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Original Scientific Article

Selection of Electric Vehicle Charging Station using PROMETHEE II and Shannon Entropy: A Case Study from Niš, Serbia

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Abstract—**The selection of an optimal Electric Vehicle Charging Station (EVCS) improves user experience, decrease costs and emissions, and contribute to sustainable urban mobility and energy efficiency. In solving this optimization problems, the application of decision support methods has an important role. This study focuses on the problem of selecting the best EVCS by analyzing real data from five stations in a specific area in Nis, Serbia. The most optimal station was chosen based on eight factors divided into two categories: benefit and cost. Their weights were determined using the Shannon Entropy objective approach. The PROMETHEE II approach was used to complete the ranking process.**

Keywords - electric vehicle, charging station, Entropy, PROMETHEE II

I. INTRODUCTION

Along with rise of urban environmental problems related to carbon emission and climate change effects, the sustainable transport initiative has gained increased attention in recent years worldwide [1]. Sustainable transport discourse considers various concepts like expansion and diversification of transportation network, promotion of energy efficient vehicles and “green” transport options like walking and cycling [2-4].

The current transportation sector is one of the most significant contributors to global greenhouse gas (GHG) emissions with an approximate share of 23% in the world's total energy-related CO_2, and adds considerably to climate change and global warming [5,6]. Sustainable transport solutions attempt to mitigate these consequences by diversifying fuel options and using renewable energy sources (RES), playing a significant role in improving public health. The increasing issues of air quality in urban areas, followed by numerous respiratory and cardiovascular diseases, largely come from vehicle emissions [7]. Transition to cleaner forms of transport, can reduce the prevalence of these health issues, improve quality of life and reduced healthcare costs for governments.

Transition process considers the development of smart infrastructure. In line with that, one of the most discussed issues is establishing an extensive network of EV charging stations (EVCS) [8,9]. With the expanding market of EV demand for accessible, reliable, and fast-charging options increases. The poor charging infrastructure is the major obstacle to the adoption of EV, since it may produce range anxiety [10,11]. To address this, investments in the widespread deployment of EVCS, ensure they are strategically located to meet the needs of urban, suburban, and rural areas alike.

Another significant segment of transition represents the integration of smart technologies into existing transportation infrastructure, which, among others includes connected vehicles, intelligent traffic management systems, and digital payment platforms. This, and other technologies will contribute to better efficiency and safety of transportation networks [12-14], enabling real-time monitoring and management of traffic flows, contribute to the reduced energy consumption, and better driver's experience.

Selecting the optimal EVCS plays a key role in protecting the environment and helping drivers pick the best choices. When drivers can choose optimal EVCSs considering criteria like proximity, cost, or charging speed, they're more likely to make choices that cut down on their impact on the environment. Informed selection cuts back on extra driving, lowers emissions, and makes sure drivers can finish their trips without a hitch striking a balance between ease and being "sustainable". By giving drivers the information, they need to make smart choices, we can keep drivers satisfied and help the environment at the same time.

The goal of this paper is to offer a multi-criteria decision support approach for selection for the optimal charging station from the driver's perspective. Study employs a real-world data from the city of Niš, Serbia. The paper firstly presents a brief literature review, secondly explain methodology, thirdly applies methodology on the case study and finally discuss results.

II. Literature Review

As a site selection problem, as far as literature suggests selecting optimal EVCS inevitably consider multi-criteria decision-making (MCDM) methods because this problem involves evaluating multiple, often conflicting factors that cannot be easily aggregated into a single metric. There are numerous studies that considers single or hybrid approach with more than one MCDM method to solve the site selection problem. Some of them are presented below.

