

Analysis of the effects of the first phase of COVID-19 pandemic on mobility choices in Italy by a multi-criteria approach

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ABSTRACT: COVID-19 pandemic has caused changes in logistics and mobility. Concerning Italian road mobility, between March and April 2020, there has been a reduction in traffic for both light vehicles and heavy goods vehicles. Italy was the first European country to implement a total lockdown, starting on March 9th, causing a deep contraction in road traffic. This paper explores the main differences in mobility choices before and after the COVID-19 pandemic in 2020. A multi-criteria decision-making method was selected for the analysis of questionnaire survey data. The fuzzy Analytic Hierarchy Process was applied, considering eight mobility types: bus, tram, taxi, train, shared vehicles, multiple modes, walking and car. An evaluation process was adopted for the modal mobility choices of the residents of Sicily, Italy. The results show a significant decline in

mobility demand during the first phase of the pandemic, especially in public transport mode. The findings provide a deeper understanding of the need to implement strategies to respect the constraints generated by the pandemic and revive the penalised transport and mobility-related sectors. Furthermore, the study's findings provide valuable insights for the policymakers, both national and local, about the mobility results of the lockdown and can be used as a forecast benchmark for planning the restrictions in the future, in case of another unexpected phenomenon, e.g., pandemic.

KEYWORDS: Mobility patterns; Sustainable mobility; Analytic Hierarchy Process; Fuzzy set; COVID-19.

1. INTRODUCTION

Over the last twenty years, the evolution of sustainable mobility has focused mainly on reducing the traffic of private vehicles and promoting integrated transport systems (Bieliński et al., 2019; Canale et al., 2019; Serafimova, 2020; Szmelter, 2018). However, pandemic events have distorted the need for users to move and caused a reduction or cancellation of movements, especially in medium and long-distance travel. Moreover, the COVID-19 pandemic has caused significant damage to the financial, economic, and social sectors (Gössling et al., 2020). In this context, the transport sector has found itself in a difficult situation, dealing with changes in mobility needs in the post-COVID-19 scenario.

As the first location with many registered infections, China has pioneered a series of measures adopted in the transport sector to curb the spread of the virus, ensuring the transport of goods and limiting the movement of people as much as possible. In addition, several other countries have adopted a series of measures to reduce human movements (Zhou et al., 2020). In Europe, the first death attributed to COVID-19 was registered in the Lombardy region, Italy. After a few weeks, the whole nation was declared to be in the red zone (Murgante et al., 2020). It resulted in the obligation to lockdown (Engle et al., 2020) and significantly reduced people's travel. This has led to the collapse of several companies in public and shared transport (De Vos, 2020). Furthermore, the implementation of obligatory interpersonal distance immediately caused a reduction in the capacity of public transport (PT) and the population's relative mistrust of vehicles. This could

potentially increase car use by many people who previously used PT (Borgomeo, 2020).

On May 4th, 2020, the Italian government began the so-called "Phase 2" of restrictions, characterised by a strategy based on the progressive removal of prohibitions on travel and reopening of some production activities and services. In small urban areas, operators of collective transport services derive their profit from maximising the degree of service coverage, discouraging the use of private vehicles, promoting vehicles with a limited number of seats, or encouraging transport on demand. Therefore, adopting effective and structural measures such as constant sanitisation activities, counting incoming/outgoing users, and controlling vehicles through intelligent transport system (ITS) solutions is essential for encouraging road users to use these services (Zhou et al., 2020).

The facts mentioned above encouraged the authors to examine the mobility changes in Italy by continuing their previously made analysis of "fresh" pandemic effects in mobility in Italy (Moslem et al., 2020). Therefore, this paper investigates the main differences in mobility choices regarding the state-of-the-art review before and during the pandemic and survey results. The additional objective of the study is to identify uncertainties by comparing AHP and F-AHP (fuzzy AHP) methods to establish a better method of multi-criteria analysis for similar studies.

The structure of the paper was subordinated to the purpose of the research. The second section is dedicated to analyse the impacts of the COVID-19 pandemic on the mobility choices before and during the pandemic, reporting national statistical data, especially for collective mobility in the first

pandemic phase. The third section describes the survey and reviews the application of Multiple-Criteria Decision Making (MCDM) methods in the transport sector. The fourth section presents the results. Finally, the last section discusses the findings, proposes the subsequent investigation steps, and concludes the work by showing the elements of the strategy implemented to improve mobility management in the analysed region (Sicily).

2. BACKGROUND

The recent pandemic has brought about numerous changes in daily life habits, particularly in travel patterns and frequency. The first outbreak of COVID-19 in Italy started in the second half of February 2020 in some areas in the country's north.

In Italy, from March 2020 to October 2020, there were three different phases of the pandemic, namely:

- the first phase from March to May 2020, characterised by a long period of containment and the definition of the whole of Italy as a red zone,
- the second phase of reduced containment and decrease of COVID-19 cases from the end of May to the end of August 2020,
- the third phase - resumption of the number of infections from September 2020 to November 2020 with the definition of yellow, orange, and red areas for each region and, therefore, different restrictions implemented.

The high contagiousness of the virus meant that within a few weeks, Italy became the country with the highest number of infected people worldwide. Many severe cases among infected people in Italy led to the hospitalisation of thousands of patients, placing a heavy burden on the national health service.

In addition to the health sector, the transport sector has also had to deal with numerous critical issues.

Studies about the changes in transport demand in Italy confirm the significant changes in mobility (Galeazzi et al., 2020; Giannotti et al., 2020; Pepe et al., 2020).

