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# Comparison of decision-making approaches to prioritization of clean air action plans for sustainable development

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**Abstract**

**Background:** Clean air action plans have been prepared and are still being implemented in Turkey to control and prevent air pollution, and improve the air quality. The plans reveal a picture of the current situation and available inventory information. However, in order to implement the identified plans in real life, they need to be prioritized. This study aimed to identify and prioritize clean air action plans for Turkey using a framework of both fuzzy and crisp evaluations.

**Methods:** In this study, priorities of the plans were identified and analyzed with a decision-making model. A three-step research methodology was provided. First, literature was reviewed regarding sustainable development and action plans. Second, in order to narrow and specify action plans, the nominal group technique (NGT) was implemented. Finally, fuzzy analytic hierarchy process (AHP) and best-worst method (BWM) surveys were applied to environmental engineers and experts working on sustainable development to prioritize the action plans.

**Results:** It was revealed that heating dimension is considered as the most important criterion with the weight of 0.7469 in fuzzy AHP and 0.758 in BWM. AP1 with a weight of 0.3356 in fuzzy AHP and AP3 with a weight of 0.3289 in BWM were the most important sub-criteria, which are the plans for reducing coal use ranked at the forefront in reducing air pollution.

**Conclusion:** According to the results, there is no significant difference in the priority ranking results. The results of fuzzy AHP and BWM are very similar. For example, traffic criterion has the best performance in both methods in the evaluation of decision makers. In addition, the main and sub-criteria with the lowest priority are the same in these two methods.

**Keywords:** Air pollution, Cities, Decision making, Surveys and questionnaires

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## Introduction

Cities have been one of the most important factors shaping the future of human beings with the accumulation of civilization and the bearing of humanity to future generations in the historical process. Indeed, it is expressed that there is a parallel between the birth of civilization and the emergence of cities. Urbanization movements, which have gained momentum in recent years, have led to an increase in the population density in urban areas. Today, 54% of the world's population lives in urban areas, and this ratio is expected to rise to 66% until 2050. According to the Department of Economic and Social Affairs (DESA) (1), it is estimated that the world's urban population fertility rate will continue to decline in developing regions and rise to 7.4 billion by 2050 instead of 6.3 billion. According to the statement of John Wilmoth, the director of the population division in the UN's DESA, managing urban areas has become one of the most important development challenges of the 21st century. Therefore, the importance of the urban areas that hosting the economy (investment), population (human power), service sector (employment), transportation (logistics), social problems, cultural contradictions, and spatial incompatibilities, is increasing day by day.

Cities that are the collective life center of human beings have been influenced by economic, social, environmental, and political factors especially since the late 19th century. In 1990-2010, sustainable development in cities has gradually become a keystone of urban planning (2). The social and environmental problems in cities reduce the quality of life and the environment in these areas. Problems, such as safety issues, air quality management, transportation problems, water consumption, waste recycling, energy consumption, and lack of effective policies for conservation of green space can be listed as common problems of people living in urban areas (3).

City administrators are trying to achieve competitive, sustainable, livable, and high-quality city targets by solving the problems of city and citizens through making policies and implementing them (4). However, lack of appropriate data at the urban level is one of the obstacles to the establishment of urban policies. Priority policies can be identified by selecting appropriate indicators and collecting necessary data for the targets to be achieved. Most cities in Turkey are exposed to air pollution, especially in winter. The reasons for this are intense urbanization, improper construction of cities, increasing number of motor vehicles, irregular industrialization, low-quality fuel usage, topographic and meteorological conditions. Air quality varies according to the intensity of heating, transportation, and industrial pollutants in the atmosphere. In Turkey, the Ministry of Environment and Urbanization published regulations to decrease high air pollution potential of cities and fight within the scope of sources. For the causes of air pollution (heating, industry, and traffic), legislation and implementation projects are being carried out to help the development of air quality by the ministry. The Konya air quality has been worked out in detail with the IKONAIR project completed in 2012 after two years of work carried out by the Ministry of Environment and Urbanization and the Netherlands Institute for Public Health and the Environment (RIVM). Scenario assessments and comprehensive action plans were prepared by the Konya Metropolitan Municipality and the Provincial Directorate of Environment and Urbanism, covering the years 2013-2019 (5).

Prioritization of action plans is being implemented in order to prevent air pollution in the coming years. It is important to develop appropriate strategies for researchers and practitioners who will implement these plans firstly. This study investigated the definition of clean air action plans for a specific region in Turkey and the prioritization of air action plans using a decision-making approach. The aim of this study was to emphasize the importance of sustainability policies and to propose a methodology for the evaluation of the policies in determining the regulations that will be effective in the evaluation and development of cities' sustainability.