For instance, in evaluating performances of nine EVCS in Istanbul [15] applied three MCDM: Analytic Hierarchy Process (AHP), Decision Making Trial and Evaluation Laboratory (DEMATEL), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to compare four main and twenty-one sub-criteria. Solving the charging problem for taxi service in [16], integrate fuzzy AHP to weight six main and twenty-five sub criteria, GIS for spatial analysis and TOPSIS for final ranking of electric taxi charging stations. To assess the effectiveness and applicability of EVCSs suggested for the Shanghai region [17] developed a Pythagorean fuzzy VIseKriterijumska Optimizacija I Kompromisno Resenje (PF-VIKOR) model, while VIKOR and TOPSIS methodologies were applied to assess feasibility, as well as economic, social, and environmental issues. Evaluating the EVCSs in the [18] combined Analytic Network Process (ANP), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and integrated cloud model considering geographical, environmental, social, service, engineering, and economic issues. Reference [19], introduced another integrated approach utilizing gray DEMATEL, to determine criterion weights, and UL - Multiple Objective Optimization on the basis of Ratio Analysis plus Full Multiplicative Form (UL-MULTIMOORA) to assess and rank the best EVCS location based on several linked parameters. Studying current and most suitable potential EVCS locations in Ankara. Reference [20] combined AHP method for weighting fifteen criteria, GIS for create a suitability map, while potential EVCS locations were identified, and alternative EVCSs were rated using the TOPSIS methodology. Reference [21] suggested a practical model for location decision of EV photovoltaic charging station combining a GIS for suitability analysis and entropy and Interative Multi-criteria Decision Making (TODIM) method are extended to the mixed attribute value environment. For selecting island photovoltaic charging station [22] applied the hybrid fuzzy approach that include AHP, entropy weight method, λ- fuzzy measure method and VIKOR. To evaluate criteria for site selection for shared charging and swapping stations [23] utilized Simultaneous Evaluation of Criteria and Alternatives (SECA) method to determine the weight of each secondary criterion, and the TRUST method to rank the alternatives. While planning the establishment of battery swapping station in Kolkata, [24] applied fuzzy based TFN method with consideration of the preference within the criteria; weights of the criteria are obtained, and Complex Proportional Assessment (COPRAS) methodology is applied to rank the selected locations. In their research, [25] studied location decision framework of electric vehicle battery swapping station fuzzy DEMATEL method is applied to determine the weights of criteria then, the Fuzzy ordered Weighted Averaging (FOWA) operator is adopted to aggregate the evaluation values on alternatives of experts and the fuzzy MULTIMOORA is used to rank the alternatives. In analyzing location of the offshore wind station [26] utilized a hybrid fuzzy ANP fuzzy DEMATEL and fuzzy Elimination and Choice Expressing Reality (ELECTRE) techniques. Reference [27] applied the Weighted Suitability Analysis (WSA) and Grey Relation Analysis (GRA) method to find the most suitable site of industrial wastewater discharge in coastal regions. Reference [28] proposed a model to evaluate the site selection problem of car sharing stations using Weighted Aggregated Sum Product Assessment (WASPAS) based TOPSIS method. In analyzing optimal site selection in Istanbul [29] employed FUCOM-GIS hybrid method.

III. Methodology

For selecting the optimal EVCS this study employs a real word data for the city of Niš Serbia, where all of the analyzed criteria are quantifiable. Therefore, a hybrid Shannon Entropy - PROMETHEE II method is applied to secure objective distribution of criteria weights, based on the variability of observed data and enable efficient balance between costs and benefits criteria.

The Shannon entropy method is often applied in MCDM and for objective determination of the weights of various criteria based on the data set. Shannon was the first scientist to develop the notion of entropy in information theory in the mid-twentieth century. The Shannon entropy technique assesses the disorder in existing data [30]. The authors Claude Shannon and Warren Weaver (1948) illustrate the following steps involved in applying this method below [31]. The initial step in the calculation of weight coefficients is the normalization of the decision matrix. Then, in the next step, the share of the value of the alternatives in the total value of the criteria is calculated. Based on the obtained values, entropy is calculated for each criterion, and then the calculated entropy value is subtracted from the maximum possible entropy value. This step indicates the calculation of the degree of variation among the entropy values, on the basis of which the weighting coefficients are calculated.

In this example, the PROMETHEE II method was used to solve the set multi-criteria problem. The PROMETHEE II method enables the prioritization of alternatives in relation to a larger number of criteria, taking into account the preferences of the decision maker [32]. The choice in the application of the PROMETHEE II method was based on the assumption that this method enables a complete ranking of alternatives even in situations where conflicting criteria appear [33].