Using PT decreased the most for obvious reasons (lockdown, restrictions, social distancing, remote work, and learning), while car travel was more resistant to limitations. However, mobility generally declined everywhere during the most strict lockdown phase (Dahlberg et al., 2020). It influenced long- (Iacus et al., 2020) and short-distance travel (Tsai et al., 2011). The available data about mobility in Italy during the COVID-19 pandemic is limited because of mostly biased mo-

bile phone datasets (Aktay et al., 2020). Limited mobility was confirmed in other European countries for a similar period (Aloi et al., 2020; Borkowski et al., 2021; Ebrahim et al., 2020; Meier et al., 2020).

In Italy, between March 4th and April 4th (first wave, analysed in this study), 2020, there was a drop in travel of more than 90% regarding people, while the transport of goods was guaranteed, albeit with restrictions. The reduction in transport demand was connected to the limitation of movement, remote work, and the closure of shopping centres and places of worship. Each region also did not allow people to travel from other regions to the area (De Girolamo, 2020).

Considering the Public Transportation (PT) system, several companies were unable to provide services and had to adapt to the restrictions, guaranteeing distance between individuals and continuous sanitisation. In addition, people suffered from the psychological and emotional stress that increased the fear of contagion in confined spaces such as buses and trains (Panchal et al., 2020). Therefore, service managers and local authorities will have to overcome those issues by focusing on different strategies in the future. The variation in the use of Public Transportation (PT) in Italy is shown in Figure 1, where three sample cities in the northern (Milan), central (Rome), and southern (Palermo) areas of Italy are compared. It is clear that the use of Public Transportation (PT) dropped sharply after March 4th, when the spread of red areas and the lockdown were declared.

The drop in the Public Transportation (PT) data between February 26th and March 10th is explained by the presence of the first contagions in Italy and the lockdown period (Pepe et al., 2020). The impact of the pandemic on the short-term vehicle rental sector was strong. In Milan, the contraction began to manifest itself in the last week of February, with a drop of 26% compared to the same period a year before. Two months later, it was approximately 90% (year-to-year) - in April 2019, users made about 16 thousand trips per day in Milan, in April 2020, only ca. 1800 (Piemontese, 2020). Before the first phase of the COVID-19 pandemic, approximately 92% of road users in Palermo, 83.9% in Rome, and 77.5% in Milan had never used micro-mobility (i.e., small electric vehicles such as scooters, single wheelers, and hoverboards). The main reason for these high percentages of non-use in Milan and Palermo is the lower amount and length of cycle path infrastructure, while the reason for Rome is the precarious maintenance conditions of the roads. However, car-sharing became necessary before COVID-19 in many cities, including Milan or Rome (Guglielmetti Mugion et al., 2019; Rotaris et al., 2019). The latest data available at the national level are for 2019 and presented by the research agency ANIASA (ANIASA, 2020).

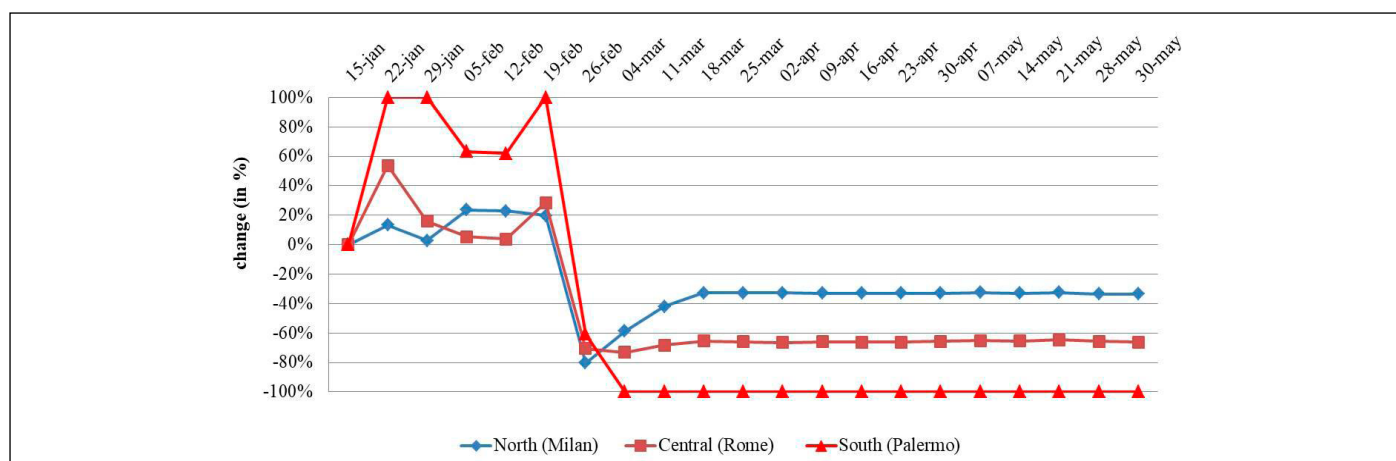


Figure 1. The public transport (PT) trend in Italy in 2020 before and after COVID-19

Source: own elaboration using the software Moovitapp.

However, the infrastructure for sustainable travel modes (PT, car-sharing, bike-sharing, other short-term vehicle rentals) should be supported financially (Basbas et al., 2020) because they provide safe and efficient mobility in urban areas (Campisi, Tibljaš, et al., 2020; Campisi, Torrisi, et al., 2020). Those actions will allow various cities to avoid traffic congestion and slowly return to regular operation. Nevertheless, some shared, or public mobility forms might stay more popular after the pandemic than before (DPCM, 2020).

The transport scenarios suggest critical issues during and after the COVID-19 pandemic. First, there is uncertainty about travel demand in the future because of the possible spread of the virus (Bargain & Aminjonov, 2020; Renaud, 2020).

