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Sustainability assessment of carpooling and ridesharing in the pandemic era

Master Thesis

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This thesis is dedicated to Eleni,
without her I wouldn't be here.

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Abstract

Urbanization, climate change, high energy consumption, and the rising travel demand present formidable challenges to the modern world and require not only an integrated urban and transport planning but also a swift towards sustainable mobility. Aiming to limit the use of private vehicle and implement low cost environmentally friendly transport policies, ridesharing (e.g., carpooling, public transit) seems to be a viable solution.

The present study performs a sustainability assessment of carpool systems on university campuses and further a carpooling SWOT analysis. Moreover, in the midst of the pandemic, this thesis examines the COVID-19 impact on urban mobility, sheds light on the subsequent changes on citizens' travel habits, and creates a typology of indicators.

The findings demonstrated that although a significant share of citizens has already reduced private car use and opt for alternative and sustainable transport modes (walking, cycling, public transport), the under research cities (Chania and Rethymno) remain car-centric. On the other hand, the slight increase in "green transportation" detected during curfew, subsided alongside the lifting of the confinement measures, and car dominance reemerged.

Another crucial parameter concerning urban mobility is safety. The sharp decline in public transit ridership revealed that passengers have safety concerns, and they are skeptical or even reluctant to use the bus. The feeling of insecurity was also prevalent regarding carsharing.

This study highlights that safety is a parameter of utmost importance in the design of sustainable, effective, yet resilient transport systems.

Περίληψη

Η αστικοποίηση, η κλιματική αλλαγή, η ανάγκη για εξοικονόμηση ενέργειας καθώς και η αλματώδης αύξηση της αστικής κινητικότητας, επιτάσσουν όχι μόνο τον ενιαίο πολεοδομικό και συγκοινωνιακό σχεδιασμό αλλά και την προώθηση εναλλακτικών βιώσιμων μορφών και μέσων μετακίνησης. Αναζητώντας χαμηλού κόστους φιλοπεριβαλλοντικές πρακτικές που αυξάνουν την αποτελεσματικότητα των μετακινήσεων, και με γνώμονα τον περιορισμό της χρήσης των ατομικών/ιδιωτικών μέσων μεταφοράς, η συμ-μεταφορά (π.χ., συνεπιβατισμός, ΜΜΜ) φαίνεται να αποτελεί μία ουσιαστική λύση βιώσιμης αστικής κινητικότητας.

Στην παρούσα εργασία πραγματοποιήθηκε αξιολόγηση βιωσιμότητας συστήματος συνεπιβατισμού σε πανεπιστημιούπολη, ενώ η ανάλυση SWOT ανέδειξε τα δυνατά (Strengths) και αδύνατα σημεία (Weaknesses) ενός τετοιού συστήματος, καθώς και τις ευκαιρίες (Opportunities) και απειλές (Threats) που προκύπτουν. Επιπλέον, κύριος στόχος της έρευνας ήταν η αξιολόγηση των επιπτώσεων της πανδημίας στην αστική κινητικότητα και η δημιουργία μιας τυπολογίας δεικτών.

Παρά το γεγονός ότι ένα ποσοστό του πληθυσμού έχει μειώσει τη χρήση ιδιωτικού οχήματος και επιλέγει εναλλακτικές και βιώσιμες μορφές μεταφοράς (περπάτημα, ποδήλατο, ΜΜΜ), το αυτοκίνητο παραμένει κύριος τρόπος μετακίνησης στις υπό έρευνα πόλεις (Χανιά και Ρέθυμνο).

Η μικρή αύξηση που καταγράφηκε στην «πράσινη μετακίνηση» κατά τη διάρκεια της απαγόρευσης κυκλοφορίας υποχώρησε παράλληλα με την αποκλιμάκωση των μέτρων περιορισμού και η χρήση αυτοκινήτου επανήλθε σχεδόν στα προηγούμενα επίπεδα.

Μια κρίσιμη παράμετρος της αστικής κινητικότητας είναι η ασφάλεια. Η απότομη μείωση του αριθμού επιβατών δημόσιας συγκοινωνίας κατέδειξε την ανασφάλεια των πολιτών και τη δυσπιστία ή ακόμα και την απροθυμία τους να χρησιμοποιήσουν το λεωφορείο. Το αίσθημα ανασφάλειας εμφανίστηκε εξίσου διαδεδομένο στην κοινή χρήση αυτοκινήτου.

Συνολικά, η μελέτη υπογραμμίζει την αναγκαιότητα επανασχεδιασμού των συστημάτων μεταφοράς υπό νέο πρίσμα, και η ασφάλεια είναι ένας παράγοντας υψίστης σημασίας που οφείλουμε να λάβουμε υπόψη στο σχεδιασμό ώστε τα νέα συστήματα να είναι βιώσιμα, αποτελεσματικά αλλά και ανθεκτικά.

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List of abbreviations

GHG	Greenhouse Gas
GPS	Global Positioning System
HVO	High-Occupancy Vehicle
NTUA	National Technical University of Athens
SOV	Single Occupancy Vehicle
TDM	Transportation Demand Management
TNC	Transportation Network Company
TPB	Theory of Planned Behaviour
TUC	Technical University of Crete
US	United States

Chapter 1. Introduction

It is beyond any doubt that the world is becoming increasingly urban. Nowadays, over half of the global population (55%) lives in cities (UN DESA, 2018), whilst Europe is regarded as one of the most urbanized regions, providing that almost three-quarters of the population dwells in urban areas (Eurostat, 2016). Urbanization is growing rapidly (22% during the period 1960-2018) (Worldbank, 2018), and by 2050, 68% of the world's population is projected to reside in cities (UN DESA, 2018).

Nevertheless, intensive urban growth presents formidable challenges to the modern world. Traffic congestion, environmental degradation, and high energy consumption are only a few to name. On the other hand, the tremendous rise in travel demand, and the consequent increased transportation-related greenhouse gas (GHG) emissions cannot be overlooked.

It should be noted that the transport sector is a significant contributor to CO_2 emissions. More precisely, it accounts for 14% of annual emissions (including non-CO_2 gases) (IPCC, 2014), while road transport holds the highest share, 72.8% (European Environment Agency, 2014). Thus, the transport sector has a profound impact on global warming and climate change. For that reason, policymakers and researchers have proposed and implemented various strategies in order to meet the increasing mobility demand while mitigating the associated negative externalities. These policies are aiming to reduce car-dependency and promote sustainable, low-carbon transportation to achieve the objectives of White Paper, 2011 (60% reduction in transport emissions by 2050) (European Commission, 2011), and Paris Agreement, 2015 (UNFCCC, 2015).

Taking into consideration the unsustainability and the environmental burden of the current transportation systems, it becomes evident that new transportation paradigms and urban mobility trends should replace the old ones in the framework of cities' sustainable development.

Therefore, as sustainable urban transport is gaining prominence, and in light of the need to introduce viable yet efficient solutions, shared mobility could partially address some of the problems that modern cities are facing. Carpooling, that is to say, the sharing of a ride in a private vehicle, is widely recognized for its contribution in reducing carbon footprint, energy consumption, traffic congestion, parking infrastructure demand, and transportation-related costs (Morency, 2007; Caulfield, 2009; Minett and Pearce, 2011; Chan and Shaheen, 2012; Jalali et al., 2017, Shaheen et al., 2018).

Regarding the environmental contribution of carpooling, revealing is the study "Zero Empty Seats" (2019) conducted by the leading company BlaBlaCar. According to the research, the direct environmental benefit from BlaBlaCar carpooling accounted to 894,000 tonnes of CO_2 in 2018, which is the equivalent of three months' traffic in a major city like Berlin. Furthermore, an additional 673,000 tonnes of CO_2 emissions were avoided due to the journeys made by

carpoolers who met on the platform and continued to share rides informally, or by people who got inspired and adopted this transport mode (BlaBlaCar, 2019).

However, apart from the environmental benefits, there is a series of additional advantages for carpooling users, such as reduced travel costs, travel time savings, and reduced commute stress (Shaheen et al., 2018). Moreover, the social impacts of carpooling are equally important, as it enables social interactions and offers accessibility. Hence, it is apparent that ridesharing could be a pathway to more livable and sustainable cities.

Although carpooling could effectively resolve some of the most pressing transport and environmental problems, it is insufficiently used. On the one hand, carpooling systems still do not manage to attract and engage potential users, neither serve them adequately (Olsson et al., 2019). On the other hand, lack of trust is a significant barrier since personal safety concerns deter numerous travellers to opt for this transport mode (Bachmann et al., 2018; Olsson et al., 2019). Moreover, there are also cultural barriers given that part of the population is not accustomed to the idea of shared mobility.

Nonetheless, modern transport systems should not only be sustainable and eco-friendly but also ensure accessibility and safety. Furthermore, it is imperative to design them in a way that can be resilient and address crises and extreme situations, such as the recent coronavirus disease (COVID-19).

A crucial question that emerges nowadays is how does the present pandemic affect shared mobility and public transit, and what does it mean for the future of transportation? As there is a lack of literature published on this topic, this study seeks not only to address the above mentioned issue but also examine the sustainability of carpooling and ridesharing during a public health emergency. Furthermore, this thesis intends to identify the potential carpoolers' characteristics and highlight possible obstacles that prevent them from carsharing. An additional objective of this research is to determine the critical factors for establishling a successful carpool system.

In parallel, the present study aims to shed light on the citizens' behavioural changes on their travel habits in the pandemic era and create a typology of indicators. It is imperative to register the impacts of the COVID-19 outbreak on the transport sector, particularly on shared mobility, in order to set policies that will boost the transformation of transportation towards more sustainable, more accessible, and more resilient mobility patterns.

The process carried out for the current study is presented in the diagram below (Figure 1.1).

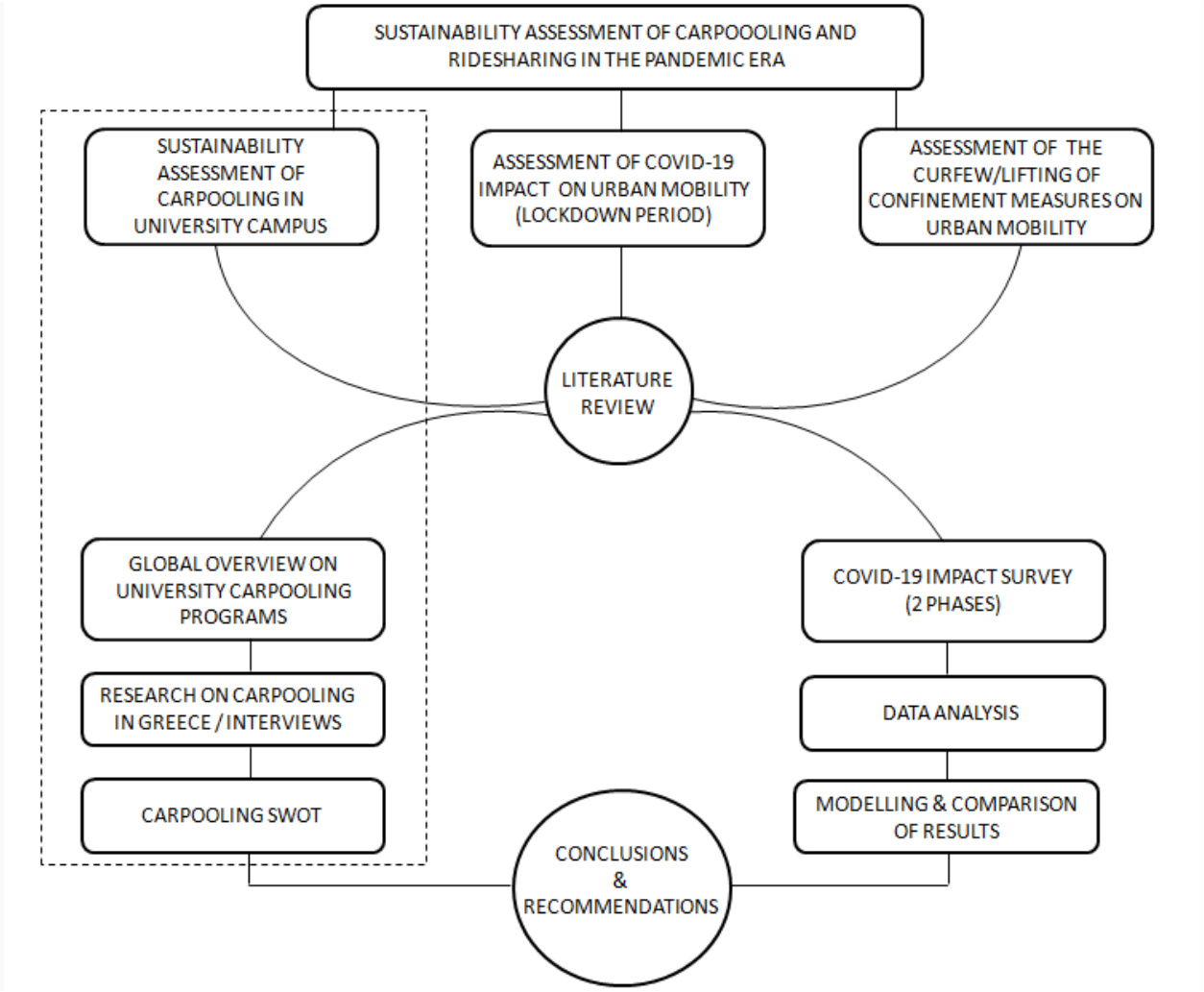

Figure 1.1 Research study flowchart

Chapter 2. State of the art

2.1 Definitions of shared mobility

There are some discrepancies concerning the use of shared mobility terms. On the one hand, agreed definitions are absent (Buliung et al., 2010; Vanoutrive et al., 2012), and on the other, the terms carpooling, ridesharing, and carsharing are often being used interchangeably.