There are several basic steps in PROMETHEE II. These are (1) defining criteria and alternatives, (2) giving each criterion a weight value, (3) picking a preference function, (4) calculating preference indices, (5) calculating positive and negative preference flows, (6) calculating net preference flow, and (7) ranking the alternatives [34]. PROMETHEE II offers six preference functions that define the preference relationship between alternatives: the usual criterion (Type I), the U-shape criterion (Type II), the V-shape criterion (Type III), the level criterion (Type IV), the linear criterion (Type V), and the Gaussian criterion (Type VI) [34]. The choice of the preference function depends on the nature of the available data and the research problem [35]. The net preference flow is obtained by subtracting the positive preference flow from the negative preference flow [34]. In order for an alternative to be highly ranked, it is necessary to have the highest possible value of the positive flow of preference, because it shows how much this alternative outranks the other alternatives, and the lowest value of the negative flow of preference, because it indicates how much this alternative is outranked in relation to the others [34]. This step enables a complete ranking of the alternatives.

For selection of EVCS infrastructural, spatial and environmental criteria are considered.

A. Infrastructural Criteria

Charger type. The EV charger type is important criterion for EVCS selection. It is reciprocal to charging time and cost. There are different types of chargers like Level 1, Level 2 or DC fast chargers, with its pros and cons. However, network with variety of chargers types can satisfy different needs that consequently can encourage adoption of EVs.

Number of chargers. More chargers at EVCSs increase drivers' chances of finding an available port, especially during peak hours, and decrease congestion that in turn improves the drivers experience and charging predictability. This is especially important in high-density urban area where the larger volume of traffic and users are expected. Stations with more chargers makes a better use of the infrastructure and distribution of load, optimizing the energy use and overall environmental impact.

Charging Price. Charging affordability increases the likelihood of driver selecting particular station. The price affects the total cost of the ownership of EV, especially the ones who totally relay on public EVCSs. It also influences competitiveness between the stations; thus, driver may give lower priority to stations with higher charging prices that do not offer some additional benefits (e.g. membership tokens, faster charging, proximity to important POIs etc.).

Available chargers' information. The access to real time information about EVCS contribute to the driver's convenience in several ways: prevent unnecessary trips, minimize waiting time, optimize route planning, book a charging spot in advance, allow price comparison and avoid unexpected costs.

B. Spatial Criteria

Distance. The range anxiety may considerably affect driver's psychological comfort, thus the proximity and accessibility to the EVCSs is an important criterion. Closer station is more probable choices for EV drivers, since it adds to less deviation from the planned route, saves time and energy.

Population density. EVCSs located in high-density areas my experience higher load that can affect the efficiency of service (e.g. waiting time), since larger number of residence (potential EV owners) are in higher proximity to the station. Also, higher usage rates influence station demand, and economic viability which can result in better maintenance and service in the long run.

Proximity to arterial road. Strategic placement of EVCS along arterial road enhances accessibility, increases utilization rates, and improves convenience for drivers, encouraging EV adoption. Furthermore, accessibility to EVCS in high-traffic areas supports more efficient energy distribution and can optimize operational costs for charging networks.

C. Environmental Criteria

Charging Efficiency. The conversion from Alternating Current (AC) to Direct Current (DC) during the charging process cause energy losses. DC fast chargers, perform lower efficiency than slower Level 2 chargers. Additionally, inefficient charging practices, particularly frequent use if fast chargers, accelerate battery degradation i.e. shorten their life. The production of new batteries considers high emissions from mining essential materials, and thus, contribute to environmental degradation.

Renewable energy source. EVCS powered by RES reduce carbon emission and contribute to environmental sustainability, energy efficiency and encourage sustainable behavior of drivers promoting cleaner transportation.

IV. CASE STUDY

For the selected criteria case study is conducted for the city of Niš, Serbia. Though online and on-site analysis fourteen EVCSs are identified. Ten of them are located within the