Second, there is a need to review transport systems' efficiency and adequacy indicators to calibrate them on new mobility needs (i.e., traffic performance score and ISO standards) (Cui et al., 2020; Tirachini & Cats, 2020). Third, an insufficient number of vehicles are available to offer a transport service with a sufficient, high capacity/frequency and a low degree of assembly (Vazifeh et al., 2018). Fourth, there is a deficit between operating and maintenance costs and revenues (Fahnenbrach et al., 2020). Regarding these considerations, the collective transport service can be revisited by abandoning traditional schemes and veering towards an on-demand business model with services activated according to users' booking requests. Furthermore, PT system could be reorganised according to alternative delivery models such as adaptive or flexible models, whereby all daily transport services are performed concerning the requests of road users. The recent solutions used in mobility are apps for self-booking (Meyer et al., 2017), e-ticketing (Schäfer et al., 2017), automatic validation

systems for travel tickets, automatic systems for counting a load of users onboard or for authorising entry to stations at holders of travel tickets, and intelligent video surveillance systems to monitor passengers and avoid gatherings inside the station premises. The collective transport providers offer some of the technologies and applications that have been available for long-distance air and rail transport, with the necessary customisations. In order to be able to evaluate possible solutions to reduce critical issues related to transport systems before and after COVID-19, it is essential to analyse the different criteria that have led to changes in transport choices, also considering the period during the pandemic. This is possible by using multi-criteria evaluation.

3. METHODOLOGY

3.1. Data collection

The primary data source was the online survey (see Table 1) disseminated through social media (i.e., Facebook) between March 20th and April 20th, 2020.

The data-gathering period was so narrow to catch the fresh effects of lockdown in Sicily.

The variables investigated in the questionnaire were classified in three sections (see Table 1):

- socio-demographic variables,
- mobility choices before COVID-19
- mobility choices during the 1st phase of COVID-19.

The Sicily region (see Figure 2) was selected for the examination for two reasons – firstly, since it has the fourth highest

Category	1st section socio-demographic data			2nd section mobility choice before the pandemic		3rd section mobility choice during 1st phase of the pandemic	
Variables	Gender	Age	Residential location	Mobility choices		Mobility choices	
Possible replies	Male	18-25	Palermo	Bus	Crisp Number 1-9	Bus	Crisp Number 1-9
		26-40	Catania	Tram		Tram	
			Messina	Taxi		Taxi	
			41-55	Enna		Train	
		Caltanissetta		Sharing mobility		Sharing mobility	
		Female	56-70	Ragusa		Multiple modes	
	Siracusa			Walk		Walk	
	>70		Agrigento			Car	
			Trapani				

Table 1. The variables on the implemented survey

Source: own elaboration.

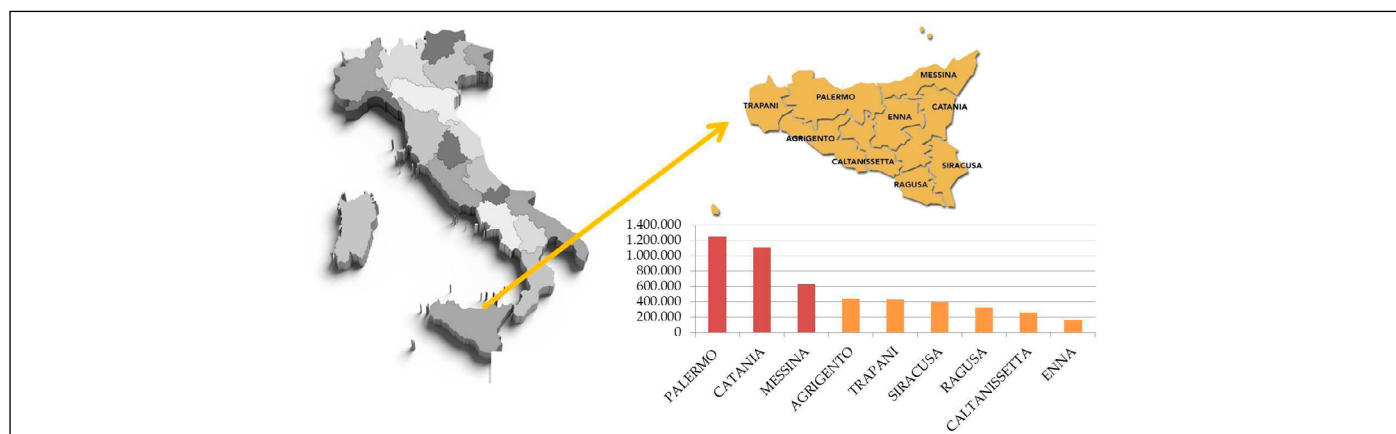


Figure 2. Monitored area geo-location and residents' distribution for each province.

Source: own elaboration.

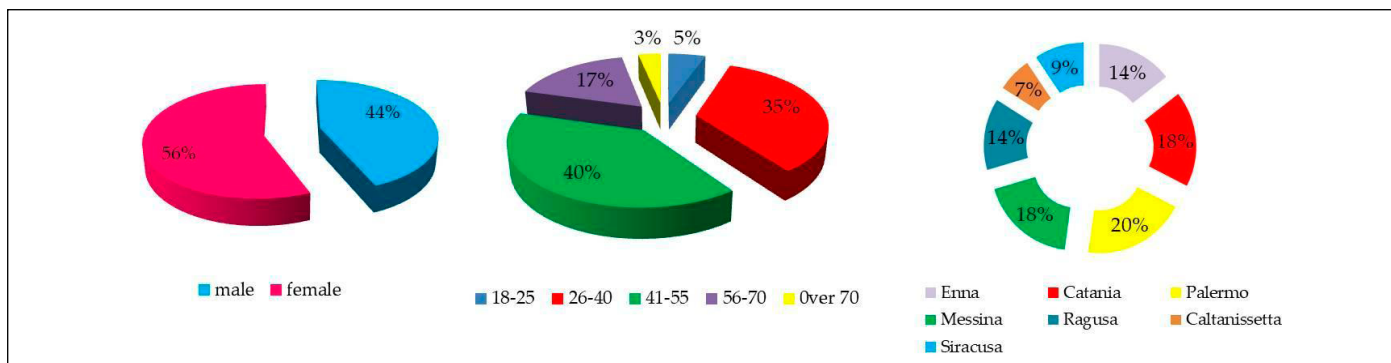


Figure 3. Statistical socio-demographic variables and sample distribution.
Source: own elaboration.