2.1.1 Carpooling

Regarding carpooling, its definition varies considerably in the literature (Table 2.1). Moreover, many times, the term mentioned above has been defined in different ways according to the aim of the study. It can nevertheless be conceptualized as a form of a flexible transport system where two or more people, typically from different households, who have similar destinations and time schedules, share the use of a private vehicle for a journey (or part of a journey), often in return for a share of the travel costs such as fuel, tolls, and parking fees. In some cases, drivers and passengers swap roles on alternate days, which removes the need for any payments between parties (Korver et al., 2012; Nelson and Wright, 2016). Conceptually, carpooling combines some of the benefits of private car use (e.g., flexibility, travel time saving) with the reduced cost of mass transit.

Teal (1987), premised upon previously developed categorization, distinguished carpoolers into three types. More precisely, he proposed the following classification: (1) *household* or *internals carpoolers*, who commute together with at least one other person from the same household, (2) *external* or *non-household carpoolers*, who share transportation with unrelated individuals and who either share driving responsibilities or drive always, and (3) *carpool riders*, who commute with other unrelated persons but who ride only and never provide a vehicle.

Moreover, due to the fact that various forms of carpooling have developed since its beginning in the 1970s, further distinctions can be observed in the literature. Terms such as *informal carpooling* (*slugging/casual carpooling*), *pre-arranged carpooling*, and *dynamic carpooling* (*real-time*, *instant*, or *ad-hoc carpooling*) have been introduced by some authors to describe different carpooling practices.

Table 2.1 Definitions of carpooling based on the literature review

Definition	Literature review
Ridesharing is any use of an automobile that includes, in addition to the driver, non-dependent passengers, without a fully commercial/formal relationship, with an agreement to share the ride, and with or without sharing the travel costs.	Amirkiaee and Evangelopoulos (2018)
Carpooling is the process by which individuals share a private vehicle for a particular journey or journeys.	Canning et al. (2010)
Ridesharing is the grouping of travellers into common trips by car or van.	Chan and Shaheen (2012)
Formal carpooling (also ride-sharing) is defined as two or more persons, not belonging to the same household, sharing a trip or a part it, with the passengers contributing to the driver's expenses.	Ciari (2012)
Ridesharing is defined as the shared use of a transportation vehicle by more than one person, for any trip and any purpose.	Evans et al. (1985)
Ridesharing refers to a mode of transportation in which individual travellers share a vehicle for a trip and split travel costs such as gas, toll, and parking fees with others that have similar itineraries and time schedules.	Furuhata et al. (2013)
Carpooling is defined as all cases in which there is more than one person in the car and is not restricted to formally arranged sharing, possibly organized by a third party.	Hunt and Mcmillan (1997)
Carpooling means that two or more people, whose starting points and destinations are similar and who travel at similar times, agree to travel together in one car.	Korver et al. (2012)
Ridesharing exists when two or more trips are executed simultaneously, in a single vehicle.	Morency (2007)
Carpooling is the sharing of a car journey, often in return for a share of the travel costs such as fuel, tolls and parking fees. In some cases, drivers and passengers swap roles on alternate days which removes the need for any payments between parties.	Nelson and Wright (2016)
In this paper, carpooling is defined as an arrangement where a household vehicle is used to drive children residing in that household, along with children from one or more other households, to or from school	Rafiq and Mitra (2018)

A carpool is when two or more people share the ride to a similar or nearby destination. The number of passengers may vary, drivers and vehicles can rotate, and a carpool might operate every day or only when it's convenient. While petrol and parking expenses might be shared, the driver isn't paid for their time.	New Zealand Transport Agency (NZTA) (2009)
In carpooling a privately owned automobile carries additional passengers when making a trip, with minimal additional mileage.	Victoria Transport Policy Institute (VTPI) (2018)

Informal carpooling refers to "sharing a ride with a driver and/or passengers, usually strangers, where the ridesharing is not pre-planned, but coordinated on the spot" (Kelley, 2007). This type of carpooling is commonly noticed in cities that have high-occupancy vehicle (HOV) lanes, like in Los Angeles, Washington D.C., or San Francisco. HOV lanes are special lanes that have restrictions on use and typically are open to motor vehicles with more than one occupant. The purpose of these lanes is twofold: (1) reduce congestion and ameliorate the transportation system, and (2) improve air quality (U.S. Department of Transportation, 2020). In the case of informal carpooling, there are designated *pick-up* points (e.g., a bus stop or a parking lot near HOV lanes), and commuters generally do not contribute to the travel cost, since for the driver the principal benefit is to use the HOV lanes and hence reduce travel time (Handke and Jonuschat, 2012). Furthermore, other authors define informal carpooling as the arrangements between family and friends. These arrangements are relatively common for certain activities, for example, the school run, and occasionally between friends at work (Nelson and Wright, 2016).

Nowadays, the technological advance and the emergence of social networks have removed numerous barriers regarding pre-arranged carpooling, and as a consequence, there are a plethora of internet-based services that provide trip planning in advance by matching the drivers' and passengers' travel preferences. Usually, the passenger contributes to the travel cost, and the majority of those systems require a small fee for the service, for instance, a monthly membership fee. It should be noted that pre-arranged carpooling is the most widespread form of carpooling (Handke and Jonuschat, 2012).

Notwithstanding, with the further development of internet and mobile global positioning systems (GPS), pre-arranged carpool systems have been overtaken by dynamic or flexible carpooling. In the latter, rideshare can be organized at short notice. It is noteworthy that with dynamic carpooling, users are even more independent and autonomous, given that they are allowed to offer and request journeys at any time and place. Moreover, apart from the instantaneous matching between passengers and drivers, another advantage of the carpooling mobile applications is the routes' optimization and the accuracy regarding waiting/journey time (Arcidiacono and Duggan, 2020).

The previously mentioned categories relate to the organizational perspective. Informal carpooling is comparable to private hitchhiking, while pre-arranged or dynamic carpooling is frequently associated with a ride-matching service. Usually, carpooling services through online platforms provide a great set of trip options and allow flexible scheduling between drivers and passengers.

Nevertheless, it is of utmost importance to distinguish carpooling from carsharing or ridesharing, given some international inconsistencies in terminology.

2.1.2 Carsharing

Concerning carsharing (also known as car clubs in the UK), likewise carpooling, instead of an official definition, most publications provide a description of this travel practice. However, carsharing can be briefly defined as a system that allows registered members to book a vehicle for a limited time, often by the hour, anywhere and at all times (Münzel et al., 2017). In other words, carsharing refers to a kind of short-term automobile rental service designed to provide an alternative to car ownership. Furthermore, it is a practice that can complement other mode choices, such as public transport, walking, or cycling.

Carsharing, apart from being a short-term car rental solution, differentiates from the traditional car rentals mainly in the flexibility. The decentralized car fleet is not only self-accessed, but it is also available for use twenty-four hours seven days a week with hourly or daily charge, including insurance and fuel (Millard-Ball et al., 2005).

The carsharing systems can be further classified into three types: *traditional*, *peer-to-peer*, and *corporate*. Traditional carsharing refers to a service, in which the cars are owned by a carsharing company. In peer-to-peer car-sharing, ordinary people rent out temporarily their personal vehicles via a website platform. In corporate carsharing, there is a dedicated fleet of vehicles that can be used only by a specified clientele. This type is common in companies who want to address their employees' mobility needs.

Carsharing systems can also be distinguished in *round-trip*, *free-floating*, and *point-to-point*. Round trip carsharing requires the user to return the car to the same location it was taken from. In free-floating carsharing, the car can be taken and returned anywhere within a specified area, while point-to-point car sharing has fixed pick-up and return locations, however, the car can be booked at one location and be dropped off at another (Laine et al., 2018).

2.1.3 Ridesharing

On the other hand, ridesharing is another term that frequently is being confused with carpooling. Although it is commonly used as synonymous, in principle, it is a broader concept as it also encompasses other sharing systems like taxi or bike trips (Handke and Jonuschat, 2012). In short, ridesharing is an innovative transportation strategy that entails adding passengers to a pre-existing trip.

Ridesharing systems can be classified into three groups: *fixed long-distance ridesharing*, *on-demand ridesharing*, and *corporate ridesharing*. In fixed long-distance ridesharing, trips are planned in advance. In contrast, on-demand ridesharing refers to shorter commutes, and the ride-matching is coordinated shortly before the departure. The corporate model ridesharing is primarily used to share the costs of commuting (Laine et al., 2018).

Nonetheless, it is critical to differentiate ridesharing from ride-hailing, given that there is a widespread misconception regarding these terms. Erroneously, transportation network companies (TNC's), such as Uber and Lyft, are considered as shared mobility services. However, these companies, through a smartphone application, provide on-demand private drivers. Otherwise stated, they are a new variant for taxi service.

Consequently, ride-hailing is a for-profit endeavour, whereas ridesharing aims to increase vehicle occupancy, reduce costs for both drivers and passengers, and mitigate traffic congestion and greenhouse gas emissions.

Last but not least, carpooling should be distinguished from hitchhiking, which is an unorganized type of ridesharing when drivers pick up strangers on the road for a part of their trip.

2.2 History of carpooling

One striking thing about carpooling is the absence of systematic historical records. Given that the first organized attempt to evaluate carpooling as a transport mode in the United States (US) took place in 1977, there is a lack of requisite data to describe the evolution of this travel mode (Ferguson, 1997).

Furthermore, regarding the academic community, for the vast majority of the scientists carpooling was not regarded as an appealing topic for academic research. For that reason, the first studies on carpooling appeared in the late seventies, a few years after governmental disseminating practices (Ferguson, 1997). Moreover, it should be noted that due to the challenge to observe and study carpools, "carpooling is often referred to as the invisible mode" (Chan and Shaheen, 2012).

Although carpooling gained popularity in the mid-1970s, it first appeared in the 1940s, during World War II, as a policy mechanism to conserve the essential resources for the war (e.g., oil, rubber) (Ferguson, 1997). The US government and the oil and car industries joined their forces to promote ridesharing and change people's travel habits by the campaign slogan "When you ride alone, you ride with Hitler" (Olsson et al., 2019). At that time, long before the computer databases, the ride-matching was performed via a bulletin board at workplaces (Shaheen and Chan, 2014).

After World War II, participation in carpooling declined as resource conservation was deemphasized. Commuters returned to their previous travel behaviour, that is to say to single-occupancy vehicle (SOV) use. In the late 1960s and early 1970s, large-scale companies implemented carpooling programs to address congestion and parking demand (Chan and Shaheen, 2012).

Later, in the mid-1970s need for fuel conservation reemerged due to the first oil crisis and the embargo that was imposed against Western Europe and the US. In an effort to achieve energy conservation goals, the US government-funded ridesharing initiatives. Concomitantly, reductions in parking subsidies aimed to discourage the overuse of SOVs. Moreover, in that period, the first regional ridesharing services were established, while carpooling became a common Transportation Demand Strategy (TDM) Cozza, 2012). Since the 1970s, other policy mechanisms, including HOV lanes, preferential parking for carpools, and park-and-ride facilities, have been developed to encourage this transport mode (Shaheen and Chan, 2014). It is noteworthy that the late 1970s was one of the most active eras in the history of ridesharing.

Once the crisis subsided by the early eighties, carpooling once again disappeared from the policymakers and the public's attention. In fact, carpooling experienced the "most shocking denouement, particularly after having done better than all other alternatives to driving alone in the immediately preceding decade" (Ferguson, 1997). The decline in carpooling during the 1980s goes in tandem with the drop in oil prices. Specifically, carpooling declined by 32% between 1980 and 1990, while gasoline prices decreased by 45% (Ferguson, 1997).

Another increase in carpooling was observed due to the rise in oil prices (2005) and the financial crisis (2008). Moreover, the advent of the internet enhanced further that rise as numerous ridesharing services emerged (Furuhata et al., 2013). However, internet-based carpooling systems did not manage a significant transportation mode shift, and carpooling was again in decline. It is worth mentioning that according to census data, ridesharing work trips reduced almost by 10% between 1980 and 2009 (from 19.7% to 10%) (Tavernise and Gebeloff, 2011; Ferguson, 1997).

Notwithstanding, the appearance of smartphones made a significant difference in the field of shared mobility. On the one hand, mobile applications facilitated ride requesting. On the other, real-time ride-matching addressed the inconvenience of traditional carpooling (Chan and Shaheen, 2012). In other words, nowadays, the flexibility provided by technological advances makes carpooling more appealing and feasible than ever before, and it is not a coincidence that companies such as BlaBlaCar, Zimride, and Lyftshare are thriving in the market (Olsson et al., 2019). Moreover, social media, for instance, Facebook, play a significant role in the promotion

of carpooling, provided that these platforms can be used by the ridesharing companies as a marketing tool.

Last but not least, it cannot be overlooked the fact that nowadays, the sharing economy has a significant impact in various sectors, with transportation not being an exception. Thus, shared mobility systems are constantly gaining ground. Furthermore, an interesting observance is that rises in carpooling are related to external circumstances (e.g., increase in fuel price, fuel shortage, economic recession). Consequently, we may be in the threshold of a new rise.

2. 3 Carpooling determinants

A considerable amount of literature endeavoured to examine and determine the characteristics that influence people to carpool. According to Buliung et al. (2010), key parameters that affect carpooling adoption are socio-demographic (e.g., age, sex, income), transportation characteristics (e.g., travel time, commute distance), auto-availability, and travel behaviour.