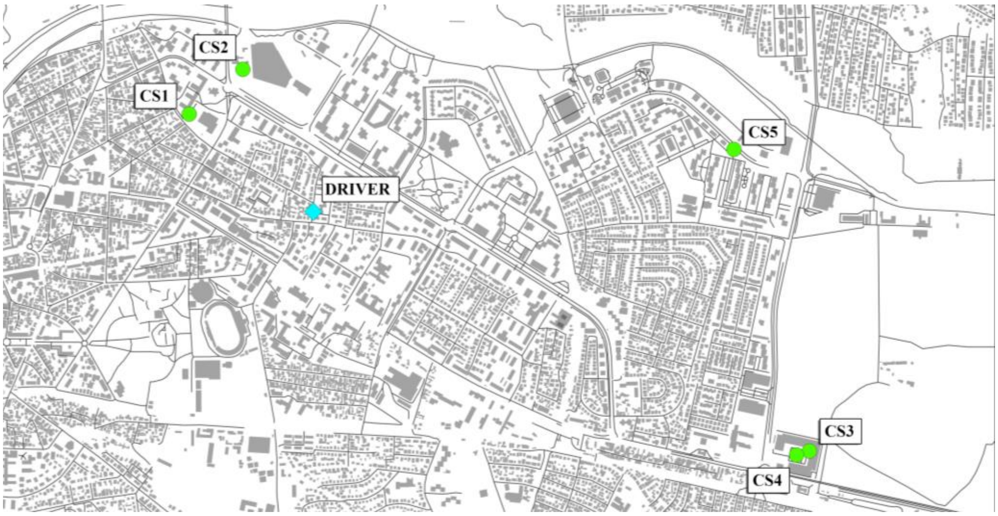

Figure 1. Locations of EVCSs in Niš and position of randomly selected location for driver.

TABLE I. CRITERIA INFO.

Criterion	Unit	Abbreviation
Charger type	kW/hour	C1
Number of chargers	number	C2
Price	RSD/minute	C3
Distance	km	C4
Population density	Low (0), Medium (1), High (2)	C5
Available charger information	No (0), Yes (1)	C6
Charging Efficiency	Low (0), Medium (1), High (2)	C7
Proximity to arterial road	Low (0), Medium (1), High (2)	C8

TABLE II. INITIAL DECISION MAKING MATRIX.

ID	EVCS	C1	C2	C3	C4	C5	C6	C7	C8
Criterion type	-	Benefit	Benefit	Cost	Cost	Cost	Benefit	Cost	Benefit
Preference function	-	Usual	Usual	Usual	Usual	Usual	Usual	Usual	Usual
CS_1	Goran Ostojic	11	2	0	1.3	High	No	High	Medium
CS_2	Delta Planet	11	10	15	0.95	High	Yes	High	High
CS_3	StopShop	100	2	153	2.7	Medium	Yes	Low	High
CS_4	Liikennevirta Oy (CPO)	120	2	153	2.7	Medium	Yes	Low	High
CS_5	Kemoimpex	22	2	15	2.5	Medium	Yes	Medium	High

commercial facilities lots (like hotels or factories), while only four that are located in the wider city central zone. Only the former are considered for this example, since the remaining ones either includes additional costs (like any kind of service in hotel) or are strictly allocated for the employees (Fig. 1). For the selected EVCSs criteria info are shown in Table I.

In the first iteration conceptual model considered EVCS powered by RES. However, field study showed that in the given context none of the identified EVCS is powered by RES, thus, we decided to omit this criterion from the final model since all of the selected cases would receive equal weight.

The initial decision matrix was formed for the purposes of creating the hybrid Entropy-PROMETHEE II in order to select the most optimal charging station for an EV. The criteria are divided according to whether they are positive/benefit or negative/cost in relation to the decision-making objective. The usual type of preference function was chosen because even minor differences in the alternatives affect the choice [35]. In accordance with the defined units of measure in the previous table, this decision matrix was transformed into a form where all criteria have numerical values (Table II).

V. RESEARCH RESULTS AND DISCUSSION

The Shannon entropy method was used to calculate the value of the weighting coefficients of the criteria. The calculation was carried out on the basis of eight criteria and five alternatives. The initial decision matrix is normalized to show uniform values of the comparison criteria. The weight coefficients' values are presented in the Table III. The results indicate that the decision-maker places significant importance on the calculated price of charging an EV. The importance of charging efficiency and charger type is approximately equal, with the former having a slight preference. The type of charger is then the next important criterion in choosing the most optimal station. Charging speed carries more weight because rapid chargers are more convenient than slower chargers and provide significant savings in charging time. The least important in the prioritization process is the proximity to arterial roads.

The application of the PROMETHEE II method necessitates the normalization of the decision matrix based on the benefit and cost type criteria. The next step, based on the values of the normalized matrix and the selection of the preference function, calculates the preference indices whose aggregate results can be seen in the Table IV.