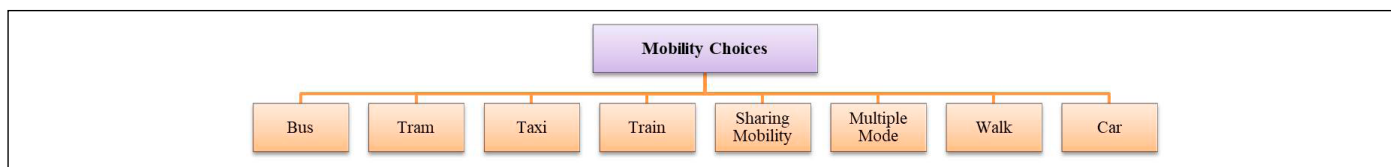


Figure 4. Mobility choices.
Source: own elaboration.

population in Italy, and secondly - it was the territory where a rapid spread of the COVID-19 pandemic occurred due to the movements of many users from northern Italy.

The analysed region is inhabited by 5 million people and records a strong fluctuation of commuters and tourists. About 51,4% of the Sicilian population are women. In terms of age, the largest percentage of residents are aged 45-75. The biggest municipality is Palermo, with 647,000 residents. In addition, about 91,000 have been buffered and the pandemic has caused about 2,200 sick people since its inception until May 2020. About 80% of the major cities were contacted and invited to fill out the questionnaire.

The survey was conducted with 900 individuals and it was made up of 56% women and 44% men, as indicated in Figure 3. The respondents' sample and population gender distribution were similar and allowed for reliable analysis in this regard. The age group that registered the highest percentage is between 41 and 55 years (about 40%), while the 18-25 and >70 age groups registered an equal value of 7%. Thus, the age structure of the sample in this regard corresponds with the structure of the residents.

All the modes of transport proposed in the survey are those used in Sicily (see Figure 4), even if not uniformly distributed among the provinces; in fact, the tram is used only in Palermo and Messina instead of the subway only in Catania. All cities are characterised by car-sharing managed by private companies with station-based or free-floating systems.

Furthermore, bike-sharing covers 70% of the analysed cities. Extra-urban and regional connections are also guaranteed by trains and buses.

3.2. Data analysis

Multiple Criteria Decision Making (MCDM) belongs to the group of operational research techniques. In general, the multi-criteria analysis highlights all the information, consequences, and perspectives linked to a possible choice of the pre-established criteria (multidimensionality)(Shang et al., 2004).

The MCDM methodology identifies the prominent participants in the decision-making process, namely the decision-maker (D.M.), analyst, and other entities interested in solving a specific decision problem. The decision (individual or collective) determines the objectives of the decision-making

process, expresses preferences, and finally evaluates the solutions as described in Figure 5.

In the literature, several studies about social sciences (Mardani et al.(2016) and mobility have included the use of an MCDM analysis. In general, the choice of the most suitable methodology to be applied depends on several factors, including, for example, the number of options/choices to be considered in decision-making (Echaniz et al., 2019, Nassereddine & Eskandari, 2017). In the public transport sector, several types of research have focused on the application of multi-criteria models, such as the Delphi method, the ordered logit model, and the Best-Worst method (BWM) (Echaniz et al., 2019; Mendoza-Arango et al., 2020), the group analytic hierarchy process (GAHP), the preference ranking organisation method for rating enrichment (PROMETHEE) (Nassereddine & Eskandari, 2017) and many others (Mardani et al., 2016; Moslem et al., 2019). This allows studying the influence of criteria weights on the final decision (Nassereddine & Eskandari, 2017).

Multi-Criteria Decision Making methods have been adopted in several studies to solve transport problems, for example, the analysis of the public transport system (Campisi et al., 2020; Gündoğdu et al., 2021) but also in the area of shared mobility, such as car-sharing (Qu et al., 2017) or bike-sharing (Kabak et al., 2018). AHP and F-AHP have also been used in sustainable urban logistics (Alkharabsheh et al., 2019) for urban transport users (Duleba & Moslem, 2019), in urban logistics stakeholder analysis (Moslem et al., 2020), in urban road networks (Nosal & Solecka, 2014) and many others.

To summarise, AHP and F-AHP can be considered as widely used in transport research, including the study of changes in people's mobility. Following the study conducted by Moslem et al., 2019, the present work focused on applying the Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (F-AHP). By comparing these two models, it was possible to measure the consistency of the results obtained compared to the other methods listed above.

