Provide technical specifications for machines and services to be purchased.
*Make a contract for services if necessary

13. CURRICULUM VITAE