The Table V shows the results of the calculation of the positive and negative flow of preference for each offered alternative. In order to approach the final ranking, the net value of the preference flow was calculated, which is obtained by subtracting the positive preference flow from the negative preference flow. The ranking prioritizes higher values of the net flow of preference, placing CS_2 Delta Planet at the top. The lowest-ranked station is CS_1 Goran Ostojic.

The results obtained using the hybrid Entropy-PROMETHEE II model show the feasibility of prioritizing the optimal EV charging station according to criteria of diverse characteristics. Considering the weight values determined objectively in this case study, the price of charging is a crucial factor in the decision-making process, highlighting the importance of cost criteria. Another criterion that prioritizes chargers with high charging efficiency approves the use of slower charger types because they cause less energy losses. In addition, the type and number of chargers play a significant role in selecting the most optimal EVCS, because a faster type of charger with a larger number of free charging stations allows for a shorter waiting time and more efficient use of resources. The wide availability of the option to monitor the state of free chargers has significantly reduced the influence of this criterion on the ranking.

TABLE III. OBJECTIVE CRITERIA WEIGHT CALCULATED BY SHANNON'S ENTROPY METHOD.

Abbreviation	Criterion	Weight coefficient
C1	Charger type	0.193
C2	Number of chargers	0.144
C3	Price	0.288
C4	Distance	0.035
C5	Population density	0.028
C6	Available charger information	0.105
C7	Charging Efficiency	0.194
C8	Proximity to arterial road	0.013

TABLE IV. AGGREGATED PREFERENCE FUNCTION RESULTS CALCULATED BY PROMETHEE II.

	CS_1	CS_2	CS_3	CS_4	CS_5
CS_1	1	0.028	0.317	0.317	0.052
CS_2	0.268	1	0.439	0.439	0.175
CS_3	0.498	0.380	1	0.000	0.235
CS_4	0.533	0.415	0.035	1	0.270
CS_5	0.262	0.145	0.264	0.264	1

TABLE V. PRIORITIZATION RESULTS BY PROMETHEE II.

ID	Charging station	Positive flow (Phi+)	Negative flow (Phi-)	Net flow (Phi)	Rank
CS_1	Goran Ostojic	0.178	0.390	-0.212	5
CS_2	Delta Planet	0.330	0.242	0.088	1
CS_3	StopShop	0.278	0.264	0.014	4
CS_4	Liikennevirta Oy (CPO)	0.313	0.255	0.059	2
CS_5	Kemoimpex	0.234	0.183	0.051	3

Decision-making places less emphasis on distance from users and population density, suggesting that even more distant stations or those in highly urbanized locations that are close to high priority roads could be suitable options if the other criteria are satisfied. Accordingly, using the PROMETHEE II method, the choice was reduced to the Delta Planet station, which offers a low EV charging price, with slow types of chargers, but with the largest number of installed charging points. Charging efficiency of this station is high leading to the energy-saving charging process. The station offers the possibility to check the availability of chargers, with services being covered by a smartphone application. Although the station is located in a densely populated area that is close to high-order roads, its distance from users is the shortest compared to other stations.

VI. CONCLUSSION

In conclusion, the application of the hybrid Entropy-PROMETHEE II method for selecting optimal EVCS demonstrates to be a useful MCDM approach in EVCSs optimization problems. This study analyses the importance of numerous parameters, with the cost of charging calculated as the crucial one. The analysis finds that, while charger type and energy efficiency are essential, cost efficiency and the number of available charging lots are more relevant in identifying the best option.

The presented model can be applied in other regions, but with context-specific adaptation that takes into consideration local infrastructure, energy polices and socio-economic conditions. For instance, in cities/regions with highly developed EVCS infrastructure factors like station density, network interoperability, or integration with smart grid networks may become more relevant. On the other side in region with poor EVCS network accent can be on accessibility, availability of public land and network capacity. The PROMETHEE II method can easily accommodate these additional criteria without compromising the decision-making logic, while Shannon Entropy can dynamically reflect the varying relevance of these factors based on regional data availability.

Further studies should consider more further analysis of the relevant criteria that are out of scope of the presented research, and consider several axis:

Analysis of the environmental impact (like source of electricity) i.e., how different EVCS locations and technologies (existing and emerging) impact the environment, supporting more informed decisions that align with sustainability goals.