Furthermore, in 2015, Neoh et al. made some adaptations to the above mentioned classification and distinguished carpooling determinants in two categories: internal and external. More precisely, researchers labelled as internal the factors that are related to the individual level of each person, and as external those who correlate with the environment level. Internal factors include socio-demographic and judgmental characteristics (e.g., an individual's attitude towards carpooling). On the other hand, external factors incorporate third-party interventions (e.g., policy measures to encourage carpooling) and situational factors (e.g., residential location, automobile availability) (Neoh et al., 2015).

The above stated distinction is a useful tool of policymaking as it highlights the critical points in which should be paid attention to.

2.3.1 Socio-Demographic determinants (Internal)

A recent meta-analysis of parameters influencing travellers to carpool by Olsson et al. (2019) corroborated previous findings (Teal, 1987; Neoh et al., 2015; Lanzini and Khan, 2017) which indicated that socio-demographic factors have a minor effect on modal choice. In other words, determinants such as age, gender, and income are somewhat limited in their effect sizes.

Nonetheless, some general trends can be observed, as shown in Table 2.2. According to various studies, there is a correlation between lower-income and higher carpooling propensity (Teal, 1987; Ferguson, 1995; Baldassare, 1998). Furthermore, employees of higher educational attainment tend to carpool less, given that their income is regularly higher than average. Moreover, individuals of multiple-worker households opt more for carpooling, due to limited

vehicle availability. In addition, women with young children do not frequently use this transport mode, because of the complexity of their daily commutes (e.g., transport children to school/ nursery) (Vanoutrive et al., 2012).

Table 2.2 Socio-economic characteristics of carpooling users/potential carpooling users based on literature review

Characteristics	Literature references
Age: young persons	Baldassare et al. (1998), Morency (2007), Correia and Viegas (2011), Tahmasseby et al. (2015), Park et al. (2018)
Income: lower than average	Teal (1987), Ferguson (1997), Baldassare et al. (1998), Tahmasseby et al. (2015)
Professional status: students/full-time workers on a fixed schedule	Neoh et al. (2015), Tahmasseby et al. (2015), Delhomme and Gheorghiu (2016)
Marital status: married with or without children	Teal (1987), Correia and Viegas (2011), Park et al. (2018)
Car availability: lower than average	Teal (1987), Ferguson (1997), Correia and Viegas (2011)

Regarding age and university affiliation, some authors concluded that younger people and graduate students appeared a higher willingness to participate in carpooling, and actually, they used it more (Correia and Viegas, 2011; Park et al., 2018). Other studies revealed that a higher education level increased carpooling likelihood with non-household members, while in contrast, decreased the carpooling probability with household members (Ferguson, 1997). As for marital status, according to studies, married persons, with or without children, stated to carpool regularly compared with single people (Teal, 1987; Park et al., 2018). Moreover, auto-availability is a strong determinant for choosing to carpool. More precisely, evidence suggests that lower than average car availability implies a higher tendency for carpooling (Teal, 1987; Correia and Viegas, 2011).

In addition, Ferguson (1995) also concluded that automobile availability and educational attainment are more influential in the choice to carpool than other characteristics like gender.

2.3.2 Judgmental determinants (Internal)

A literature review demonstrates that judgmental determinants, that is to say, psychological factors, play a significant role in travel mode choice. Furthermore, it should be noted that not only are more important than socio-demographic ones but also easier to change (Neoh, 2015).

For that reason, lately, more scientists are examining the reasons or intentions to carpool from a psychological standpoint. In other words, recent studies attempt to shed light on peoples' attitude towards carpooling, provided that according to the Theory of Planned Behaviour (TPB), "there is a positive relationship between attitude towards the behaviour and an individual's intention to perform the behaviour" (Ajzen, 1991).

Attitude refers to the evaluation, positive or negative, towards a particular idea and can substantially influence an individual's behaviour and actions. Recent evidence (Bachman et al., 2018) suggests that a positive predisposition towards carpooling does not necessarily coincide with the adoption of carpooling. In other words, attitude cannot predict intention concerning carpooling or transport choice. Thus, it is vital to take into consideration a broader range of factors.

Parameters such as trust, safety, convenience, reliability, and environmental awareness, play a major role in travel mode choice. For example, it was shown that commuters tend to carpool when they consider it to be convenient. In contrast, the lack of privacy deters people from this modal choice (Olsson et al., 2019). Moreover, trust is an essential factor, given that generally, people report a high preference to travel with persons who already know (Liakopoulou et al., 2017). However, individuals with a high level of trust towards strangers are more prone to carpool (Bachmann et al., 2018). Furthermore, it is noteworthy that environmentally-conscious persons are not only more likely to change transport (Clayton and Manning, 2018) but also demonstrate a propensity toward carpooling (Tahmasseby et al., 2015).

Last but not least, scientists underline that intentions, habits, and past use might predict modal choice and actual behaviour, and it is critical to distinguish intentions from behaviours, since frequently fall in the same category (Lanzini et al., 2017).

2.3.3 Interventions (External)

Interventions and incentive programs aim to shift peoples' commuting behavior and encourage them to carpool. For that reason, policymakers are using different approaches. On the one hand, since financial incentives are a strong motivator for modal choice, many companies and universities offer free or low-cost parking to carpoolers, alongside with rewards to regular users. On the other, another method to promote carpooling is by imposing additional parking fees for driving alone. Nevertheless, although this method might be more effective, reward measures are considered as a more appropriate policy (Olsson et al., 2019).

Furthermore, Neoh et al. (2015) concluded that there is an unambiguous relationship between parking-based incentives and HOV lanes and propensity to carpool. By making SOV use less convenient, modal shift to carpooling becomes more probable.

Moreover, research has indicated that the simplicity in ride-matching motivates commuters to carpool. Consequently, internet-based platforms and mobile applications are indispensable features for carpooling promotion. Other measures, such as a guaranteed ride home, proved to have a low impact on travellers' choice (Neoh et al., 2015).

2.3.4 Situational factors (External)

Situational factors are essential for transport mode choice. Some authors concluded that long-distance trips, high travel cost, and fewer household vehicles per worker motivate people to opt for carpooling (Teal, 1987; Ferguson, 1997).

Moreover, economic parameters also play a vital role. Fuel costs undoubtedly should be taken into consideration, given that it was found that a rise in fuel prices signifies an increase in carpooling and vice versa (Ferguson, 1997). This trend can be attributed to the fact that fuels are the main cost of driving a car.

Similarly, population density has a significant impact on carpooling. More precisely, carpooling rates are HIGHER in urban areas due to the greater number of residents that increases both supply and demand. Furthermore, the lack of transportation alternatives, for example, limited public transit, or the inability to use active modes (cycling, walking) enhances carpooling (Olsson et al., 2019).

It should be noted that authors are not unanimous regarding the effect on travel distance on carpooling. While several researchers concluded that there is a significant positive correlation between longer distances and carpooling (Teal, 1987; Ferguson, 1997; Tahmasseby et al., 2015; Park, 2018), others identified no connection (Gheorghiu and Delhomme, 2018).

Finally, carpooling systems appear to be attractive transportation solutions in universities or workplaces, where there is not only schedule compatibility between students/employees but also a higher level of trust (Buliung et al., 2010; Morency, 2007).

Chapter 3. Analysis of selected carpool programs

3.1 Introduction

With ever-growing enrollment rates, universities around the globe are urgently looking for ways to address the emerging challenges that come with the enlarging student populations. Undoubtedly, transportation is one of the most vexing issues as it creates several direct and indirect impacts.

On the one hand, there is an environmental burden, given that the majority of the college commuters use private automobiles (Miralles-Guasch and Domene, 2010). Deterioration of air quality, noise pollution, and land use for parking facilities are a few to name. On the other, social effects cannot be disregarded. Health implications, traffic congestion, reduced safety, increased risk of accidents, and inaccessibility are issues of great concern to university administrations (Dehghanmongabadi and Hoşkara, 2018).

3.2 University transportation demand management solutions

Over recent years, a considerable number of institutions have taken measures to tackle the previously mentioned externalities that stem from car dependency and unsustainable transportation systems. By developing and implementing mobility plans, universities are trying to instill in the next generation the importance of switch from private automobiles to alternative, sustainable modal choices.

Indisputably, the promotion of sustainable transport modes on university campuses has a plethora of environmental, social, and economic advantages. Beyond the obvious cost savings and reduction of carbon footprint, the educational benefits of such initiatives are more profound. More precisely, the implementation of such initiatives influences not only students' current mindset regarding mobility, but also their future attitudes and behaviours. In other words, it helps them develop new eco-friendly travel habits, something that is of utmost importance.

Notwithstanding, apart from the above mentioned, there is a series of hidden benefits. Innovative and sustainable transportation systems, such as carpool programs, make campuses more prestigious and attractive not only to future students but also to distinguished academics. Moreover, they help community members establish social ties and build strong relationships. Furthermore, the interaction with different cultures that offers carpooling, is equally important as it removes social barriers, cultivates open-mindedness, and forges a more cohesive environment. In addition, these social connections enable students to achieve their academic

goals, provided that interpersonal relationships play a pivotal role in academic performance (Pym et al., 2011).

Apart from that, carpooling offers a viable solution to transport problems, which are linked with poor attendance and, thus, low academic achievement (Kelly, 2012). Finally, carpool systems by reducing SOV use, foster an environment friendlier to active modes of transportation (cycling, walking).

3.3 Implementation of carpool systems on campuses

However, how can universities resolve the issue of unsustainable student commute and its subsequent adverse effects? It is beyond any doubt that rideshare is an effective campus mobility solution that can address both traffic congestion and parking problems.

The outstanding technological advancements of the 21st century enable universities to implement tech-driven carpooling programs and resolve the challenges they are facing efficiently. By using mobile technology and dynamic artificial intelligence, universities' TDM strategies optimize the advantages of carpooling systems and reach their ambitious sustainability goals. For that reason, smart college rideshare programs are spiking in popularity.

Nonetheless, to design and establish a successful carpool program, it is not an easy undertaking. There are several parameters that should be taken into consideration. For instance, since affordability is a key component of modal choice, universities' mobility plans are aiming to reduce cost barriers in order to keep the engagement to the program high.

Nowadays, numerous universities in order to promote carpooling initiatives and motivate more students and faculty members to participate in them provide financial incentives, such as free or low-cost parking on campus (e.g., Harvard University, Stanford University). In general, as parking congestion is a crucial problem for many universities, guaranteed spaces to those who carpool to the campus could be a strong stimulus for commuters. Apart from that, frequently, regular users are being rewarded with vouchers that can be redeemed through a large variety of retailers.

Another key to successful university carpool programs are smart, user-centric features that meet the needs and preferences of its users. Furthermore, the system's flexibility is vital also, given that adjustments and adaptations according to peoples' requirements are indispensable for long-term success.

Nevertheless, a crucial point in all carpool initiatives is the attainment of a critical mass. Promotion campaigns to raise awareness in tandem with incentives play a significant role. Moreover, friendly competitions, carpool challenges, and gamification are a great way to not

only attract more users but also retain them. In addition, a guaranteed ride home program for emergency transportation, if need be, is equally important.

It is noteworthy that recently, many institutions are collaborating with carpool or rideshare companies such as Zimride and Liftango, to be provided with a tailored made, tech-smart carpool system capable of adapting to the requirements of the campus. By that, not only they are at the forefront of innovation and stay competitive, but also overcome the challenges that accompany campus transportation.

Universities such as Harvard, Cornell, Stanford, Berkeley, and Monash are illustrative examples of campus TDM initiatives.

a. Harvard University

The prestigious Harvard University, in collaboration with Zimride, the leading company of rideshare and carpool systems in North America encourages students and faculty members to green their commute. More precisely, Zimride has designed an entirely private Harvard network that matches persons based on their commute time and location. Regarding the incentives, participants who carpool with another person 4-5 days/week, get a 50% reduced rate on parking, while there is a 75% discount on parking fees for carpools with three or more commuters (Various, 2020a).

b. Monash University

Monash is Australia's largest university, set in a suburban zone. Due to the long commutes and inefficient public transport, many students and faculty members use their private vehicles to transport to the campus. Nevertheless, the limited parking facilities cannot address the enormous demand, and frequently students have to spend as long as 40 minutes searching for a parking space. This phenomenon has significant repercussions on attendance rates and the university´s smooth operation (Liu, 2017).

Although Monash University has reduced since 2008 SOVs coming to campus to 30% (Various, 2020b) aims to a further decrease. Hence, in July 2019, it introduced a new carpooling program powered by Liftango.

To motivate the academic community to opt for carpooling instead of SOV use, Monash University offered free parking to all participants. This benefit was of utmost importance given that parking permits typically cost over $400. Moreover, smart integrations and user-friendly features made the program more attractive (Various, 2019).

Regarding the dissemination of the carpooling scheme, it was promoted at open days, orientation week, and through events such as the Sustainable Transport Fiesta and the Race for Sustainability. It should be mentioned that these actions were significantly effective since they manage to reach critical mass.

From the above mentioned, it becomes evident that tech-smart carpooling systems are an efficient way to provide sustainable transport options to a university setting and tackle its transportation problems. Many leading universities have already implemented such schemes in an attempt to bring campuses in the new era of technology and sustainability. As for the lessons learned from these implementations, economic incentives and a well-designed launch of the program are essential for obtaining the initial adequate number of users. Moreover, the program must address the specific features and needs of each university in order to be successful in the long term. Therefore the collaboration with a company that specializes in the field of shared mobility might be useful. Finally, the university´s open days, orientation week, or events such as Mobility Week offers an ideal opportunity for the project's promotion.