The prioritization of action plans is a multi-criteria question with many conflicting dimensions, which make the evaluation process difficult and uncertain. On the other hand, it is difficult to evaluate the human opinions with definite numbers through linguistic variables. For this reason, in many studies, fuzzy logic has been successfully used to model such uncertainty. In order to overcome the uncertainty and ambiguity in the evaluations during the prioritization of the action plans, it is recommended to integrate the fuzzy set theory with the analytic hierarchy process (AHP) method. The AHP is a method that constructs hierarchically interconnected decision problems as a goal, criteria, and alternatives, which obtaining relative weights between factors. Although fuzzy AHP method has been used in many real-world applications, it requires many pairwise comparisons between criteria. Thus, Rezaei developed the best-worst method (BWM) to acquire weights of criteria with fewer data requirements (6). The BWM uses a highly structured and understandable way to collect the data required for pairwise comparisons. In this study, both AHP and BWM methods were considered to provide a methodology for air action plans. To the best knowledge of author, there are no comparative studies on these methods for dealing with action plans in air quality perspective.

## Literature Review

In this section, the literature on municipal policies on sustainable development, action plans, and city sustainability in urban studies are summarized, and the research gaps in the present study are described.

Multi-criteria decision making (MCDM) methods are accepted as an important tool in structuring and solving decision-making problems. This tool is widely used in the field of sustainable development because of the flexibility, which allows decision makers to make decisions considering all criteria and alternatives at the same time. Many authors have reviewed MCDM methods for sustainable development. Munda showed how sustainability indicators can be combined to address sustainability indicators and developed a multi-criteria framework (7). Kumar et al discussed some key features of the MCDM in the context of energy planning based on renewable energy sources (8). Cinelli et al demonstrated the performance of five MCDM methods (MAUT, AHP, PROMETHEE, ELECTRE, and DRSA) with respect to 10 key criteria of sustainability assessment tools (9). Huang et al showed that the application of MCDM methods in environmental science has grown considerably over the past two decades (10). Between 1990 and 2009, a significant increase in the number of articles published in environmental publications was observed. Also, studies about the application of the nominal group technique (NGT) method have been performed for solving various problems, such as supplier development (11), risk identification (12), safety management system (13), military promotion screening (14), evaluation of ERP projects (15), management of pregnant women (16), and risk assessment (17).

There have been many studies in the literature about sustainable development and MCDM methods at the same time. Awasthi and Chauhan presented a hybrid approach based on the affinity diagram, AHP, and fuzzy TOPSIS to evaluate sustainable city logistics initiatives in a fuzzy environment (18). Theodoridou et al conducted a case study in Thessaloniki city by applying geographic information system (GIS) to predict energy saving and solar systems potential in urban environments (19). Gonzalez-Garcia et al proposed an integrated multi-criteria approach (combining material flow analysis, life cycle assessment, and data envelopment analysis) to analyze the sustainability of a sample city, taking into account environmental, social, and economic parameters to a sample of 26 Spanish cities (20). Onnom et al proposed a method to develop the livable city index by integrating AHP and GIS techniques (21). Egilmez et al improved a model to assess the sustainability performance of Canadian metropolitan areas considering 16 sustainability indicators and multi-criteria intuitionistic fuzzy decision-making (22). They found that $CO_2$ emissions and public transport have the greatest influence on the sustainability scores. González et al developed a GIS-based decision-support system (DSS) by incorporating elements of urban metabolism with the framework of sustainability impact assessment. The DSS was implemented within the framework of the BRIDGE project to assess planning alternatives in five European cities (Athens, Gliwice, Helsinki, Firenze, and London) (23). Jakimavičius and Burinskiene analyzed the urban transport system in Vilnius using TOPSIS and SAW methods based on accessibility and other indicators, and proposed a decision support system (24). Fetanat and Khorasaninejad applied a new hybrid MCDM approach based on fuzzy ANP, fuzzy decision DEMATEL, and fuzzy ELECTRE methods for the offshore wind farm in the Persian Gulf of Iran (25). Tadić et al proved the applicability of fuzzy DEMATEL, fuzzy ANP, and fuzzy VIKOR methods for the city of Belgrade (Serbia) in choosing city logistic concept (26). Vafaeipour et al prioritized the solar projects in Iran using integrated SWARA-WASPAS approach and Yazd city was ranked as the first one in the research (27). Milutinović et al implemented an AHP-based model in Nis (Serbia) to assess the sustainability of waste management (28). Nadal et al established an assessment tool in Barcelona (Spain) to assess the potential establishment of sustainable roof houses in schools (29). Reza et al proposed an integrated framework of AHP and life cycle analysis for the selection of sustainable flooring system in Tehran using the triple-bottom-line sustainability criterion (30). Jovanović et al formulated a simulation model for analyzing energy claims, which analyzes the identification and sustainable development of energy needs envisaged for Belgrade (31). Cai et al proposed a hybrid approach for identifying Beijing's taxi fleet development strategies on a sustainable scale, including life cycle assessment and multi-criteria decision analysis (32). The proposed approach provides a comprehensive analysis of the taxi fleet in Beijing to reduce air pollution in the city. Azapagic et al proposed a new decision support methodology for Sheffield city (England), including GIS, life cycle assessment, transport modeling, health impact assessment, and multi-criteria decision analysis to assess the impacts of pollution on human health and environment (33). Awasthi et al evaluated the selection of sustainable transport systems using TOPSIS method in the fuzzy environment, taking into account the air pollutant criteria (34).