A detailed geospatial analysis to understand how spatial factors like infrastructure, spatial distribution (density and proximity) of EVCS, or traffic pattern and population density influence EVCS placement and accessibility.

Exploration of the potential integration of EVCS with renewable energy sources, and its effect on station selection, i.e., how green energy solutions can enhance the sustainability and attractiveness of charging stations.

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REFERENCES

[1] Eswaranathan, K., Sivakumar, T., De Silva, M. M., & Kumarage, A. S. (2024). Modelling the factors influencing carbon efficiency of consumer choice to promote energy-efficient vehicles. *Transport Economics and Management, 2*, 130-142.

[2] Ullah, Z., Qazi, H. S., Rehman, A. U., Hasanien, H. M., Wang, S., Elkadeem, M. R., & Badshah, F. (2024). Efficient energy management of domestic loads with electric vehicles by optimal scheduling of solar-powered battery energy storage system. *Electric Power Systems Research, 234*, 110570.

[3] Naik, M. B., Kumar, P., & Majhi, S. (2019). Smart public transportation network expansion and its interaction with the grid. *International Journal of Electrical Power & Energy Systems, 105*, 365-380.

[4] Monazzam, M. R., Karimi, E., Shahbazi, H., & Shahidzadeh, H. (2021). Effect of cycling development as a non-motorized transport on reducing air and noise pollution-case study: Central districts of Tehran. *Urban Climate, 38*, 100887.

[5] Leicht, J. B., & Leicht, M. (2024). Climate change and transportation companies: A bibliometric and systematic literature review. *Transportation Research Part F: Traffic Psychology and Behaviour, 101*, 160-185.

[6] Wang, T., Qu, Z., Yang, Z., Nichol, T., Clarke, G., & Ge, Y. E. (2020). Climate change research on transportation systems: Climate risks, adaptation and planning. *Transportation Research Part D: Transport and Environment, 88*, 102553.

[7] Pradhan, R. P., Nair, M. S., Hall, J. H., & Bennett, S. E. (2024). Planetary health issues in the developing world: Dynamics between transportation systems, sustainable economic development, and CO_2

emissions. *Journal of Cleaner Production, 449*, 140842.

[8] Goli, P., Gampa, S. R., Kumar, N. M., Jasthi, K., Parimi, A. M., Das, D., ... & Guerrero, J. M. (2023). Strategic planning of distribution network integrated with EV charging stations using fuzzy pareto optimality for performance improvement and grid-side emission reduction benefits. *Sustainable Energy, Grids and Networks, 36*, 101199.

[9] Saldanha, J. J., Nied, A., Trentini, R., & Kutzner, R. (2024). AI-based optimal allocation of BESS, EV charging station and DG in distribution network for losses reduction and peak load shaving. *Electric Power Systems Research, 234*, 110554.

[10] Goncearuc, A., De Cauwer, C., Sapountzoglou, N., Van Kriekinge, G., Huber, D., Messagie, M., & Coosemans, T. (2024). The barriers to widespread adoption of vehicle-to-grid: A comprehensive review. *Energy Reports, 12*, 27-41.

[11] Pamidimukkala, A., Kermanshachi, S., Rosenberger, J. M., & Hladik, G. (2024). Barriers and motivators to the adoption of electric vehicles: a global review. *Green Energy and Intelligent Transportation, 100153*.

[12] Ouallane, A. A., Bakali, A., Bahnasse, A., Broumi, S., & Talea, M. (2022). Fusion of engineering insights and emerging trends: Intelligent urban traffic management system. *Information Fusion, 88*, 218-248.

[13] Yang, M., Jiang, K., Wijaya, B., Wen, T., Miao, J., Huang, J., ... & Yang, D. (2024). Review and Challenge: High Definition Map Technology for Intelligent Connected Vehicle. *Fundamental Research*.

[14] Mogaji, E., & Nguyen, N. P. (2024). Evaluating the emergence of contactless digital payment technology for transportation. *Technological Forecasting and Social Change, 203*, 123378.

[15] Karaşan, A., Kaya, İ., & Erdoğan, M. (2020). Location selection of electric vehicles charging stations by using a fuzzy MCDM method: a case study in Turkey. *Neural Computing and Applications, 32*, 4553-4574.