3.3 Analytic Hierarchy Process

AHP has been the most often used MCDM methodology to solve complex decision problems with multiple criteria and/or alternatives (Cieplińska & Szmelter-Jarosz, 2020; Rześny-

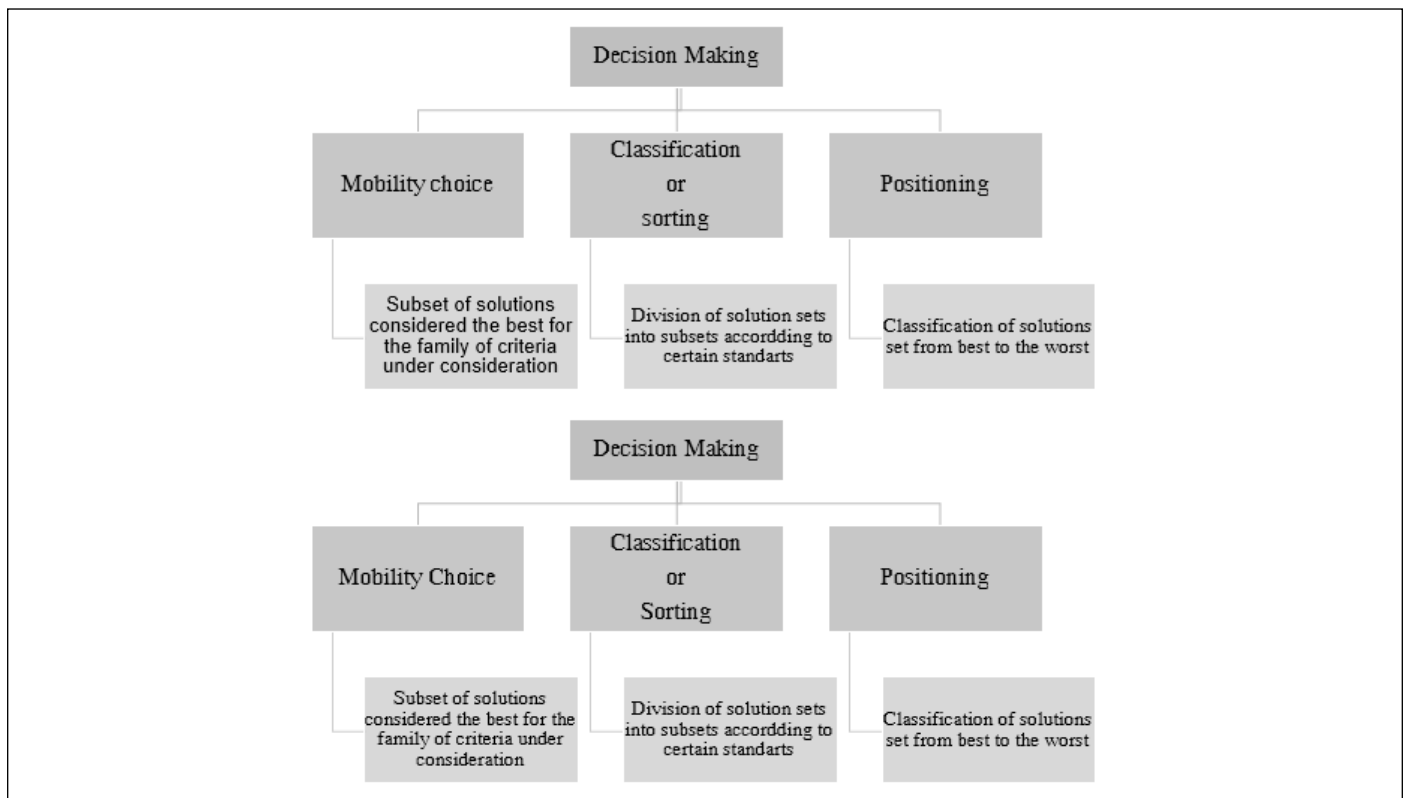


Figure 5. Multicriteria decision-making approach in this study
Source: own elaboration.

Cieplińska & Szmelter-Jarosz, 2019). However, for mobility choices, there are no examples for applying AHP and only one (to the best of our knowledge) for an MCDM technique (Duleba et al, 2021), namely the Best-Worst Method (BWM). BWM can be considered as an incomplete AHP, in which the complete pairwise comparisons are reduced and restricted to the relations of each criterion to the best and the worst criterion or alternative. In particular, AHP allows prioritising a series of decision alternatives, linking qualitative and quantitative assessments, which would otherwise not be directly comparable, and combining multidimensional scales of measures into a single priority scale (Echaniz et al., 2019). The AHP method is based on a series of pairwise comparisons of the criteria with a relative importance score and ends with assigning a percentage weight. The essential steps of the AHP method, which help to make a decision in a suitable way to provide priorities for criteria and alternatives, are as follows: defining the decision problem; setting up the hierarchy structure of the problem; constructing the pairwise comparison matrices based on the created hierarchy structure; exploring the consistency for each pairwise comparison matrix; generating the weight scores of the criteria and the alternatives, and conducting the sensitivity analysis on the final results. It was suggested by Kabak et al. (2018) that the scale of crisp numbers from 1 to 9 should be applied according to the classical approach (Site & Filippi, 2009) in order to conduct the comparisons (see Table 2).

Number	Scale
1	Equal importance
3	Slight importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between adjacent scale values

Table 2. The comparison scale of crisp numbers from 1 to 9
Source: (Ghorbanzadeh et al., 2018).