Simoes et al presented an integrated approach for modeling energy system involving the transition of the energy system in the four European countries and developed an action plan for the transition of the city energy system (35). Grima et al presented a new approach based on the interdisciplinary framework to develop an agenda and action plan in land management decision in Jalisco, Mexico (36). Ali et al used the Bilan Carbone model based on the MCDA to analyze the technical carbon reduction potential and to propose decarbonization action plans for Bangkok metropolitan area, Thailand (37). Neves et al implemented an MCDA methodology to assist local authorities with the development of an energy action plan for more sustainable municipal energy systems, using the ELECTRE III method, in the Municipality of Odemira, Portugal (4). Neves et al proposed a decision support methodology to assist locally sustainable energy planning processes, covering the entire energy planning process (38). The MACBETH approach was used to illustrate the preferences of the local actors in Portugal. Ruiz-Padillo et al developed a methodology classification with priority order for road extension actions covered by noise action plans and implemented the fuzzy AHP method with two different fuzzification methods (39). Doukas et al extended a linguistic assessment methodology with 2-tuples to illustrate the aim of energy policy for sustainable development (40). During the implementation of the method, renewable energy sources proposed in the Hellenic National Action Plan for Greenhouse Gases, were discussed. De Gisi et al developed a planning support tool in the field of municipal waste water treatment plants and proposed technical solutions through the identification of appropriate action plans. The proposed vehicle was applied to the Italian municipal wastewater treatment plants (41). Dall'O et al proposed a multi-criteria analysis methodology to support public administration/local governments in programming sustainable energy action plans, based on the method of ELECTRE III (42). Kiewchaum et al conducted multi-criteria analysis (MCA) of the appropriateness and effectiveness of each mitigation measure to determine the most appropriate greenhouse gas mitigation measures to be implemented in Bangkok, Thailand (43). Baker et al proposed a multi-criteria framework to local jurisdictions in the Southeast Queensland, setting numerical scores as criteria for assessing seven local adaptation plans (44). Pablo-Romero et al examined the impact of energy action plans and demonstrated that by using the econometric methods, the municipal council contract had a positive effect on reducing electricity consumption (45). Ruiz-Padillo et al obtained the weights for the criteria defined by fuzzy AHP to reduce the environmental impact of road traffic noise, and then, alternatives were ranked using the ELECTRE and TOPSIS methods (46).

The above-mentioned literature review shows that important studies have been carried out for the improvement of sustainable development. Although there have been studies involving action plans, no study has been found dealing with clean air action plans. In order to fill this gap, an advanced methodology has been proposed to prioritize action plans by comparing the application of two MCDM methods in the context of air quality in this study. Although most of the above-mentioned studies utilized the AHP method, but the AHP and BWM methods were evaluated separately in this study.

## Materials and Methods

In this study, the prioritization of action plans was discussed with an organizational point of view. A three-stage methodology was applied to prioritize action plans that can be implemented in air pollution mitigation efforts. Firstly, internationally published articles were taken into account in order to facilitate the data collection process and to lay the groundwork for designing the questionnaire. Secondly, a decision-making group consisting of experts, academicians, and engineers were formed and action plans were defined and evaluated. The NGT was used to provide a list of key action plans, which are divided into three main dimensions by experts using the NGT. Thirdly, fuzzy AHP and BWM methods were applied to provide a simple approach that will help decision-makers to understand the priority of the selected plans. The fuzzy AHP approach uses linguistic variables or fuzzy numbers in fuzzy environments to address the uncertainty of experts' decisions (47). A flow diagram for the proposed model is presented in Figure 1.

### A real case application for Konya

#### *Problem definition*

It is difficult to say which plan is more important than others in the implementation of action plans. However, by using the proposed approach, action plans for decision-makers were prioritized and a more logical and constructive system was established. The proposed assessment approach was tested in Konya, which is the largest city in Turkey by area (Figure 2). In Konya, air pollution problems arise for various reasons as well as many cities in Turkey. Konya is the 7th largest city in Turkey with a population of 2 180 149 people. Konya air quality was studied as IKONAIR project completed in 2012 within the context of air pollution control and prevention, and air quality improvement activities in Konya, and comprehensive action plans during 2013 to 2019 were prepared with all positive and negative scenario evaluations. While the identified action plans included precautions to reduce air quality, there was no extensive research on the plans and the barriers to implementation.

#### *Identification of action plans*

The NGT is a special form of brainstorming and a structured meeting that is held between group members to find a solution to the problem being discussed. It is aimed to reach a general agreement or consensus about a specific issue. The processing steps of the NGT are as follows: 1) listing the opinions, 2) giving the sequence number to each view, 3) rating the opinions, 4) collecting the points, and 5) ranking the opinions from most important to least important (15). In this study, a meeting was held to determine which of the action plans specified by the Provincial Directorate of Environment and Urban Planning would be included in the analysis. Environmental engineers, expert managers who work in public institutions on sustainable development and academicians, were invited to participate in the meeting. Experts were selected from among those with at least two years of experience in their field. At the meeting, the action plans were put in priority ranking and the final list of action plans was prepared for prioritization. The action plans were divided into three main dimensions and sub-dimensions so that the hierarchical structure of the