[16] Kaya, Ö., Alemdar, K. D., & Çodur, M. Y. (2020). A novel two stage approach for electric taxis charging station site selection. *Sustainable Cities and Society, 62*, 102396.

[17] Cui, F. B., et al. (2018). Optimal siting of electric vehicle charging stations using Pythagorean fuzzy VIKOR approach. *Mathematical Problems in Engineering. 2018*(1), 9262067.

[18] Wu, Y., Xie, C., Xu, C., & Li, F. (2017). A decision framework for electric vehicle charging station site selection for residential communities under an intuitionistic fuzzy environment: A case of Beijing. *Energies, 10*(9), 1270.

[19] Liu, H. C., Yang, M., Zhou, M., & Tian, G. (2018). An integrated multi-criteria decision making approach to location planning of electric vehicle charging stations. *IEEE Transactions on Intelligent Transportation Systems, 20*(1), 362-373.

[20] Erbaş, M., Kabak, M., Özceylan, E., & Çetinkaya, C. (2018). Optimal siting of electric vehicle charging stations: A GIS-based fuzzy Multi-Criteria Decision Analysis. *Energy, 163*, 1017-1031.

[21] Zhou, J., Wu, Y., Wu, C., He, F., Zhang, B., & Liu, F. (2020). A geographical information system based multi-criteria decision-making approach for location analysis and evaluation of urban photovoltaic charging station: A case study in Beijing. *Energy Conversion and Management, 205*, 112340.

[22] Dang, R., Li, X., Li, C., & Xu, C. (2021). A MCDM framework for site selection of island photovoltaic charging station based on new criteria identification and a hybrid fuzzy approach. *Sustainable Cities and Society, 74*, 103230.

[23] Lu, F., Yan, L., & Huang, B. (2022). Site selection for shared charging and swapping stations using the SECA and TRUST methods. *Energy Reports, 8*, 14606-14622.

[24] Koirala, K., & Tamang, M. (2022). Planning and establishment of battery swapping station-A support for faster electric vehicle adoption. *Journal of Energy Storage, 51*, 104351.

[25] Wang, R., Li, X., Xu, C., & Li, F. (2020). Study on location decision framework of electric vehicle battery swapping station: Using a hybrid MCDM method. *Sustainable Cities and Society, 61*, 102149.

[26] Fetanat, A., & Khorasaninejad, E. (2015). A novel hybrid MCDM approach for offshore wind farm site selection: A case study of Iran. *Ocean & Coastal Management, 109*, 17-28.

[27] Li, Y., Lin, C., Wang, Y., Gao, X., Xie, T., Hai, R., ... & Zhang, X. (2017). Multi-criteria evaluation method for site selection of industrial wastewater discharge in coastal regions. *Journal of Cleaner Production, 161*, 1143-1152.

[28] Deveci, M., Canıtez, F., & Gökaşar, I. (2018). WASPAS and TOPSIS based interval type-2 fuzzy MCDM method for a selection of a car sharing station. *Sustainable Cities and Society, 41*, 777-791.

[29] Gökler, S. H. (2024). Optimal site selection for electric vehicle charging stations: analysis with hybrid FUCOM and geographic information systems. *Energy, 132659*.

[30] Wu, J., Sun, J., Liang, L., & Zha, Y. (2011). Determination of weights for ultimate cross efficiency using Shannon entropy. *Expert Systems with Applications, 38*(5), 5162-5165.

[31] Shannon, C. E. (1948). A mathematical theory of communication. *The Bell system technical journal, 27*(3), 379-423.

[32] Martínez-Maldonado, V., Barragán-Escandón, A., Serrano-Guerrero, X., & Zalamea-Leon, E. F. (2023). Optimal routing for mass transit systems using multicriteria methodologies. *Energy Strategy Reviews, 47*, 101077.

[33] Oubahman, L., & Duleba, S. (2021). Review of PROMETHEE method in transportation. *Production Engineering Archives, 27*(1), 69-74.

[34] Brans, J. P., & De Smet, Y. (2016). PROMETHEE methods. *Multiple criteria decision analysis: state of the art surveys*, 187-219.

[35] Zhaoxu, S., & Min, H. (2010, June). Multi-criteria decision making based on PROMETHEE method. In *2010 international conference on computing, control and industrial engineering* (Vol. 1, pp. 416-418). IEEE.