3.4 Fuzzy Analytic Hierarchy Process (F-AHP)

The subjective judgement and evaluation of the specific relations in the pairwise comparisons in conventional AHP critically influence the priorities of criteria and alternatives. If the evaluation process is improper, that will lead to bad, incorrect outcomes. In the case of laypeople evaluator involvement, the uncertainty of the judgement is increased, and in these situations, it has to be considered in the decision-making process. The AHP in the fuzzy environment was adopted to solve several real-world transport problems (Duleba & Moslem, 2019; Moslem et al., 2019), and due to the reasons mentioned above, it is suggested that the relative importance of the alternatives be measured in the hierarchical structure with the help of the fuzzy scale in order to overcome the pitfalls of problem-solving in the conventional AHP (Moslem et al., 2020). In fuzzy logic, we propose that the evaluators could provide approximate scale numbers in the pairwise comparisons, but the change in values is so slight that, without proper expertise, the given priority could be untrustworthy. The proposed fuzzy sets in this study were implemented by Nosal & Solecka (2014) and Singh et al. (2020). Thus, a questionnaire survey was constructed based on the fuzzy logic with the fuzzy triangular numbers, and the outcomes were determined.

Fuzzy number \tilde{M} on the set of real numbers R is a triangular fuzzy number if its membership function has the mapping $\mu_{\tilde{M}}(x): R \rightarrow [0, 1]$, and it is defined by

$$(1) \quad \mu_{\tilde{M}}(x) = \begin{cases} \frac{x-l}{k-l}, & l \leq x \leq k \\ \frac{d-x}{d-k}, & k \leq x \leq d \\ 0, & \text{otherwise} \end{cases}$$

where l and d are the lower and upper limits of the fuzzy number \tilde{M} , and k is the modal value for \tilde{M} .

The triangular fuzzy number (TFN) can be denoted by $\tilde{M} = (l, k, d)$. The operational laws of the triangular fuzzy number are $\tilde{M}_1 = (l_1, k_1, d_1)$ and $\tilde{M}_2 = (l_2, k_2, d_2)$.

Addition of the fuzzy number \oplus :

$$(2) \quad \tilde{M}_1 \oplus \tilde{M}_2 = (l_1, k_1, d_1) \oplus (l_2, k_2, d_2) = (l_1 + l_2, k_1 + k_2, d_1 + d_2)$$

Multiplication of the fuzzy number \oplus :

$$(3) \tilde{M}_1 \otimes \tilde{M}_2 = (l_1, k_1, d_1) \otimes (l_2, k_2, d_2) = (l_1 l_2, k_1 k_2, d_1 d_2) \text{ for } l_1, l_2 > 0; k_1, k_2 > 0; d_1 d_2 > 0$$

Subtraction of the fuzzy number \ominus :

$$(4) \tilde{M}_1 \ominus \tilde{M}_2 = (l_1, k_1, d_1) \ominus (l_2, k_2, d_2) = (l_1 - d_2, k_1 - k_2, d_1 - l_2)$$

Division of the fuzzy number \oslash :

$$(5) \tilde{M}_1 \oslash \tilde{M}_2 = (l_1, k_1, d_1) \oslash (l_2, k_2, d_2) = \left(\frac{l_1}{d_2}, \frac{k_1}{k_2}, \frac{d_1}{l_2}\right) \text{ for } l_1, l_2 > 0; k_1, k_2 > 0; d_1 d_2 > 0$$

Reciprocal of the fuzzy number:

$$(6) \tilde{M}^{-1} = (l_1, k_1, d_1)^{-1} = \left(\frac{1}{d_1}, \frac{1}{k_1}, \frac{1}{l_1}\right) \text{ for } l_1, l_2 > 0; k_1, k_2 > 0; d_1 d_2 > 0$$

In this study, the calculations are based on the fuzzy numbers defined by Moslem et al. (2020) and Moslem and Duleba (2019) and presented in Table 3.

Fuzzy numbers	Linguistic scale	Fuzzy number scale
9	Perfect	(8, 9, 10)
8	Absolute	(7, 8, 9)
7	Very good	(6, 7, 8)
6	Fairly good	(5, 6, 7)
5	Good	(4, 5, 6)
4	Preferable	(3, 4, 5)
3	Not bad	(2, 3, 4)
2	Weak advantage	(1, 2, 3)
1	Equal	(1, 1, 1)

Table 3. Fuzzy numbers, linguistic scale and fuzzy number scale
Source: own elaboration.

The employed pairwise comparison matrix was constructed based on the mobility type alternatives. Linguistic terms were assigned to the pairwise comparisons by asking which criterion is more significant than the other, and has the following form:

$$(7) \tilde{M} = [1 \tilde{a}_{12} \tilde{a}_{21} 1 \cdots \tilde{a}_{17} \tilde{a}_{18} \tilde{a}_{27} \tilde{a}_{28} \cdots \tilde{a}_{71} \tilde{a}_{72} \tilde{a}_{81} \tilde{a}_{82} \cdots 1 \tilde{a}_{78} \tilde{a}_{87} 1] = [1 \tilde{a}_{12} 1 / \tilde{a}_{12} 1 \cdots \tilde{a}_{17} \tilde{a}_{18} \tilde{a}_{27} \tilde{a}_{28} \cdots 1 / \tilde{a}_{17} 1 / \tilde{a}_{27} 1 / \tilde{a}_{18} 1 / \tilde{a}_{28} \cdots 1 \tilde{a}_{78} 1 / \tilde{a}_{78} 1]$$

where the fuzzy comparison value of dimension i to alternative j is:

$$\tilde{a}_{ij} = \{\tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, \tilde{3}^{-1}, \tilde{2}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9}, 1, i \neq j, i = j\}$$

The fuzzy geometric mean was implemented for aggregating the evaluated pairwise comparison matrices. w_i is the fuzzy weight score of the i -th alternative and can be defined by a triangular fuzzy number as $w_i = (lw_i, kw_i, dw_i)$. The lw_i , kw_i , and dw_i stand for the upper, middle, and lower values of the fuzzy weight score of the i -th dimension.