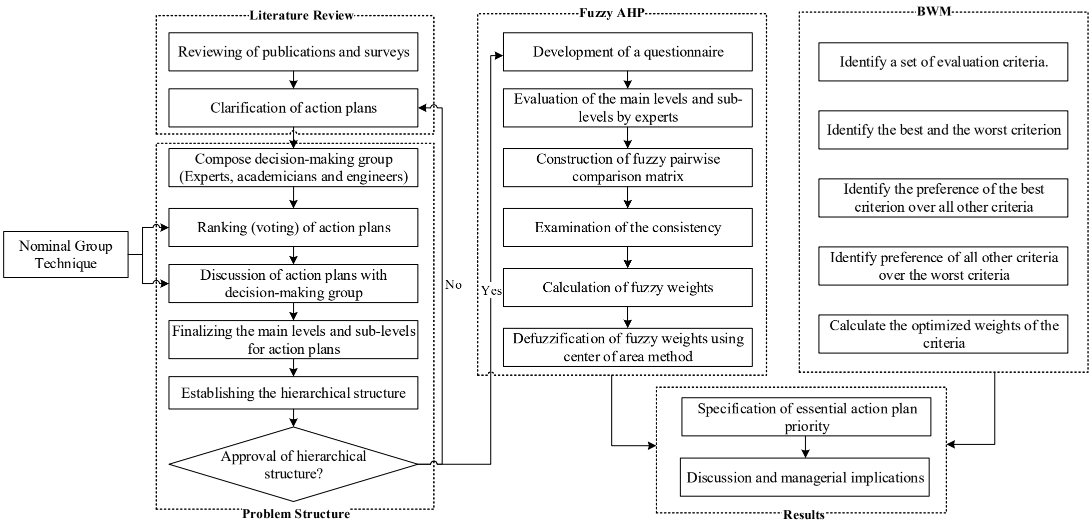


**Figure 1.** A systematic procedure of research for prioritization of the essential action plans.


**Figure 2.** The illustrative map of the study area.

research was established.

Figure 3 shows three dimensions to determine the most important action plan: target, the main criteria, and sub-criteria. The aim of the present study was to prioritize existing action plans. Air quality varies according to the atmospheric concentration of heating, traffic (transportation), and industrial air pollutants. For this reason, in the second dimension, the three dimensions of the criteria (traffic, industry, and heating) were defined and included in the hierarchy. In the next step, the sub-criteria below each main criterion were included. The necessary notions for evaluating the defined main and sub-criteria are described in Table 1.

## Results

### Fuzzy AHP application results

The prioritization of action plans to prevent air pollution was primarily done using the fuzzy AHP approach. Then, data were collected by interviewing experts. A questionnaire was designed to collect data based on the hierarchical structure given in the identification of action plans. Four experts from the NGT were consulted to collect the data. The decision-making group made a pairwise comparison of three main criteria and 17 sub-criteria using the triangular fuzzy numbers given in Table 2. Assessments of decision makers for the main criteria are given in Table 3. Next, the linguistic variables were converted to triangular fuzzy numbers and assessments of the four decision makers were combined for the main criteria, and finally, pairwise comparison matrices and the calculated weights are given in Table 4. Chang (1996) extent analysis method and Buckley (1985) geometric mean method were used to calculate the weights and the results are presented in Table 4. The calculations were performed in computer using MS-Excel.

Similarly, the priorities of the sub-criteria associated with the main criterion were calculated after checking the pairwise comparison matrices and consistency ratios. Table 5 shows the local and global weights of the various sub-criteria associated with the main criteria. The global weights were obtained by multiplying the local weights by the weight of the relevant criteria. For example, for the sub-criteria AP1, the local weight is 1 and for the heating criterion, the local weight is 1, so the overall weight of AP1 is obtained as AP1 = 1× 1 = 1.

According to Tables 5 and 6, it is concluded that among the dimensions of the action plans, the plans for heating have the first priority. The air pollution caused by the heating of cities increases with the start of winter. Heat-induced change is an expensive and important obstacle to air pollution prevention efforts. Industry-borne air pollution received the next highest weight. In addition, pollutants left uncontrollably from the industrial sector, as in many cities, combined with the lack of adequate measures for Konya caused serious air pollution. The increasing number of housing due to urban growth brings traffic density in big cities. However, air pollution action plans were prioritized for heating, industry, and traffic, respectively.

### BWM application results

Before presenting the BWM results, the linear formulation of the BWM is given below:

The optimal weights for the linear model should be determined by minimizing the maximum absolute differences $\{|w_B - a_{Bj}\, w_j|, |w_j - a_{jW}\, w_W|\}$, and the problem can be formulated as follows:

$$\min \max_j \{|w_B - a_{Bj}\, w_j|, |w_j - a_{jW}\, w_W|\}$$
$$\Sigma_j w_j = 1$$