3.4 Carpooling in Greece

A critical part of this research was to investigate not only the current situation regarding carpooling in Greece, but also the former initiatives that took place in this specific field. This step was considered vital, given that it would provide essential information concerning people's perspective for this mode of transport, and it would illustrate the reasons behind successful or unfruitful past attempts. In order to establish a successful sustainable carpooling system avoiding previous errors is of utmost importance. Furthermore, identifying potential weaknesses and highlighting good practices is equally significant. Taking the above mentioned into consideration, and under the lack of official data, online research, in parallel with personal interviews, was conducted, with the aim to gain insight into the past and current state regarding shared mobility in Greece. The gathered information is reported in Table 3.1.

3.4.1 Websites

As mentioned earlier, carpooling is not a novel form of transportation as it dates back in 1914. Nevertheless, despite the fact that it is a widespread practice around the world for several decades, and also a well established one in many countries, in Greece, it made its appearance at the end of 2005. The first initiative, *carpooling.gr*, was realized by three college students who, based on the carpooling trend in foreign countries, endeavored to provide an alternative and economical mode of travel. The initial platform was released in December of 2005 and has attracted wide public acceptance. In 2006 the second improved version of the platform, which offered at the potential travellers additional services, such as interactive maps and wish list, was launched. Further, at the beginning of 2013, the third and final edition of the site was on the air. Nowadays, the platform still operates and offers users an alternative way of travel (Adamopoulos, 2012).

Another initiative took place in 2007 under the name *synepivatis.gr*. However, unfortunately, as it is presently out of order, additional data regarding the operation period, the number of registered members, etc., is nonexistent (Various, 2020c).

An additional carpooling platform, *pamemazi.gr*, emerged two years later, in 2009. It was the Greek version of the international platform *carpooling.com*, and its innovative feature was the fact that the travel destinations were not only domestic but also international (Various, 2020c). Like the aforementioned case, currently, the platform does not operate, and the causes behind this ineffective attempt remain unknown as there is a lack of available data.

In 2018, the municipality of Karditsa, in the framework of European Mobility Week and in order to comply with the guidelines and recommendations regarding sustainable urban mobility and more precisely multimodal transportation, implemented a carpool system for the citizens through the municipality's web site (dimoskarditsas.gov.gr) (Various, 2018). The central concept was to facilitate the urban transport in one hand and provide an alternative for travelling to/from the nearby villages in the other, given that on Saturday afternoon or Sunday, the public means of transport does not serve specific destinations. Apart from the above mentioned, it was assumed that it would be useful for teachers, professors, or civil servants that commute daily to the same destination. It should be noted that there was no funding for this action, and no prior survey has been conducted to investigate the public's preferences concerning the upcoming scheme. Nonetheless, the lack of promotional actions on the part of the municipality's marketing department and also local press, led consequently to the failure of the attempt, as citizens were and still are unaware of the existence of this particular alternative.

3.4.2 Social media

It is beyond any doubt that technological advances played a significant role in the expanding of carpooling. Similarly, the emerge and gaining prominence of social media contributed equitably, as it did not only facilitate the communication between users but minimized the feeling of insecurity as well. As many users declare, access to the Facebook profile of a potential fellow traveller can provide them with useful information about the character and the mindset of the other person.

It was a matter of time that social media, like Facebook, for example, would be used as amateur carpooling platforms. The first and most successful Facebook page of that kind, *Share the ride ;)*, which is active thus far, appeared in 2009. Today it amounts to more than 41.000 members, and it is worth noting that the registered users are steadily increasing at an accelerating pace as each month, 1000 new members are joining the group. Though it started as a post on a personal "wall", in a blink of an eye, it became a group as the founder perceived from the beginning people's acceptance of this alternative mode of transport.

However, which are the critical elements of this success according to the establisher? First and foremost is the fact that it is not oriented toward citizens of a specific city, but on the contrary, it

is aimed at people who want to travel from one city to another. Thus, there is a significant number of posts daily, which maintains the page active. More precisely, every day, there are approximately more than 50 new posts. Secondly, the broad public's acceptance and support from the beginning gave the essential boost and set the wheels in motion.

Since March of 2019, a new system that scans all the posts and presents to the user only the ones with the specific destination that he/she is interested in has implemented. That initiative has been remarkably useful as it facilitates extremely the searching. Nevertheless, it is not only that. Furthermore, there are no longer necessary the smaller groups; for instance, *Share the ride - Crete!*, provided all the posts can be accessed effortlessly and rapidly through the main group. It should be noted that the peak period is observed in the summertime, long weekends and also during Christmas or Easter holidays.

Two additional Facebook pages that are active nowadays are *Volos Carsharing Pool* (2.800 members) and *Share the Ride – Patra* (1000 members), which were created in 2015 and 2018, respectively. Nonetheless, besides the above stated, additional initiatives realized in 2016, namely *ShareMyCar* (Pantazopoulos, 2017), *Thess.Carpooling* (Various, 2016), and *ThessISMUN Carpooling*, but all of them are currently inactive.

3.4.3 Applications

On the other hand, the technological development alongside with the extensive use of smartphones brought the era of applications, with the carpooling related ones not being an exception. *HopIn* was launched in 2013 (Belegrinis, 2016), and three years later, in 2016, another one, *Poolit*, made its appearance (Barba, 2016). Unfortunately, both of them have now have stopped.

Table 3.1 Carpooling initiatives in Greece

Websites	Date of establishment	Operating period
carpooling.gr	2005	2005 - up to today
synepivatis.gr	2007	No available data
pamemazi.gr	2009	No available data
carpooling.ntua.gr	2011	2011 - 2012
carpooling.uth.gr	2014	Did not operate
dimoskarditsas.gov.gr	2018	Did not operate

Social media (facebook pages)		
Share the ride ;)	2009	2009 - up to today
Volos Carsharing Pool	2015	2015 - up to today
Share the ride - Crete!	2016	2016 - up to today
Thess.Carpooling	2016	No available data
ThessISMUN Carpooling	2016	Did not operate
ShareMyCar	2017	2017 - 2018
Share the Ride - Patra	2018	2018 - up to today
Applications		
HopIn	2013	No available data
Poolit	2016	No available data
Slugg	2017	Did not operate

3.5 Carpooling on Greek campuses

Taking into consideration the fact that this study seeks to explore and evaluate the sustainability of a carpooling system on a university, considerable attention was paid to the initiatives that performed on campuses. Although nowadays none of the universities is offering this alternative mode of transportation, in the last decade, three academic institutions tried to adopt the trend of sustainable mobility and carried out carpooling schemes.

a. National Technical University of Athens

To begin with, the National Technical University of Athens (NTUA) was the pioneer in the specific field. In 2011, the university's unit of sustainable mobility attempted to introduce and promote a new approach to commute to the campus. Prior to launching the carpooling system, an online survey has been conducted, with the view to examine people's willingness to support and participate in the upcoming project. Of the 1004 students and faculty members who completed the questionnaire, the vast majority appeared to be favorable to the idea. In that context, the plan was set in motion. Since in those days, applications were not as prevalent as today, in the initial stage, the project was not supported by a web platform, and the program's

participants had been provided with a special card which they were using to be recognized with each other (Various, 2011).

Notwithstanding, the attempt was partially successful, given that it operated for only one year. Hence, the question that arises is why the system mentioned above did not succeed? The answer to the above-mentioned question is not a one-sided one. According to the founders, the unsuccessful outcome could be attributed to various factors. For a start, even though the prior research has demonstrated high public acceptance and willingness of participation, in reality, the rate was significantly low. Moreover, the academic community at that time was not mature enough to embrace this alternative mode of transport. Likewise, ten years ago, the notion of sustainable mobility was in its infancy and the environmentally friendly mindset not as widespread as today. Apart from the previously noted, in retrospect, the absence of a web platform was a major disadvantage provided that the card method was not user-friendly.

Nevertheless, a surprising and noteworthy observation that emerged was the fact that women, either as passengers or drivers, opted to co travel with women. This phenomenon highlights the potential fear of sexual harassment and pinpoints that the feeling of insecurity is a principal obstacle that hinders people from carpooling. Furthermore, another observation that cannot be overlooked and underlines as well the safety parameter, was the fact that the project was more successful in the smaller faculties, where the students could at least facially recognize their classmates from the classroom, library or cafeteria. Moreover, for the same reason, students preferred to carpool with members of their faculty. In a nutshell, the establishment of trust relationships between strangers appeared to be a common theme and a significant barrier to shared transport.

b. University of Thessaly

A few years later, in 2014, another initiative was realized at the University of Thessaly. It was observed that due to the financial crisis, several visiting professors and PhD students, who lived permanently in other cities than Volos and visited the campus for only a few days a week, opted for public transport instead of using their private car. It is interesting to note that eight out of ten faculty members preferred this mode of transportation for economic reasons. The main concept of the endeavor was to establish a carpooling system that would facilitate the commute and would provide a low-cost way of travel. A web platform with unique and innovative features was designed (Skagiannis, 2015); nevertheless, contrary to expectations, the attempt was unfruitful provided that failed to reach the critical mass. On the one hand, the lack of promotional actions was a critical point that led to the project's failure. On the other hand, cultural impediments played a significant role in the unsuccessful outcome, given that many professors were reluctant to share a ride with a stranger colleague of a different faculty. Thus, once again, it became apparent that society's conservatism was a major hindrance to the adoption of new and alternative travel habits.

c. Technical University of Crete

Last but not least, a worth mentioning attempt took place at the Technical University of Crete (TUC) in 2017. As the campus is located about 5 km away from the city's center (Chania), the daily commute can sometimes be challenging. A striking observation that cannot be overlooked is the fact that at the bus station outside of the campus, there are always students that hitch hick. This phenomenon illustrates that the bus service might be insufficient, and underscores an existing transportation problem that should be addressed. In addition, students that reside in the university's dormitories encounter difficulties in returning to the hall late in the evening when the public transport does not operate.

With the above stated in mind, two students of TUC designed *Slugg*, a carpooling application that would facilitate the transportation of the academic community. There have been some posters, and a presentation regarding the forthcoming project and the student body appeared to be in favor of the idea (Various, 2017).

Although no prior survey had been carried out, something interesting that was observed through personal contacts and cannot be ignored was the different attitudes between drivers and passengers. More precisely, the drivers were more interested in participating in the carpooling system. Conversely, the passengers appeared to be more sceptical and less willing to embrace shared mobility. As anticipated, the trust issue emerged again.

Despite the fact that the application was well designed and user-friendly, the effort was ineffective. A major cause of that failure, as stated by the founders, was the limited participation that prevented crossing the critical mass point. To that contributed significantly the absence of a marketing campaign.

Summing up, none of the carpooling initiatives that implemented on campuses was successful. There are several possible explanations for this result. From one side, it is evident that the lack of promotional actions was a common issue in all the attempts and played a vital part in the unfruitful outcome. On the other side, cultural barriers contributed equally, given that people hesitated to try this alternative transport mode.

Furthermore, the findings from the investigation imply that in order to have long-term success a carpool program, a series of parameters should be taken into consideration. In the first place, it is considered indispensable, a strong debut with many participants and high engagement of the carpoolers. That can be achieved by taking into account people's preferences, and subsequently by adjusting and adapting the carpooling system to their needs. Secondly, it is essential to present to the people the advantages of shared mobility and inform them about the benefits they could reap by opting for it. Thus, advertising is of utmost importance, alongside with awareness campaigns that cultivate an eco-friendly mindset. Another crucial point is the creation of a trusted environment for all commuters, considering that safety was a common impediment for many users.

Taking into consideration the previously mentioned, the major strengths, weaknesses, opportunities and threats (SWOT) of carpooling are summarized in the table below (Table 3.2)

Table 3.2 SWOT analysis of carpooling

Strengths	**Weaknesses**
1. Sharing the expenses → Saves money 2. Meeting new people/getting in touch with different cultures → Makes the journey enjoyable 3. Useful for people that don't drive or don't own a vehicle 4. Corresponds to the modern socio-economic challenges and the travel behavioural changes 5. Saves time	1. Safety reasons 2. Lack of flexibility with your schedule and activities 3. Lack of privacy 4. Less comfort/convenience 5. Low reliability 6. Low awareness regarding CP 7. Uncertainty on how to use
Opportunities	**Threats**
1. Reduction of road congestion in urban areas 2. Reduction of air pollution 3. Eco-friendly transportation 4. Cultivates an eco-friendly mindset 5. Reinforces bonding within the (academic) community 6. Adoption of sustainable transport mode 7. New job opportunities 8. Increase in parking spaces	1. Discredit due to unsuccessful previous initiatives 2. Acceptability (commuters) 3. Conflict of interest with taxi drivers/bus owners

Chapter 4. Transportation in the COVID-19 pandemic era

4.1 Introduction

Undeniably, the COVID-19 pandemic is causing a series of adverse impacts. Given that the escalation of the outbreak is a public health emergency, governmental authorities around the world have adopted a mix of interventions to help the delay of the pandemic, giving health care systems time to prepare and assimilate the impact. As containment is the major pillar in these strategies, lockdowns and other coordinated restrictive measures are regarded as necessary to curtail the immense threat and save lives.

In that framework, the Greek government, on March 11, 2020, with a legislative act, decided the temporary suspension of schools/educational institutions, courts, and prosecutors' offices. Three days later, on March 14, 2020, shopping malls, restaurants, cafes, entertainment centers, libraries, cinemas, theatres, sports facilities, hairdressers and beauty salons closed. Furthermore, the authorities forbade access to religious places (16/3/2020), and alongside suspended the operation of retail stores, except from supermarkets, grocery stores, and pharmacies (18/3/2020). Banks and gas stations also remained open. Concomitantly, on March 16, 2020, the government suggested self-isolation and applied restrictions to citizens' movement, while a week later, on March 23, set in effect a curfew (Various, 2020d). Furthermore, to enhance social distancing, remote working policies were implemented.