To examine the pairwise comparison matrix consistency, the Consistency Ratio (CR) was computed for all pairwise comparison matrices by applying Formula 9 and 10, by comparing the consistency index (CI) with the random index (RI). The consistency of the pairwise comparison matrix is acceptable if CR is smaller than 0.1. This threshold was proposed by Saaty (1987).

$$(8) CR = CI/RI$$

Here CI is calculated by implementing the following formula:

$$(9) CI = (\lambda_{max} - 1)/(n - 1)$$

where n is the size of the judgement matrix.

In this work, the authors proceeded in steps, identifying the study area limited to the region of Sicily, acquiring data through an online survey from a sample of road users, and processing the results to obtain comparisons of propensity to use specific modes of transport before and during the pandemic.

Two methods were combined in this research, namely AHP and F-AHP (fuzzy AHP). The first method is suitable for this analysis as it allows both to express judgments through comparisons of the criteria in pairs and break down the problem in an appropriate hierarchy (Saaty, 1987), making it possible to consider all the decisional variables. The second method adopted, e.g., F-AHP is highly effective for its ability to model language categories, owing to a concept's "step-by-step" representation. This feature is well represented by the idea of fuzzy sets, highlighting the importance of an interface between data from the physical world and the categories through which we understand and make the best use of that information.

4. RESULTS

4.1. Conventional AHP outcomes

The constructed judgement matrix consists of 28 pairwise comparisons (all possible pairs of the eight mobility elements). The analysis was conducted by adopting the geometric mean, aggregating the individual pairwise comparison matrices and generating weight scores for the alternatives. To examine the pairwise comparison matrix consistency, the Consistency Ratio (CR) was computed.

All pairwise comparison matrices were strongly consistent and used for generating the final aggregated pairwise comparison matrix. The results of AHP and F-AHP were compared. The most visible change in the preferences can be detected in the dropped rank of tram, taxi, and train, while walking gained a higher position and became the most preferred mode, but shared mobility received even higher importance, and the most significant gain belonged to multiple modes, jumping to 4th place from 7th. Based on the survey, it turned out that, during the COVID crisis, walking, car, and bus were the most preferred transport modes, which corresponds to the previous situation, except for the change in the first two places (from car to walking). However, in the least preferred positions, the pandemic caused a more serious turn from the community transport modes to the individual ones.

4.2. Comparison between Conventional AHP and F-AHP

The differences between AHP and F-AHP outputs were slightly realised in the alternative weight scores. However, from the alternatives ranking order, it appears that there are no differences between the results of the conventional AHP and F-AHP approaches (Tables 4 and 5). Thus, both AHP and F-AHP results have proven the robustness of the final outcomes. This suggests that transport policymakers can consider the rankings when preparing to tackle the impacts of the pandemic on the urban transport system. Nevertheless, the slight alteration of the alternative weights indicates that cars were slightly more utilised just as trains during the crisis, which might better reflect the reality of mode choice preferences, and this indicates F-AHP as more suitable for technique selection.

Mobility Type	AHP		F-AHP				
	Scores	Rank	Triangular numbers			Scores	Rank
			Lower	Middle	Upper		
Bus	0.1750	3	0.1421	0.1841	0.2413	0.1892	3
Tram	0.0762	5	0.0534	0.0673	0.0858	0.0689	5
Taxi	0.0629	6	0.0434	0.0548	0.0698	0.056	6
Train	0.1381	4	0.1078	0.1384	0.1852	0.1438	4
Sharing Mobility	0.0277	8	0.0196	0.0242	0.0305	0.0248	8
Multiple Modes	0.0366	7	0.0257	0.0322	0.0407	0.0328	7
Walk	0.2043	2	0.1614	0.2163	0.2841	0.2206	2
Car	0.2792	1	0.2196	0.2828	0.356	0.2861	1

Table 4. AHP and F-AHP priority weights for mobility type before COVID-19

Source: own elaboration.

Mobility Type	AHP		F-AHP				
	Scores	Rank	Triangular numbers			Scores	Rank
			Lower	Middle	Upper		
Bus	0.1056	3	0.0641	0.1048	0.1625	0.1104	3
Tram	0.0263	8	0.0172	0.0246	0.039	0.0269	8
Taxi	0.0347	7	0.0228	0.0337	0.0543	0.0369	7
Train	0.0578	5	0.0365	0.0569	0.0909	0.0614	5
Sharing Mobility	0.0549	6	0.0351	0.054	0.0858	0.0583	6
Multiple Modes	0.0873	4	0.0566	0.0859	0.1278	0.0901	4
Walk	0.3418	1	0.247	0.3455	0.4779	0.3568	1
Car	0.2915	2	0.2069	0.2946	0.419	0.3068	2

Table 5. AHP and F-AHP priority weights for mobility type during COVID-19

Source: own elaboration.

5. DISCUSSION

This research examined the implementation of conventional AHP and F-AHP approaches in assessing mobility problems before and during the pandemic. Adopting the two different approaches allowed us to compare the classification of alternatives and the stability of the results (Moslem et al., 2020; Nosal & Solecka, 2014; Singh et al., 2020). Our case study sheds light on the eight types of travel choices (e.g., bus, tram, taxi, train, shared mobility, multiple modes, walking, and car); these types were evaluated in two time periods and compared with the AHP and F-AHP. Former studies were found recently in terms of pollution analysis and policies related to the characteristics of alternative modes of transport (Moslem & Duleba, 2019; Rossi et al., 2013, 2014). The results and interpretations in these studies have provided helpful information on the ability of models to be used as alternatives to traditional methods of assessing travel mode choices.