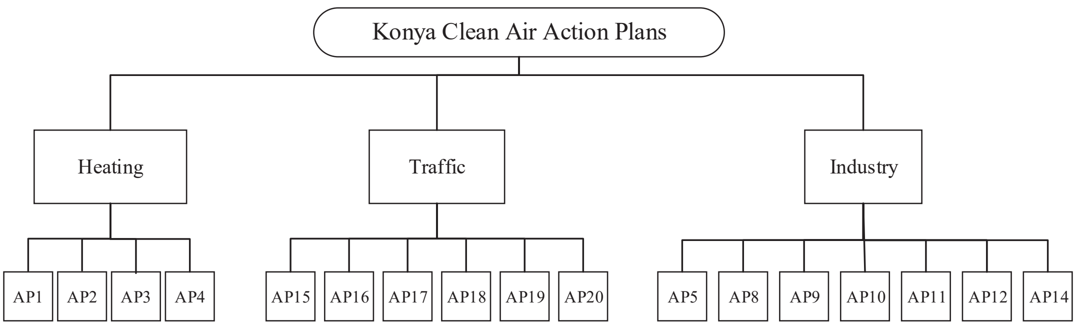


**Figure 3.** Decision hierarchy for prioritizing major action plans for clean air in Konya.

**Table 1.** Description of clean air action plans for prioritization

| Dimensions of Action Plans | Evaluation Criteria | Brief Description |
|---|---|---|
| Heating | AP1. Termination of the use of coal in buildings with central system solid fuels | Reduction of the use of coal with the most important source of PM emissions in residences using the central heating system |
| | AP2. Termination of the use of coal in public buildings | Reduction of the use of coal in all buildings belonging to public institutions and organizations |
| | AP3. Reducing the use of coal in individual heating and promoting the use of alternative clean fuel | The use of alternative energy sources in houses instead of coal |
| | AP4. Promoting and disseminating standards of heat insulation for energy conservation in buildings | Heat insulation according to standards in buildings |
| Traffic | AP15. Instant exhaust emission control for vehicles in traffic | Instant measurements of exhaust emissions of vehicles in traffic using a portable emissions measurement tool |
| | AP16. Preventing the use of oil No.10 for vehicles | Prevention of the use of oil No. 10 that is a generic name for substances consisting of oil waste engines, hydraulic oils, and untreated crude oils, and mostly sold as diesel substitutes in tinplate as a fuel in the vehicles |
| | AP17. Reducing traffic emissions by dissemination and encouragement of public transportation and tramway line between Alaaddin boulevard and a new courthouse | Promotion and dissemination of public transportation |
| | AP18. Encouraging the use of bicycles and new 196 km bicycle route network for safe transport, as well as the expansion of the network of bicycle roads | Dissemination of the use of bicycle routes |
| | AP19. Reducing urban traffic emissions by completing new belt highway road construction | Completion of the construction of a new ring road |
| | AP20. Increasing measurement parameters and establishing meteorological sensors to air quality monitoring stations | Establishment of a metrological sensor in each station by adding various parameters to existing stations for air quality measurements |
| Industry | AP5. Creation of pickup systems to prevent the use of wastes as fuel in industrial sites | Creation of collection systems for industrial wastes in industrial sites where small and medium-sized enterprises are involved |
| | AP8. Termination of coal use in milk production facilities for heating and production-renewal of dust-holding filter technologies | Termination of coal use in milk production facilities and ensuring the use of alternative clean fuels |
| | AP9. Termination of coal use in enterprises active in the foundry industry | Renewal of production and filter technologies of enterprises operating with old technology in casting facilities |
| | AP10. Closed system production of ready-mixed concrete plants | Transition of ready-mixed concrete plants to closed system production |
| | AP11. Closed system production of coal production facilities | Establishment of fully closed system production transition in coal production plants |
| | AP12. Reduction of 50% of emissions arising from quarrying | Ensuring of stone quarries (crushing, screening, and stocking) transitions to closed system production |
| | AP14. Reduction of NOx emissions arising from a cement plant | Reduction of NOx emissions from Konya cement plant |

$w_j \geq 0$ for all $j$ (1)

Model (1) can be transformed into the following problem:

$$\min \xi^L$$
$$|w_B - a_{Bj}\, w_j| \leq \xi^L$$
$$|w_j - a_{jW}\, w_W| \leq \xi^L$$
$$\textstyle\sum_j w_j = 1$$
$$w_j \geq 0 \text{ for all } j \quad (2)$$

By solving problem (2), the optimal weights ($w^*_1$, $w^*_2$, …, $w^*_n$) and consistency index ($\xi^L$) were obtained.

Table 2. Linguistic scales used in pairwise comparison matrices (48)

| Linguistic Variables | Intensity of Importance | Triangular Fuzzy Scale |
|---|---|---|
| Equally important | 1 | (1, 1, 1) |
| Intermediate | 2 | (1, 2, 3) |
| Weakly more important | 3 | (2, 3, 4) |
| Intermediate | 4 | (3, 4, 5) |
| Strongly more important | 5 | (4, 5, 6) |
| Intermediate | 6 | (5, 6, 7) |
| Very strongly more important | 7 | (6, 7, 8) |
| Intermediate | 8 | (7, 8, 9) |
| Absolutely more important | 9 | (9, 9, 9) |

Table 3. Linguistic assessments for the main criteria

| | Heating | Traffic | Industry |
|---|---|---|---|
| Heating | 1, 1, 1, 1 | 5, 8, 9, 8 | 4, 7, 4, 7 |
| Traffic | | 1, 1, 1, 1 | 1.3, 1.3, 1.6, 1.3 |
| Industry | | | 1, 1, 1, 1 |

After determination of the priorities using fuzzy AHP method, a questionnaire was designed. Using a 9-point Likert scale (1: very low to 9: very high), experts expressed their preference of the best criterion over all other criteria and the preference of all other criteria over the worst criterion. The best and worst comparisons for the main criteria are listed in Table 7.