The disruption and implications of these measures are noticeable in every sector. Regarding the transport sector, on the one hand, significant changes in the citizens' travel patterns can be observed. On the other, subjects such as public transport, shared mobility (e.g., carpooling), and sustainable mobility need to be reconsidered, not only because of the sharp decline in travel demand but also due to behavioral change of individual users.

Nevertheless, as people still need to transport either for work, doctor visits, or their basic needs (supermarket, pharmacy, etc.), a series of questions emerge. Which transport mode do the commuters choose today, and to what extent has the coronavirus outbreak affected their travel habits? Is there a shift towards active transport modes (walking, cycling)? Can be detected a general change of mobility behavior? Those above are only some issues that are seeking answers.

After 42 days of strict quarantine, the new SARS-CoV-2 cases declined significantly, and the spread of the virus seemed to be under control. Hence, the government decided on the gradual de-escalation of the confinement measures. Considering that the re-launch of economic and other activities should not jeopardize public health, the recovery plan involved several phases.

From 4 May, 2020, citizens could move freely within their prefecture of residence, and the smaller retailers and some services were allowed to reopen (e.g., bookstores, electric appliance stores, sports stores, hairdressers). One week later (11/5/2020), all retail stores reopened, while senior high school students resumed classes. The next stage towards normalization was

implemented on 18 May, 2020, with the opening of middle and high school classes as well as shopping malls, botanical gardens, zoo, and archaeological sites. Moreover, free travel between regions on the mainland and to the island of Crete also restarted.

Subsequently, restaurants and cafes (with customers only in outdoor space) returned to business (25/5/2020), and ferry services resumed. Later, on 1 June, lockdown restrictions were lifted for hotels, open-air cinemas, and public swimming pools. Primary school students also returned to classes. The next phase of the measures' relaxation involves the reopening of gym centers and seasonal tourist accommodation facilities, as well as the restoration of international flights (Various, 2020d).

As the confinement measures are easing and we are stepping into the post-lockdown period, a whole new series of questions emerge. How has quarantine affected people's mobility behaviours? Have the citizens developed travel patterns that they maintain and after the lockdown lifting? Do they feel safe to use public transport or to share a car ride?

Although research on transportation might appear as a paradox in the challenging period of quarantine due to the daily commuting restrictions, the circumstances offer a unique opportunity. The ability to register the changes in traveling could be significantly useful for future transport demand management schemes and city planning. The end of the current crisis will require the redesign of sustainable transport systems from a different perspective. Consequently, it is critical to investigate and identify provoked urban mobility shifts to develop effective and resilient transport systems.

4.2 State of the art

Urbanization prevails in the modern world. Nowadays, over half of the global population (55%) resides in urban centers, and according to United Nations, by 2050, this percentage is projected to increase up to 68% (UN DESA, 2018). As cities are expanding, travel demand is escalating, and consequently, urban transportation planning and management become a formidable challenge.

Although transportation plays an essential role in cities' socio-economic development (Eddington, 2006), concomitantly, it generates a series of health adversities that cannot be disregarded. The health impacts of urban transport are a major concern given that numerous studies highlight the positive correlation between transport-related exposures and increased risk of disease, morbidity, and premature mortality (Cohen et al., 2014; Mueller et al., 2016; Khreis et al., 2016).

The dominance of the private motorized transport in urban areas contributes substantially to air and noise pollution, traffic congestion, and physical inactivity; thus, it has detrimental effects on public health and quality of life (Dora, 1999; Black and Black, 2009; Khreis et al., 2017).

Furthermore, a growing body of evidence underscores the health and well-being implications of long commute time (Mattisson, 2016; Chatterjee et al., 2019; Sha et al., 2019).

Considering the above mentioned, urban planners and transport policymakers are shaping the future of mobility services in a way that not only is sustainable and addresses the increasing travel demand, but also ensures the public health and safety.

When we refer to safety, the first issue that crosses our mind is the road or personal safety. However, the COVID-19 outbreak has brought our attention to another parameter: the risk of contamination. Mobility and particularly public transit might contribute to the spread of the disease due to the enclosed spaces and the peoples' agglomeration. As scientists underline, the proximity of commuters inside a public vehicle is a significant risk for infectious diseases. For that reason, public transport systems are highly vulnerable to disease outbreaks (Edelson and Phypers, 2011). On the other hand, the social distancing that epidemiologists encourage, that is to say, at least 2 meters distance between individuals, is incompatible with public transit. Hence, questions such as "How do we keep people using public transport but ensure their safety at the same time?" emerge and demand a feasible and efficient solution.

Besides public transportation, the shared mobility sector was also severely affected by the pandemic, provided that according to experts, the SARS-CoV-2 virus can live for hours or even days on hard surfaces (Van Doremalen et al., 2020). Therefore, shared vehicles could be vectors for transmissions. In the same vein, carpooling might likewise be a source of contagion due to the small and confined space.

Nevertheless, the changes in transport activities stemmed from COVID-19 exert a substantial impact on environmental quality. Since road transport in cities with lockdowns in place declined between 50% and 75% (International Energy Agency, 2020), air quality improved significantly. More precisely, Le Quéré et al. (2020) estimated that the decrease in daily fossil CO_2 emissions from the quarantine policies was 17%, and surface transport accounts for roughly half of it. Moreover, the increase in active travel modes (walking, cycling) is another benefit of the pandemic, given that it is not only environmentally friendly but also has attributes of social distancing, which is desirable at the moment.

The recent pandemic has considerably changed the face of urban transportation and has brought in the light the weaknesses of the current transport systems/operations. Although it is not the first time that humankind comes across a public health emergency, there is a gap in the transport policies regarding mobility and public health during a pandemic.

However, this public health crisis has also provided us with a unique opportunity to rethink and redesign the urban mobility plans in a more sustainable, more accessible, and more resilient way. Henceforth there will be longer-term changes in transportation designing that will also include pandemics or other types of crises that can cause health implications.

4.3 Study area and research methodology

4.3.1 Study area

The research took place in the cities of Chania and Rethymno. Regarding Chania, according to the latest census the permanent population amounts to 108.642 inhabitants. Notwithstanding, the area of interest was the municipal units of Chania downtown, Akrotiri, and Souda, with 61.275 inhabitants (Hellenic Statistical Authority, 2011). On the other hand, the Municipality of Rethymno amounts to 55.525 permanent citizens, whilst approximately 34,300 of them reside in the city of Rethymno (Hellenic Statistical Authority, 2011).

The climate of the regions is the subtropical Mediterranean, with sunny, dry summers and very mild, rainy winters. Snow and frost are rare near the coast, but quite frequent in the highlands. Concerning the topography, in both cities, the town's center can be described as mild, with minimum elevations. However, in the city of Chania, high altitude differences of over 200 m can be observed to the Akrotiri Peninsula, which extends northeast of the city. It is noteworthy to point out that the Technical University of Crete, a major part of the city's life, is located in the peninsula mentioned above. Last but least, it should be noted that in the city of Rethymno are located three schools of the University of Crete, and therefore the city accommodates a significant number of students.

4.3.2 Research methodology

The current research focused on identifying the critical implications of the pandemic on urban mobility. More precisely, it attempted to shed light on the transformations on daily commuting and analyze the mobility trends. Since the implemented curfew has changed people's life dramatically and therefore their mobility patterns, it was set as a milestone, and the survey was performed in two phases, before and after the quarantine.

Furthermore, it was regarded as crucial to determine the citizens' travel habits in four different periods: a) the pre-pandemic period (January-February), b) the first week of the complete lockdown and the guidelines for self-isolation/movement restrictive measures (16/3-22/3/2020), c) the curfew period (April), and d) the post-quarantine/lockdown period (1/6-7/6/2020). In other words, each phase of the survey was divided into two periods.

Another under investigation topic was the travel mode choice determinants, alongside with the trend on private vehicle use. Moreover, the consequences of the present crisis on travel time were also examined. Last but not least, shared mobility could not be excluded from this study, given that it is an essential component of urban mobility systems, and furthermore, it was significantly impacted by the COVID-19 outbreak. More specifically, the research aimed to assess how safe people feel about travelling in this transport mode.

The study was implemented with the aid of a structured questionnaire (McNeill, 1990; Bechhofer and Paterson, 2000; Burns, 2000), and tested through a pilot study:

1. the development of a structured questionnaire
2. its distribution
3. data gathering/recording
4. data analysis.

The questionnaire included both closed-ended questions (yes-no, ranking, multiple-choice and specified-answer questions) and open-ended ones (Bradburn et al., 2004). Moreover, participants were given the opportunity to state their viewpoint freely on the issue, exchange their ideas and make suggestions.

The survey was conducted online and it was addressed to adult citizens of Chania and Rethymno. The 1st phase was carried out between March 25, 2020, and March 31, 2020, and the 2nd one between June 8, 2020, and June 14, 2020.

In all cases, participants' consent was obtained, and since the questionnaire was anonymous, there was no need to abide by the General Data Protection Regulation (GDPR). The digital format of the questionnaire was created with the tool 'Google forms', and the collected data was analyzed statistically using SPSS v.20 (Green et al., 2000; Apostolakis et al., 2009). Furthermore, it was tested for face-value validity, while its reliability was assessed with the Cronbach alpha coefficient (Cronbach, 1951).

4.4 Results

4.4.1 Socio-demographic characteristics

a. Phase 1

The random sample taken consisted of 308 citizens (56.5% women and 43.5% men). Almost 60% and 30% of the study population are permanent residents of Chania and Rethymno, respectively.

Regarding the participants' age, the majority, 31.2%, belong to the age group of 18-24, while 17.9% are adults between the ages of 25 and 34. Furthermore, approximately one-quarter of them (24.4%) is middle-aged (35-44 years old). The respondents aged 45 to 54 comprise 16.6% of the total, those 55 to 64 years 8.1%, and finally, the 65 years old and over group adds up to 1.9%.

Concerning the respondents' employment status, 33.8% of them are university students. Moreover, 21.8% of those surveyed claimed themselves as self-employed, while 24.4% and

13.3% are working in the public and private sector, respectively. Just a small number, 2.6%, is retired, and an even smaller one, 1.6%, stated to be a homemaker (housewife).

Moreover, the vast majority of those questioned (84.7%) have a valid driver's license, while seven out of ten persons own a vehicle. On the other hand, 47.4% declared that their family possesses two vehicles, and fewer participants, 15.6%, stated to own more than two automobiles. On the contrary, 3.9% of the respondents reported not having a car in their property.

Last, almost 30% of the participants are bike owners, whereas a lower percentage (18.8%) possesses a motorcycle/scooter.

b. Phase 2

In the 2nd phase of the survey, 193 individuals participated, and the analogy between males and females was the same as in stage 1 (56.5% women and 43.5% men). Moreover, almost 55% and 45% of the sample reside permanently in Chania and Rethymno, respectively.

The majority of the respondents, 42.5%, are adults between the ages of 18 and 24, while 14.5% belong to the age group 25-34. Furthermore, 16.6% of the study population is middle-aged (35-44 years old), whereas an almost equal percentage (17.1%) pertains to the age group 45-54. The participants aged 55-64 comprise 8.3% of the total, and those over 65 years 1%.

Concerning the professional status, the majority of the interviewees, 45.1%, studies at the university. Moreover, 21.2% and 12.4% of those questioned declared to work in the public and private sector, respectively. Further, a small number, 15%, claimed to be self-employed, while 2.1% is retired. Finally, six participants (3.1%) stated to be unemployed.

Furthermore, 78.8% of the participants have a valid driver's license, whereas almost six out of ten persons own an automobile. It is interesting to note that two-third of those interviewed (65.9%) stated that their family possess more than one vehicle. In contrast, only 2.6% reported not having a car in their property.

Last, one-third of the respondents possess a bicycle, and a lower proportion (16.1%) is a motorcycle/scooter owner.

4.4.2 Travel characteristics

4.4.2.1 Travel mode choice

The identification of travel mode choice plays a predominant role in the development of sustainable transport systems. Furthermore, it is regarded as vital for the successful transport demand management, particularly during periods of crisis like the current pandemic.

a. Phase 1

In order to determine the impact of the restrictive measures on people's travel mode choice and discern the differences, we investigated the daily commute patterns in two periods: (i) during the period January – February, and (ii) during the first week of the restricted movement implementations (16/3 – 22/3).

i) First period (January-February)

As shown in Table 4.1, car use and walking were the prevalent modal choices for everyday commutes. More precisely, almost four out of ten participants opted for travelling by car daily, either as a driver (39.3%) or as a passenger (3.9%). An equal percentage, 42.5%, chose walking, while almost 10% used public transport (bus) or another 10% transported by motorcycle. Furthermore, hardly any of the respondents (0.6 %) used a taxi or drove an e-scooter.

It is noteworthy that although the percentage of the car passengers was relatively low referring to everyday transport (3.9%), the proportion increases significantly concerning the trips made once or twice a week, given that almost one-quarter of citizens opted for this travel mode. Concerning public transport, the higher usage, 12.7%, was observed for commutes made three to four times a week. Finally, regarding cycling, almost three-quarters of those surveyed did not use the bicycle for commuting during this period.