The results show a similar trend to that discussed by Moslem et al. (2020), and additionally, it focuses on the evaluation of metropolitan cities and smaller ones. The analysed sample has tripled concerning what Moslem et al. (2020) described. The structure of the research sample was similar to the population, which should be considered as a strength of this research. However, the authors are aware of the limitations of the study. Firstly, at the moment of ending the survey, several Sicilian cities still had connection problems, and this has re-

duced the possibility of collecting survey questionnaires from potential respondents (as it was only possible by telematic means). Moreover, it must be said that the group of people over 70 years old is usually in the digital gap. Therefore, this part of the population is missing and conclusions cannot be made about it. Finally, in order to be able to show the "fresh" effect of the lockdown and restrictions in the first wave of the COVID-19 pandemic, it was decided to investigate in a limited period for carrying out the survey. This influenced the size of the total sample.

At first glance, it is surprising that some public transport modes, especially bus usage, remained in a relatively high position in the ranking. The possible explanation for that is that mode choice merely refers to those situations in which travelling is inevitable (e.g., in those professions which were not suspended even during the pandemic or travelling to stores and markets). What is more, some residents cannot drive a car (lack of licence, bad health conditions, costs of car maintenance, lack of parking space in the city or costs of the parking place), so they will choose an available and cheap transport mode. These respondents will prefer PT regardless of the situation. This phenomenon sheds light on the need to maintain some public transport modes even in times of pandemic and strict restrictions.

It is needed to highlight that this study is based on the primary data obtained for a country with severe mobility restrictions during the first phase of the COVID-19 pandemic. Many published works were dealing with Google data, even if a large group, only from Google users who agreed to use such data from their mobile devices (Luther, 2020; Morita et al., 2020). This study, however, was designed to indicate real values for different groups of people and an extensive, representative research sample from the analysed region. There are other papers regarding mobility choices in the first phase of the pandemic (Klein et al., 2020; Yilmazkuday, 2020), but very few are based on primary research. Nevertheless, the cited research presents similar results for people's mobility choices to those presented for this study. However, the pandemic urban mobility research state is still initial and needs more input from many countries.

6. CONCLUSION

The research findings provide valuable insights about changing mobility choices when unexpected phenomena appear. These changes' fresh, short-term effect can be presented based on the first wave of the COVID-19 pandemic. The changes mentioned in the results section are particularly significant in urban strategic planning decisions (as well in the short term, in crisis management), where the scale and scope of planning set the expectations for identifying the spatial extent of the proposed development. The survey outcomes highlight the relative robustness of citizens' mode choices in the most preferred modes of transport (e.g., car and walking) but draw attention to the radical change in choosing the least preferred modes, e.g., streetcars and taxis, during the crisis period. The reduction in car choice could be related to the irrational behaviour of human beings in their transport decisions and requires more attention from transport planners and decision-makers.

According to the findings of this research, shared mobility visions may need to be rethought in times of pandemics around the world because people may be more reluctant to use shared vehicles when they feel their lives are in danger. On the other hand, continuous monitoring of sanitisation, respect for social distancing within public transport and shared vehicles could increase users' propensity for use. This should be important for mobility service providers, both public and private.

Several political strategies have been implemented in different European countries to avoid dangerous gatherings in outdoor and indoor spaces and vehicles (e.g., continuous police controls to avoid more than 2-3 people in each car wearing masks). Furthermore, the choice of some cities to implement the model of the 15min cities, such as Paris or Milan, means that people can find all the necessary services within 15 minutes of walking distance, thus considering a spatial dimension of the neighbourhood.

The results of this research also confirm the need to take short- and medium-term actions to discourage private transport, for example, through the following solutions:

1. implementation of demand-responsive services to support the local public transport service, including on-demand services,
2. limiting the number of people on board and increasing the frequency of the service in certain areas where demand is the greatest,
3. encouraging soft mobility (walking, hiking or micro-mobility) by defining limited traffic areas and by creating cycling and walking areas or lanes.

The findings may also be useful for planning the post-COVID-19 reality in the area of mobility. At the beginning of the post-COVID-19 restart phase, there is a need to define action lines to reorganise collective transport services. It should be effective in ensuring adequate standards of performance and safety and feasibility, also sustainability, e.g., by collective transport service operators. The implemented strategies should not only be temporary and preparatory for managing the post-COVID-19 restart phase. They should also be structured to respond to changes in mobility needs in a long period. Regarding the local PT, its systems showed the first signs of inadequacy with market share losses favouring more flexible methods, such as carpooling or car sharing. Changes in PT offer, flexible and accessible for the current sharing mobility users, would have been necessary to increase the attractiveness of PT

The apparent limitation of this situation makes this study one of the first to examine the effects of COVID-19 on the choice of mode of operation in Sicily. The trend in mobility choices defined by the results obtained allows us to reflect on future mobility strategies and the related investment and financing plans by the European community, always aiming at the evolution of mobility with a low environmental impact and high user satisfaction in terms of safety, the reduction of delays, and cleanliness. Some policies were implemented in April 2020 to encourage walking and cycling through the construction or adaptation of infrastructure or the dissemination of discount vouchers to purchase vehicles such as bicycles and micro-mobility. In addition, the results allow us to understand how collective public transport has been the most affected field. Several considerations can be made on the modification of the transport offer, for example, better sanitization and control of social distancing with the implementation of physical controls (personnel onboard) or through sensors (low-cost networks and systems such as radio-frequency identification or sensors); reduction in the cost of the ticket or the use of smaller means of transport or bus institution on demand. Comparing AHP and F-AHP has helped to overcome this gap, but further investigations (in different cities and countries, using different models) are needed to discover the actual impacts of the current pandemic period. As an observation for further research, the use of other MCDM like PROMETHEE (Preference ranking organisation method for enrichment evaluation), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje), or BWM

for further analysis and comparison of the AHP and F-AHP results presented in this study is recommended and expected.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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