After making a comparison of preferences for the main and sub-criteria, the linear BWM model was solved using Excel. Weights of the main criteria were obtained as shown in Table 8.

The similar procedure was performed to calculate the weights of sub-criteria (Table 9). The following sections discuss the outcome of global action plans, based on the opinions of air pollution experts.

## Discussion

Air pollution in cities is closely related to natural conditions as well as human conditions. Especially, due to population growth and industrialization, the increase in energy consumption and motor vehicle usage plays an increasing role in air pollution. Population increased in Konya's rapid urban population, which was 504,125 in 1927 in the early years of the republic and reached 2,180,149 in 2017. Air quality is reduced due to the increase in air pollution, and

Table 5. Local and global weights for 17 sub-criteria according to Chang's extent analysis method

| Criteria | Sub-criteria | Local Weights | Global Weights | Global Ranking |
|---|---|---|---|---|
| Heating (1) | AP1 | 1 | 1 | 1st |
| | AP2 | 0 | 0 | - |
| | AP3 | 0 | 0 | - |
| | AP4 | 0 | 0 | - |
| Traffic (0) | AP15 | 0 | 0 | - |
| | AP16 | 0.8059 | 0 | - |
| | AP17 | 0.1941 | 0 | - |
| | AP18 | 0 | 0 | - |
| | AP19 | 0 | 0 | - |
| | AP20 | 0 | 0 | - |
| Industry (0) | AP5 | 0.3303 | 0 | - |
| | AP8 | 0.3606 | 0 | - |
| | AP9 | 0 | 0 | - |
| | AP10 | 0 | 0 | - |
| | AP11 | 0 | 0 | - |
| | AP12 | 0 | 0 | - |
| | AP14 | 0.3091 | 0 | - |

air pollution is tried to be eliminated by local, regional, national, and global scale arrangements. In this sense, laws are enacted for cleaner air, various organizations are formed, and economic and educational measures are taken. In this study, prioritization of the action plans was carried out using previous studies on the evaluation and management of air quality within the Konya borders.

The results of Buckley's geometric mean method are discussed in the following stage because Chang's extent analysis method assigns 0 weight to the main and sub-criteria. In Tables 5 and 9, the ranking of the criteria for the main dimension in the evaluation of the action plans was obtained as follows: Heating > Industry > Traffic. In the implementation of the main dimensions of the action plans, it can be concluded that the emissions from heating are predominant. Household space heating is one of the significant natural sources of haze pollution (49,50). Due to the increase in the number of houses, it is clear that the choice of residential heating system and the use of poor quality heating systems are among the most crucial elements in the studies on air pollution reduction. Ruiz-Padillo et al (39) determined variables that had the most

Table 4. Combined pairwise comparison matrix for the main criteria according to the four decision makers

| | Heating | Traffic | Industry | Chang's Weights | Buckley's Weights |
|---|---|---|---|---|---|
| Heating | (1, 1, 1) | (6.4807, 7.3257, 8.1324) | (4.2426, 5.2915, 6.3246) | 1 | 0.7469 |
| Traffic | (0.1230, 0.1365, 0.1543) | (1, 1, 1) | (0.2174, 0.2803, 0.3976) | 0 | 0.0763 |
| Industry | (0.1581, 0.1890, 0.2357) | (2.5149, 3.5676, 4.6007) | (1, 1, 1) | 0 | 0.1958 |

Table 6. Local and global weights for 17 sub-criteria according to Buckley's geometric mean method

| Criteria | Sub-criteria | Local Weights | Global Weights | Global Ranking |
|---|---|---|---|---|
| Heating (0.7330) | AP1 | 0.4579 | 0.3356 | 1st |
| | AP2 | 0.0925 | 0.0678 | 4th |
| | AP3 | 0.3503 | 0.2568 | 2nd |
| | AP4 | 0.0993 | 0.0728 | 3rd |
| Traffic (0.0748) | AP15 | 0.1676 | 0.0125 | 12th |
| | AP16 | 0.3935 | 0.0294 | 8th |
| | AP17 | 0.2057 | 0.0154 | 11th |
| | AP18 | 0.0828 | 0.0062 | 16th |
| | AP19 | 0.0908 | 0.0068 | 15th |
| | AP20 | 0.0595 | 0.0045 | 17th |
| Industry (0.1921) | AP5 | 0.2401 | 0.0461 | 6th |
| | AP8 | 0.2475 | 0.0475 | 5th |
| | AP9 | 0.0572 | 0.0110 | 13th |
| | AP10 | 0.0902 | 0.0173 | 10th |
| | AP11 | 0.0543 | 0.0104 | 14th |
| | AP12 | 0.0912 | 0.0175 | 9th |
| | AP14 | 0.2195 | 0.0422 | 7th |