Table 4.1 Travel mode choice (%) (phase 1)

	Daily		3-4 times per week		1-2 times per week		Never	
	January-February	16/3-22/3	January-February	16/3-22/3	January-February	16/3-22/3	January-February	16/3-22/3
Car (driver)	39.3	29.5	15.6	8.4	10.1	24.0	27.3	38.0
Car (passenger)	3.9	4.5	12.0	6.5	26.0	25.6	24.0	63.3
Motorcycle (driver)	9.4	6.8	4.2	2.9	3.2	7.1	80.5	83.1
Motorcycle (passenger)	1.0	0.3	2.6	3.2	3.6	3.6	86.7	92.9
Bus	9.7	2.6	12.7	2.9	6.5	8.8	56.8	85.7

Taxi	0.6	-	1.9	2.9	2.6	3.9	75.6	93.2
E-scooter	0.6	-	2.6	2.3	1.0	2.3	94.5	95.5
Bicycle	3.9	2.3	6.2	4.2	7.1	10.4	73.7	83.1
Walking	42.5	26.6	19.5	19.8	14.6	27.3	11.7	26.3

ii) Second period (16/3-22/3)

It can be observed that, during the first week of the restrictive measures, the majority of the citizens reported opting for driving a vehicle (29.5%) or walking (26.6%) for daily commuting. It is notable that the substantial decline in the use of public transport. As illustrated in Figure 4.1, the daily use of the bus decreased by 7.1%, and a more significant reduction, 9.8%, observed for commutes made three to four times a week. In contrast, the percentage of persons who used public transport less, that is to say once or twice per week, increased by 2.3%. Furthermore, in the table above is apparent that participants who did not use the bus at all during this period (16/3-22/3) were 30% more versus those of the previous period (January-February).

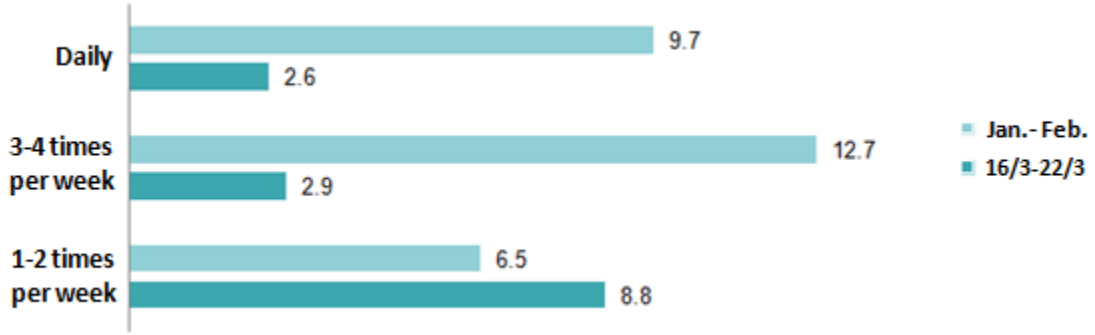

Figure 4.1 Public transport use (%) (phase 1)

Another remarkable finding concerns walking. Although there was no significant difference for the non-daily commute (3-4 times per week), a sharp decline of 15.9% observed for daily transport. On the contrary, the proportion of the participants who chose walking one to two times a week almost doubled (Figure 4.2).

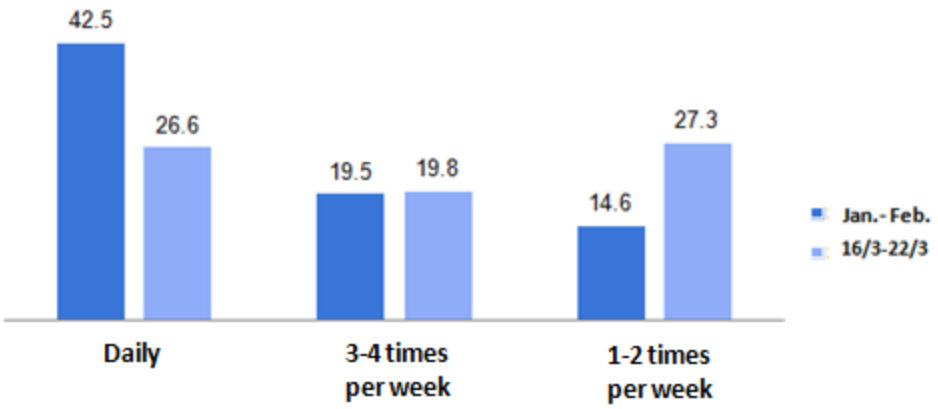

Figure 4.2 Walking (%)

A general observance is that citizens, due to the restrictive actions limited their daily or regular (3-4 times per week) commute. In other words, the findings revealed that they reduced their transportation to once/twice a week, perhaps only for their basic needs.

Furthermore, the data revealed that during this period, the percentage of citizens that avoided driving their private vehicle was 10.7% higher than that of the period January-February (Figure 4.3). Moreover, the commuters who did not travel by car as passengers increased by 39.3% (24% in January-February, versus 63.3% the week 16/3-22/3). A similar trend was observed for taxi use, given that 17.6% more participants did not opt for that transport mode.

Concerning cycling, contrary to expectations, it was not observed an increase in the number of bike users. More precisely, the proportion of citizens who did not use a bicycle during the week 16/3-22/3 was 9.4% higher than that of the previous period (January-February). This unanticipated finding suggests that although cycling is an ideal transport mode during the pandemic as it ensures physical distancing, people did not opt for it due to cultural barriers and lack of infrastructure. Apart from that, during that week, the majority of the citizens significantly limited their daily commutes, and either did not travel at all or transported only for their basic needs (e.g., supermarket, groceries), which might not be so convenient to perform by riding a bike.

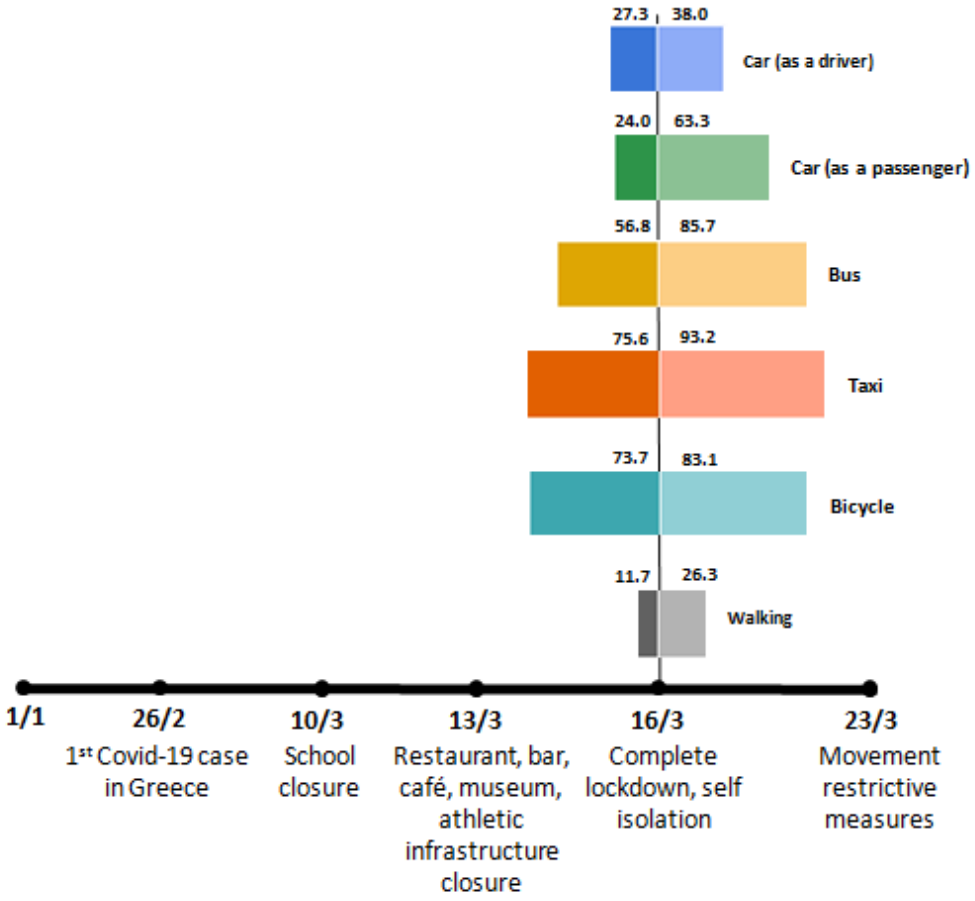

Figure 4.3 Not using transport mode (%), compare between the two periods (January-February and week 16/3-22/3)

In order to summarize the above results and find a possible (psychological) explanation of the respondents' behavior for the time interval 16/3-23/3, we run exploratory factor analysis/ e.f.a. i.e. we tried to find out factors/latent variables explaining the data. The analysis gave two (new) factors: one factor loads the variables "car (driver)", "walking", and the other one loads the variables "car (passenger)", "motorcycle (driver)", "motorcycle (passenger)", "bus", "bicycle", "e-scooter" and "taxi". We could name the 1st factor "restrictions' driven, transport means, choices " and the 2nd factor "secondary, transport means, choices" (Figure 4.4). Here, for the requirements of the analysis, KMO=0.801 showing sampling adequacy, for Bartlett's test $p<0.05$ and factors explain 53.86% of the common variable variance. The factor loadings (using Varimax rotation) on the latent variables can be seen in the following two equations:

Y_1=-0.760*Car (driver) +0.712*walking

Y_2=0.517*Car (passenger)+0.505*motorcycle (driver)+0..785*motorcycle (passenger)+

+0.626*bus+0.601*bicycle+0.900*scooter+0.849*taxi

We notice that the loadings/coefficients of the two equations are above 0.5 and in many cases above 0.7 which indicates a strong correlation between a variable and a factor, so the variable contributes greatly to its interpretation. The results of the analysis are in accordance with the ones of the above descriptive analysis, and also with what someone (probably) expects since the usual means of transport during the restricted measures' week (mainly attributed to these measures) were the car (as a driver) and walking.

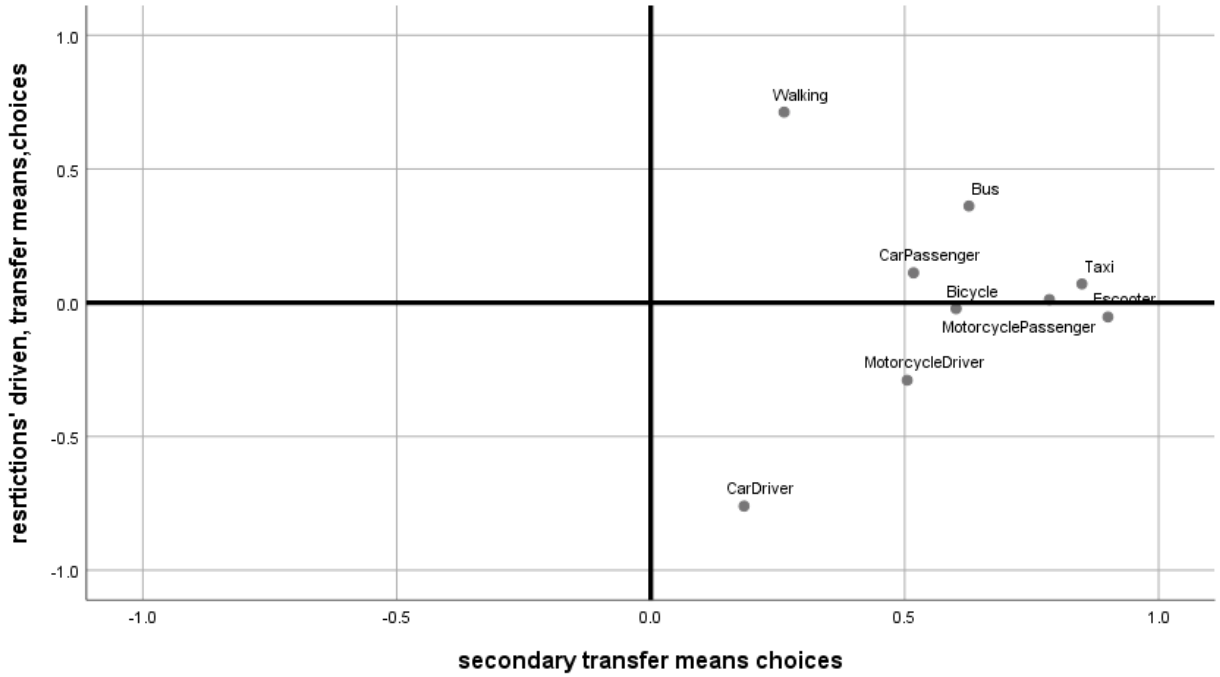

Figure 4.4 Coordinates of the variables (means of transport) in factors'

b. Phase 2

In order to identify the impact of the curfew on citizens' modal choice and determine the mobility trends that are being shaped as the confinement measures subsidy, we investigated the daily commuting behaviours in two periods: (i) during April (the strict quarantine/complete lockdown period), and (ii) during the week 1/6-7/6, when the majority of the measures had been lifted.

i) First period (April)

As can be seen in Table 4.2, there is a clear trend towards walking regarding daily commuting. According to data, more than half of the study population (53.9%) chose this transport mode for everyday urban traveling. However, no similar tendency was detected for cycling, provided that bike trips did not exceed 11.9%.

Furthermore, the percentage of car drivers during quarantine was relatively low, since it reached 15%, with no significant differences between the daily trips and the less frequent ones. On the other hand, the number of persons who transported by car but as a passenger tripled for commutes made once or twice a week compared to the more frequent ones (daily/3-4 times per week). This observation underscores the fact that citizens followed the regulations and limited their transportation significantly to once/twice a week.