significant impact on the population as the variables with the highest weight. Likewise, heating dimension plays an important role on the population. There are four sub-criteria in this group. Among these sub-criteria, AP1 achieved the highest rating. According to Şehircilik Bakanlığı (51), among residents who use coal for heating in Konya, 87% use individual heating systems (stove) and 13% use central heating systems. Within the framework of the action plans, 100% of the buildings, which were heated by coal, have switched to natural gas usage. Thus, about 10-13% reduction have been achieved in the residential heating category. Similarly, government of China aimed to decrease the concentration of particulate matters at least 10% nationwide (51). The AP3 sub-criterion is listed after AP1. The use of coal in individual heating system, the poor quality of the fuels, etc, became the most basic causes of air pollution in Konya, especially in winter. Compared to other seasons, $PM_{2.5}$ concentrations are higher in winter due to uncontrolled coal consumption in Northern China (52). In this sense, while the use of coal is high in Konya, the tendency towards the use of clean energy sources have attracted attention recently. The AP4 sub-criterion was ranked in the third place in the heating dimension. Kiewchaum et al stated that increasing efficiency of electricity consumption in building plays an important role in reducing greenhouse gas emissions in Bangkok, Thailand (43). Therefore, the thermal insulation in accordance with the standards in the buildings causes less emissions due to less fuel usage. Finally, the last dimension is the AP2 criterion. The use of alternative clean fuel will reduce the emissions when coal, liquid fuel,

Table 8. Weights of the main criteria obtained using BWM

| Experts | Heating | Traffic | Industry | Consistency (ξ) |
|---|---|---|---|---|
| 1 | 0.740 | 0.091 | 0.169 | 0.104 |
| 2 | 0.787 | 0.083 | 0.130 | 0.120 |
| 3 | 0.719 | 0.063 | 0.219 | 0.156 |
| 4 | 0.787 | 0.083 | 0.130 | 0.120 |
| Average | 0.758 | 0.080 | 0.162 | |

Table 9. Weights of all criteria obtained using BWM

| Criteria | Sub-criteria | Local Weights | Global Weights | Global Ranking |
|---|---|---|---|---|
| Heating (0.7330) | AP1 | 0.3404 | 0.2581 | 2nd |
| | AP2 | 0.1340 | 0.1016 | 3rd |
| | AP3 | 0.4338 | 0.3289 | 1st |
| | AP4 | 0.0918 | 0.0696 | 4th |
| Traffic (0.0748) | AP15 | 0.1481 | 0.0119 | 11th |
| | AP16 | 0.3787 | 0.0303 | 8th |
| | AP17 | 0.1210 | 0.0097 | 15th |
| | AP18 | 0.0770 | 0.0062 | 17th |
| | AP19 | 0.1370 | 0.0110 | 13th |
| | AP20 | 0.1381 | 0.0110 | 12th |
| Industry (0.1921) | AP5 | 0.2610 | 0.0422 | 5th |
| | AP8 | 0.2279 | 0.0369 | 6th |
| | AP9 | 0.0476 | 0.0077 | 16th |
| | AP10 | 0.0793 | 0.0128 | 10th |
| | AP11 | 0.0677 | 0.0109 | 14th |
| | AP12 | 0.1204 | 0.0195 | 9th |
| | AP14 | 0.1961 | 0.0317 | 7th |

Table 7. Comparison results reported by the experts

| Experts | Best | Criteria | | | Worst | Criteria | | |
|---|---|---|---|---|---|---|---|---|
| | | Heating | Traffic | Industry | | Heating | Traffic | Industry |
| 1 | Heating | 1 | 7 | 5 | Traffic | 7 | 1 | 3 |
| 2 | Heating | 1 | 9 | 7 | Traffic | 8 | 1 | 3 |
| 3 | Heating | 1 | 9 | 4 | Traffic | 9 | 1 | 6 |
| 4 | Heating | 1 | 8 | 7 | Traffic | 8 | 1 | 3 |

natural gas, and electricity are being used for heating in public buildings.

Wrong site selection in the establishment of industrial facilities, not taking the necessary precautions in terms of environmental protection (chimney filtration, no treatment plant, etc), not use of appropriate technologies, the use of high-sulfur fuels in energy-generating units are among the factors causing air pollution. In terms of the industry dimension, AP8 is the most important sub-criterion for this dimension. While 12 dairy production facilities were using coal for the production and heating in 2012, within the framework of the action plans, the studies on the system conversion were completed and the use of coal in the production was terminated during winter. Due to the fact that in the distribution of industrial emissions, milk production facilities have 30% of their capacity and insufficiently dust-holding systems at emission points lead to very high emissions within industrial pollutants, this rate is reduced by the action plans. The AP5 sub-criterion owned the second rank. While the industrial wastes cause air pollution from the enterprises operating in the industrial zones where the small and medium-sized enterprises are located in the residential area of Konya, this effect is reduced by creating collection systems for industrial wastes. According to Li et al, incentives to accelerate structural adjustment should be increased. The next sub-criterion is AP14 (53). It is a fact that nitrogen oxide (NOx) and sulfur dioxide (SOx) gases from the cement plant not only influence air pollution but also the human health. Within the industrial emissions of the cement plant, the industry is the main source of pollutants. The other criteria were listed as AP12 > AP10 > AP9 > AP11.