Last, it is critical to note that in April, hardly any citizens used public transport. More specifically, the proportion of bus users ranged between 1% and 5.2%.

Table 4.2 Travel mode choice (%) (phase 2)

	Daily		3-4 times per week		1-2 times per week		Never	
	April	1/6-7/6	April	1/6-7/6	April	1/6-7/6	April	1/6-7/6
Car (driver)	15.0	32.6	16.1	17.6	17.1	9.8	41.5	39.9
Car (passenger)	5.7	5.2	6.2	15.0	19.2	35.8	42	44.0
Motorcycle (driver)	5.7	7.3	7.3	8.3	4.1	3.6	80.3	80.8
Motorcycle (passenger)	2.1	1.0	4.1	6.2	3.1	7.3	84.5	85.5
Bus	1.0	1.0	5.2	9.8	3.1	17.6	80.8	71.5
Taxi	0.5	-	4.1	4.7	1.6	6.2	88.1	89.1
E-scooter	1.0	1.0	4.7	3.6	0.5	-	91.7	95.3
Bicycle	6.2	8.8	9.3	6.2	11.9	6.7	64.2	78.2
Walking	53.9	46.1	19.7	21.8	17.1	19.2	4.1	13.0

ii) Second period (1/6-7/6)

The results obtained from the survey revealed that as the city gradually recovers from the lockdown, car use reemerges and holds a significant share in urban transportation. As shown in the table above, the percentage of respondents who opted to drive their private vehicle on a daily basis in the first week of June doubled compared to the daily use during April (32.6% in June, versus 15% in April). On the other hand, the commuters who travelled by car but as passengers increased remarkably, 16.6%, for the journeys realized once/twice a week, while an uptake of 8.8% was observed for the more regular commutes (3-4 times per week).

The observed increase in daily car use may be correlated with the decline in walking (from 53.9% to 46.1%). Moreover, the 9% rise in the individuals who preferred travel by another means of transport than walking, underlines the fact that the swift towards active transportation was not permanent and subsided alongside with the lifting of the lockdown measures.

The above mentioned can also be concluded from the notable decline in bike trips. More precisely, the number of people who did not cycle for urban transportation increased by 11% in the first week of June. This finding might be attributed to the increased number of cars and the subsequent limited road safety, given the lack of bike networks. Nonetheless, a small percentage of people (2.4%) used more their bicycles daily in early June than in April.

Regarding public transit use, as illustrated in Figure 4.5, although no difference was detected for daily trips, the regular journeys (3-4 times per week) were increased by 4.6% in June (1/6-7/6). However, the rise in bus commutes realized once or twice a week was substantially higher, 14.5%. Furthermore, it is noteworthy that participants who avoided using public transit were 9% less versus those of the previous period (April). This finding illustrates that citizens become less reluctant and skeptical concerning using public vehicles. In other words, there are signs that the public transportation sector slowly recovers and regains its ridership. Nonetheless, it is a long way ahead, provided that seven out of ten persons did not use the bus at all during this period (1/6-7/6).

Furthermore, it should be noted that the vast majority of the study population, almost 90%, avoided using a taxi both in April and early June.

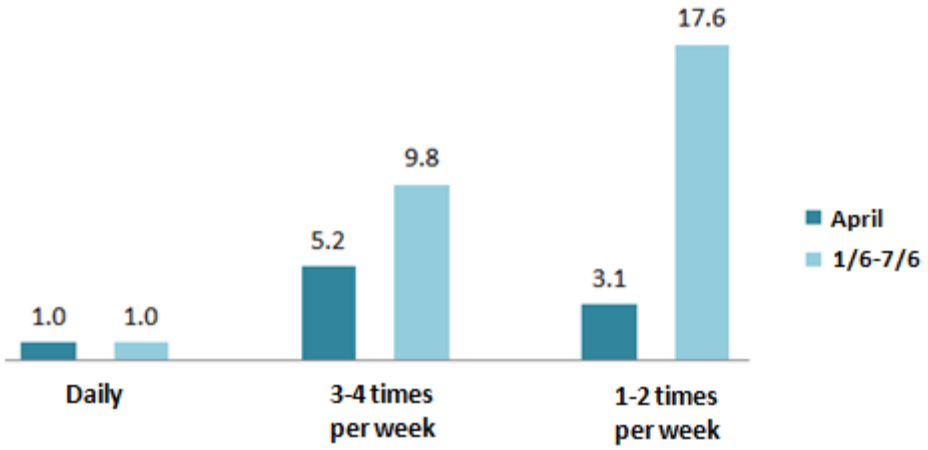

Figure 4.5 Public transport use (%) (phase 2)

A comparison of the daily travel mode choice in the four different time periods, January-February, 16/3-22/3, April, and 1/6-7/6, reveals that in both cities, Rethymno and Chania, the predominant transport mode is walking. As can be seen in Figure 4.6, the percentage of citizens that chose walking for daily commutes during curfew was 11.4% higher than that of the period January-February, and although a decline was observed after the lifting of restrictive measures, the proportion (46.1%) remains higher than the one that registered at the beginning of the year (42.5%).

Furthermore, a similar trend can be identified in cycling. More precisely, the daily bike trips increased by 4.9% in the post-curfew period (3.9% in January-February, versus 8.8% the week 1/6-7/6). The previously mentioned observations dictate a slight increase in active transportation that cannot be disregarded.

Concomitantly, the number of daily car journeys performed in early June was approximately 7% lower than those who realized in January-February. This finding reinforces the slight change in the citizen's travel behaviour towards environmentally friendly transport modes. Nonetheless, private vehicle use still holds a considerable share in urban transportation. This might also be associated with the sharp decline (8.7%) in public transit use between January-February and April, and the surprisingly low percentage of public transport ridership (1%).

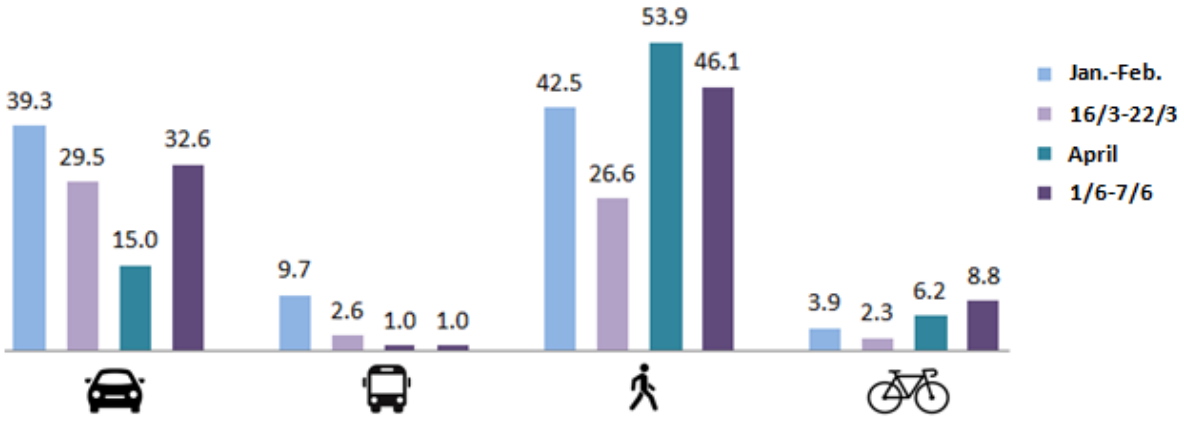

Figure 4.6 Daily travel mode choice (%)

A striking yet unexpected observation is that although there was a relative increase in daily bike journeys after lockdown, the percentage of citizens who did not use a bicycle during the week 1/6-7/6 was 4.5% higher than that of the beginning of the year (Figure 4.7). Consequently, it may be assumed that the increased traffic and the lack of proper infrastructure hinder people from cycling, considering that bike users increased during April. However, cultural barriers also impede city cycling from blossoming, since the proportion of non-cyclists is relatively high for Rethymno and Chania, considering they are small, seaside Mediterranean cities.

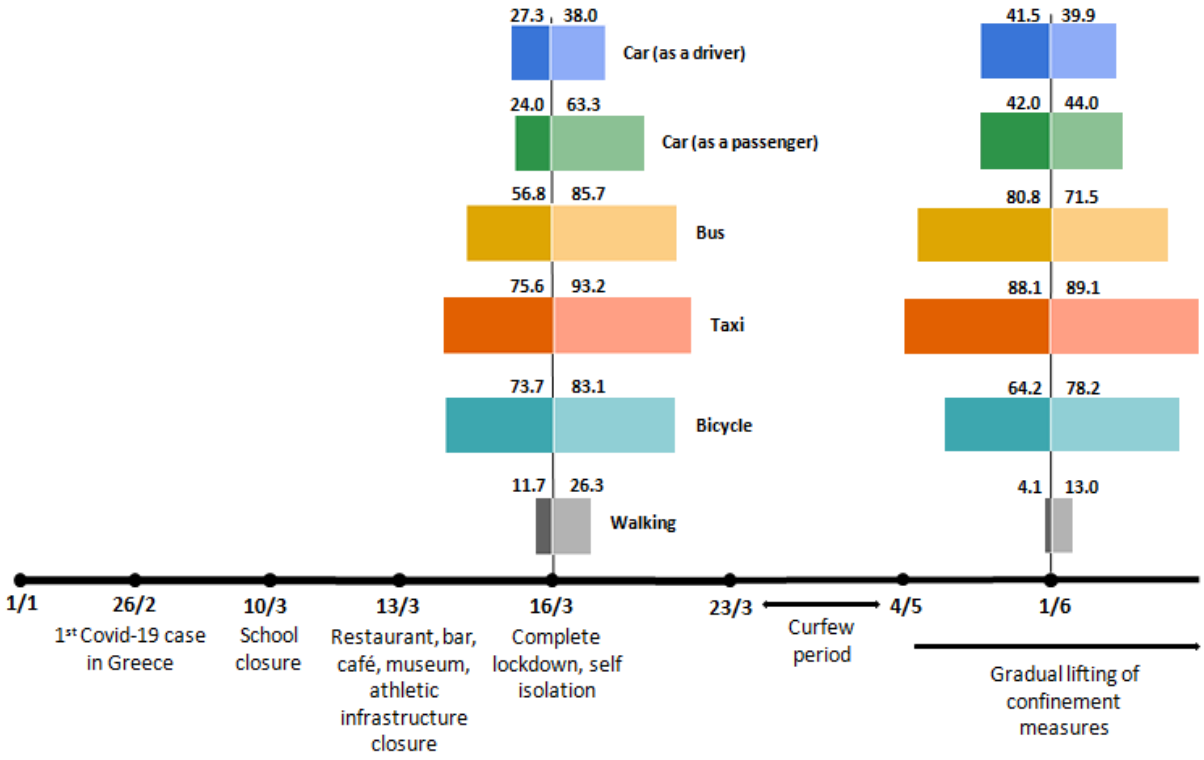

Figure 4.7 Not using transport mode (%), compare between the two periods (pre-quarantine and post-quarantine)

4.4.2.1 Travel time

a. Phase 1

As shown in Table 4.3, for the vast majority of the participants, the travel time for commuting to the workplace is up to thirty minutes. It is noteworthy that during the week of the restrictive measures, although no significant difference was observed for the longer commutes, that is to say for trips longer than half an hour, a decline of 9% was detected for the trips between fifteen and thirty minutes. Moreover, an even higher decrease in travel time, 12%, was noticed for the shorter commutes, that is, for trips less than fifteen minutes. Similarly, equivalent decreases were observed in travel time for university commute for both trips less than fifteen minutes (11.7%), and those between 15-30 minutes (8.8%).

Table 4.3 Travel time for commuting to the workplace/university (%) (phase 1)

	Workplace		University	
	January-February	16/3-22/3	January-February	16/3-22/3
<15'	61.1	73.1	40.4	52.1
15'-30'	29.7	20.7	45.8	37.0
31'-45'	7.0	5.9	10.2	9.6
46-60'	0.9	1.6	1.8	1.4
>60'	0.9	0.5	1.8	-

Furthermore, a similar trend was noticed in both cities, Rethymno and Chania, regarding transportation to the workplace. More precisely, while 70.3% of participants in Rethymno travelled less than fifteen minutes for commuting to work during January-February, the week 16/3-22/3, the proportion was 77.4% (Figure 4.8). As for the city of Chania, the equivalent numbers were 59.7% versus 70.0%.

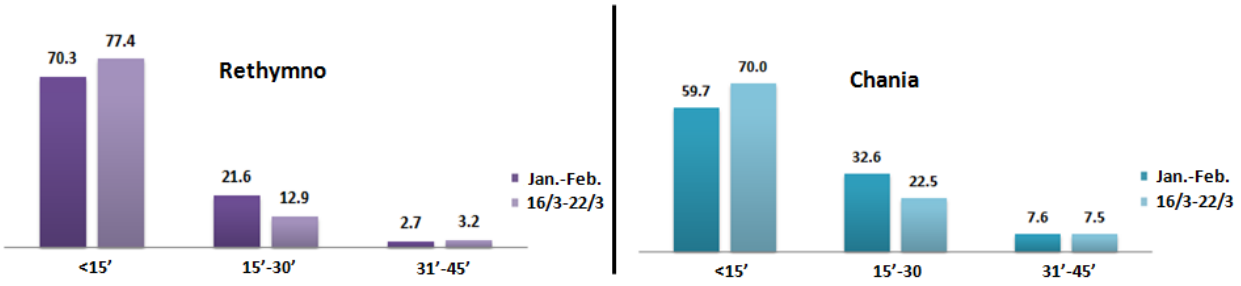

Figure 4.8 Travel time for commuting to the workplace in the cities of Rethymno and Chania (%) (phase 1)

These differences might be attributed to the reduced traffic congestion since many people limited their daily transportation significantly and stayed at home. In addition, this finding could relate to the remarkable decline in public transport. In other words, it is possible that commuters instead of public transit opted for using a private car.