Traffic dimension ranked in the third place. Along with population growth and rising income levels, exhaust gases from motor vehicles, which are rapidly increasing in number, are an important factor in air pollution. There are 6 sub-criteria in this dimension. However, according to the sub-criteria in the heating and industry, the weights of the sub-criteria in this dimension were low. Among the sub-criteria, the AP16 sub-criterion had the highest priority with a weight of 0.0294. Due to its low cost in vehicles other than its intended use in recent years, the use of fuel oil No. 10 leads to serious health problems with increasing traffic-related pollutants. In recent years, except for the purpose of use, vehicles have used oil No. 10 because of low cost, leading to serious health problems by increasing traffic-related pollutants. Especially in Konya, the oil No. 10, which is used more than other cities, causes not only air pollution but also serious health problems. The traffic load in the city center, which is one of the important tourism and trading region of the city, is located in the Mevlana region. The AP17 sub-criterion ranked in the second place in this dimension due to the promotion and dissemination of public transportation and the reduction of traffic loads and traffic emissions.

According to the results, there is no significant difference in the priority ranking results. The results of the fuzzy AHP and BWM are very similar. For example, heating criterion has the best performance in both methods in the evaluation of the decision makers. In parallel, the main and sub-criteria with the lowest priority are the same in both methods. However, the ranking of sub-criteria can be changed according to the methods. For example, the sub-criteria of AP5 is the sixth best in the fuzzy AHP, while it is the fifth one in the BWM.

The present study makes the following contributions to the literature:

- Although there are some studies about prioritization of energy and noise action plans, clean air action plans were discussed for the first time according to the author's knowledge.
- A comprehensive list of criteria including qualitative and quantitative criteria was defined.
- An MCDM framework that deals with fuzzy AHP and BWM, was developed for prioritizing the air action problem.
- The ranking of the prioritization of action plans was discussed taking into account both uncertain conditions and precise evaluations.
- The proposed framework and identified action plans were implemented in Konya in a real case study to address the prioritization process.

As anywhere in the world, air pollution in Turkey is a big global concern and governments must improve air quality in the cities to protect human health. In order to prioritize the action plans for improving air quality in Konya, a methodology was proposed in this study. Some of the key obstacles that can be faced in the implementation of the action plans are summarized here:

- Lack of management in both public and industrial organizations
- Insufficient financial resources in industrial enterprises
- Lack of human resources
- Lack of coordination between ministries and municipalities related to air pollution reduction
- The inadequate infrastructure for air pollution and transformation
- Lack of new technology, materials, and processes
- Education and culture weaknesses
- Lack of public participation programs to reduce air pollution
- Using old technology and diesel-fueled vehicles

## Conclusion

In order to control air pollution, which is becoming more evident by industrialization and increasing ineffectiveness, legal arrangements have been made primarily in the industrialized countries and various action plans have emerged. To evaluate the impact of sustainable development of cities on the sustainability of current policies and practices in the context of information on environmental, economic, and social conditions of cities. For sustainable cities, the policies need to be defined and transformed into actions. A quantitative approach is needed to determine the policies that will achieve the purpose of urban sustainability. In this context, studies have been made relating to the assessment and management of air quality in the city of Konya, Turkey. For this reason, a systematic evaluation system for emission reduction and classification according to the priority ranking is required under air action plans.

The definition of priority plans for the implementation of action plans is complicated by the inclusion of different characteristics. This study presented a framework for investigating these complex elements, making tasks for managers' decisions easier, and prioritizing action plans. This initiative was achieved through the identification of action plans based on the literature, legal regulations, and perspectives of environmental experts. Then, the decision-making team gave priority to linguistic evaluations to provide the criteria. The fuzzy AHP and BWM methods were used to evaluate the relative importance weights of the action plan criteria.

Konya Metropolitan Municipality and Provincial Directorate of Environment and Urbanization carried out the works between 2013-2019, and the action plans for the proposed framework were addressed. Finally, 20 action plans determined as a result of the work, were first narrowed down to the NGT and the number of action plans to be included in the evaluations was reduced to 17. Then, the fuzzy AHP and BWM methods were applied to determine the priorities. Heating dimension was considered as the most important variable for each method. AP1 and AP3 sub-criteria, which are the plans for reducing coal use, were at the forefront in reducing air pollution. The main source of air pollution is the fossil fuels used for heating purposes.

## Limitations

One of the limitations of this work was employment of unqualified specialists to carry out the decision-making process, which can be solved by employing qualified specialists to perform the process. Another limitation is that experts gave inconsistent opinions during the evaluation process, which led to the prolongation of the study period. In future studies, other decision-making methods can be used to prioritize action plans and these results would be compared with the present study. Also, other dimensions of the problem, such as necessary resources for the implementation of the action plan, time for the implementation, adaptation with the regulations, etc, can be considered in the future studies.

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## Competing interests

The author declares that he has no competing interests.

## Ethical issues

The author certify that all data collected during the study are as stated in the manuscript, and no data from the study has been or will be published separately elsewhere.

## Authors' contributions

AC is the single author of the paper.

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