Finally, it should be mentioned that generally, citizens of Chania need more time to commute to their workplace. That might be correlated with the size of the city and the higher density of the population.

b. Phase 2

Undoubtedly, the easing of the lockdown measures affected travel time. As Table 4.4 shows, regarding transport to the workplace, there is an increase of 5% for the short commutes (less than fifteen minutes). Furthermore, an almost equal rise (5.4%) was observed for the trips between fifteen and thirty minutes. However, no significant impact was identified on longer commutes, that is, for trips longer than half an hour.

A similar trend was detected in travel time for commuting to the university. More specifically, the time needed to transport to the university campus increased by 4.9% for trips less than fifteen minutes, while the increase for those between fifteen and thirty minutes was insignificant (1.5%).

Table 4.4 Travel time for commuting to the workplace/university (%) (phase 2)

	Workplace		University	
	April	1/6-7/6	April	1/6-7/6
<15'	67.3	62.3	48.9	44.0
15'-30'	23.5	28.9	35.6	37.1
31'-45'	3.1	3.5	6.7	9.5
46-60'	4.1	3.5	4.4	6.9
>60'	2.0	1.8	4.4	2.6

Concerning time spend in home-to-work travel in the city of Rethymno (as demonstrated in Figure 4.9), during curfew, 78% of the participants travelled for less than fifteen minutes. However, during the week 1/6-7/6, that proportion decreased by 10.2%. At the same time, the percentage of commuters that travelled for fifteen to thirty minutes increased by 9.7%. A somewhat unanticipated outcome is the fact that we cannot observe the same for the city of

Chania. In other words, regarding Chania, no significant changes in commute time were detected between April and early June.

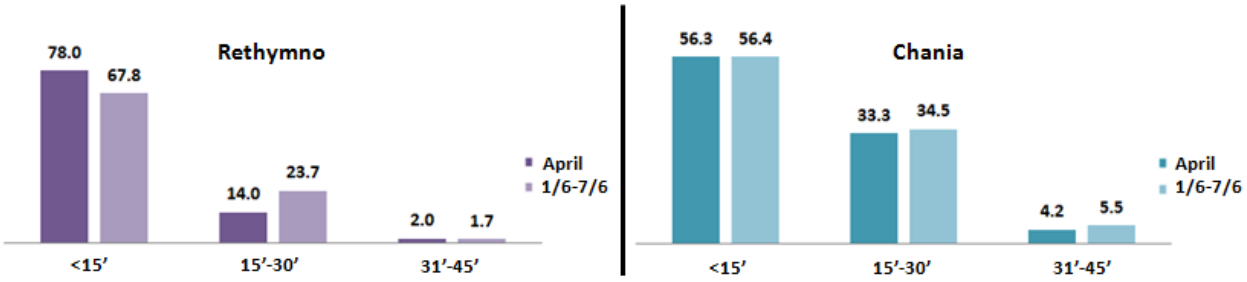

Figure 4.9 Travel time for commuting to the workplace in the cities of Rethymno and Chania (%) (phase 2)

It is evident that in the post-quarantine period, the reappearance of private car use that we mentioned in the above section generates traffic congestion and, therefore, impacts commute time.

Nonetheless, by comparing travel time between January-February and the week 1/6-7/6, it can be seen that in June, citizens needed less time for commuting either to the workplace or the university. This observation may be attributed on the one hand to the decrease in daily car journeys (see Figure 4.6), on the other, to the fact that the 'new normality' has not been reached yet, and share of the population still limits its transportation (e.g., teleworking, e-learning, etc).

4.4.3 Travel mode choice determinants

a. Phase 1

A crucial question is which factors influence individual travel mode choice? According to data, road safety is of paramount importance for 80.5% of the participants. An equal percentage, 80.5%, declared that personal safety is a major driver regarding travel mode choice. Furthermore, travel time plays a predominant role for almost three-quarters of those surveyed, while approximately 58% consider very important the travel cost. Interestingly enough, flexible departure time classified as "very important" by the 73.4% of the respondents, whereas weather conditions and surprisingly, ecological footprint listed as factors of high priority by almost half of the study population (Figure 4.10).

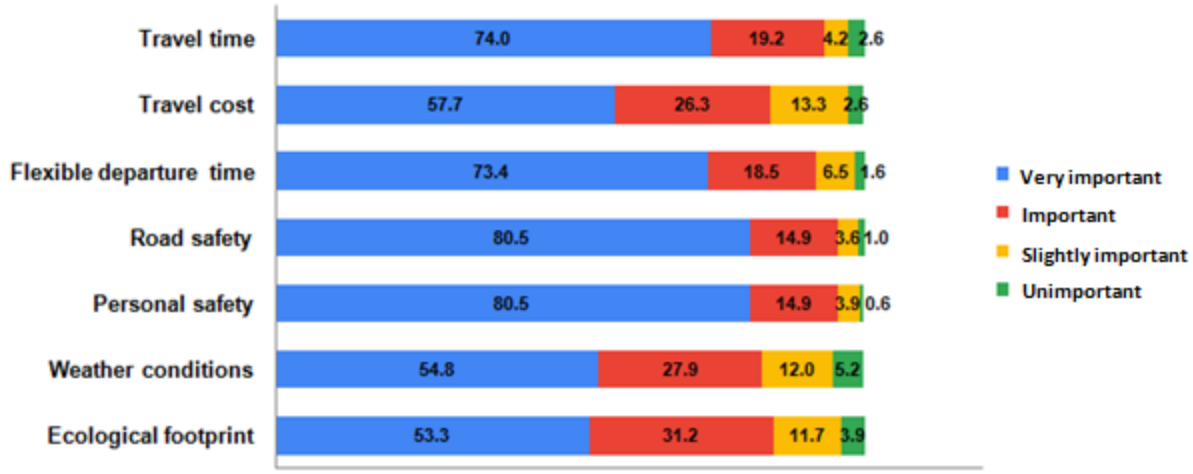

Figure 4.10 Travel mode choice determinants (%) (phase 1)

Nevertheless, most of the aforementioned factors affect men and women differently. From the table below (Table 4.5), it is apparent that personal safety and road safety are significantly more important for women. More specifically, six out of ten women reported them as "extremely important", while almost 40% of men shared the same opinion. Furthermore, flexible departure time, weather conditions and travel cost are determinants that have a higher impact on the female population. Even though flexible travel time seems more important to women, the difference is not (statistically) significant. Finally, ecological footprint is a less essential parameter for travel mode choice for men.

Table 4.5 Travel mode choice determinants (%) with reagard to gender (phase 1)

	Travel time		**Travel cost**		**Flexible departure time**		**Road safety**		**Personal safety**		**Weather conditions**		**Ecological footprint**	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Extremely important	38.1	**46.0**	23.9	**31.6**	31.3	**36.2**	42.5	**58.6**	41.8	**59.2**	21.6	**28.2**	14.9	**27.0**
Very important	**34.4**	29.3	23.1	**34.5**	35.1	**42.5**	**32.8**	25.9	**32.1**	26.4	25.4	**32.8**	28.4	**33.9**
Important	17.9	**20.1**	**34.3**	20.1	**23.1**	14.9	**19.4**	11.5	**19.4**	11.5	**30.6**	25.9	**32.8**	29.9
Slightly Important	**6.0**	2.9	**15.7**	11.5	**9.0**	4.6	**3.7**	**3.4**	**6.0**	2.3	**12.7**	11.5	**17.9**	6.9
Unimportant	**3.7**	1.7	**3.0**	2.3	1.5	**1.7**	**1.5**	0.6	**0.7**	0.6	**9.7**	1.7	**6.0**	2.3
x^2 test of independence	non significant		x^2=11.845, p-value=0.019		non significant		non significant		x^2=11.103, p-value=0.025		x^2=12.639, p-value=0.013		x^2=16.511, p-value=0.002	

b. Phase 2

A question that emerges is, did the quarantine affected people's opinion regarding travel mode choice determinants? Unlike the 1st phase of the survey, personal and road safety, although they are quite significant factors for modal choice, do not come first on the list, since, 79.3% of those interviewed considering that in the 2nd stage, flexibility in departure time is the key driver for choosing transport mode. On the other hand, travel time plays a crucial role for 77.7% of the participants, while approximately 76% declared that personal safety is very important (Figure 4.11).

An entirely unexpected result is that road safety comes 5th on the list (74.1%), whereas travel cost is substantially vital for almost seven out of ten individuals. Furthermore, as in the previous phase of the research, weather conditions and ecological footprint are not factors of paramount importance, provided that significantly lower percentage of respondents classified them as "very important" (58.6% and 57.0%, respectively).

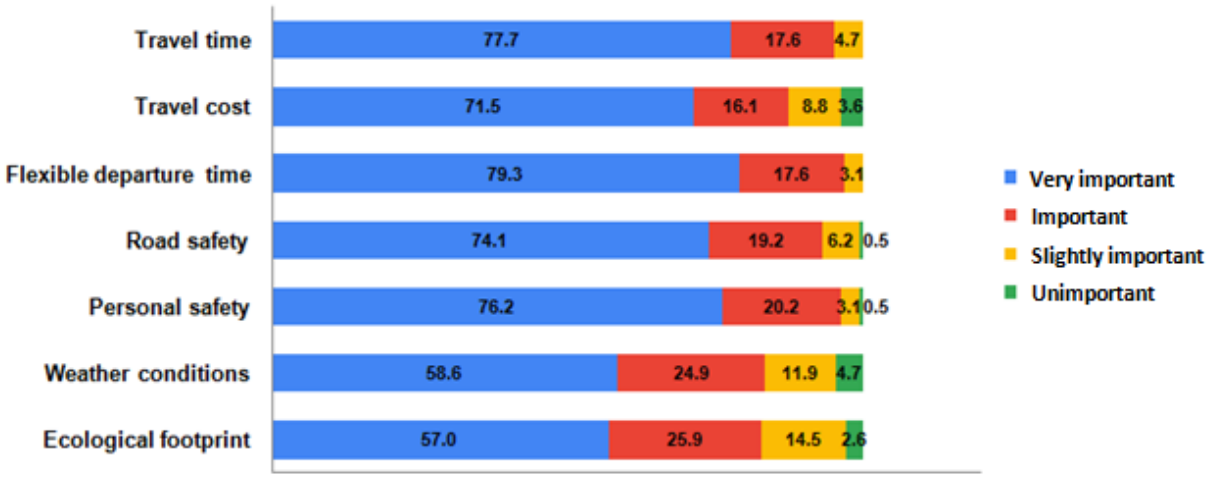

Figure 4.11 Travel mode choice determinants (%) (phase 2)

From the aforementioned, it becomes evident that travel mode choice priorities differ to some extent between the two phases of the survey. The most significant difference was identified for travel cost, provided that 13.8% more participants consider is a major determinant for modal choice (57.7% in phase 1, versus 71.5% in phase 2). The reason for that change is not completely clear, but it may be correlated with the economic challenges that several people are experiencing due to the lockdown.

Although personal safety lost significance for 4.3% of those questioned, the impact factor that has on the female population remains the same as previously (Table 4.6). Additionally, flexible

departure time concerns more women, alongside with travel time. On the other hand, travel cost appeared to be a less essential parameter for males, while weather conditions and ecological footprint also have a minor impact on them. Finally, regarding road safety, no significant differences were detected between men and women

Table 4.6 Travel mode choice determinants (%) with regard to gender (phase 2)

	Travel time		Travel cost		Flexible departure time		Road safety		Personal safety		Weather conditions		Ecological footprint	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Extremely important	38.1	**57.8**	28.6	**35.8**	33.3	**47.7**	46.4	**50.5**	42.9	**50.5**	16.7	**31.2**	19.0	**22.0**
Very important	**32.1**	25.7	**40.5**	37.6	36.9	**38.5**	23.8	**26.6**	25.0	**32.1**	31.0	**35.8**	34.5	**37.6**
Important	**23.8**	12.8	15.5	**16.5**	23.8	12.8	**20.2**	18.3	**25.0**	16.5	**32.1**	19.3	28.6	**23.9**
Slightly Important	**6.0**	3.7	8.3	**9.2**	**6.0**	0.9	**8.3**	4.6	**6.0**	0.9	**17.9**	7.3	**15.5**	13.8
Unimportant	-	-	**7.1**	0.9	-	-	**1.2**	-	**1.2**	-	2.4	**6.4**	2.4	**2.8**

4.4.4 Travel behaviour

To better predict future transportation requirements, knowledge about travel behaviour across transportation modes is considered as vital, since it forms the basis for transport models used in transport planning. Concomitantly, data on travel behaviour and trends is equally important for policymakers provided that enables them to make significant progress in encouraging sustainable urban mobility.

a. <u>Phase 1</u>

Regarding car usage, just over one-third of the participants declared being satisfied with the degree of using a private vehicle and finds no reason to reduce it. Furthermore, 23.7% of the study population reported that they have already decreased car usage for their daily commute by opting for alternative modes of transport, such as bus, cycling or walking. Additionally, a small percentage (7.1%) has been thinking about limiting automobile usage and travel with other transport modes.

On the other hand, 10.4% of those questioned commented that they have been thinking of substituting public transport with active transport modes (cycling, walking). Last, the data

revealed that hardly any citizens (1.9%) were considering replacing public transport (bus, taxi) with private car.

b. Phase 2

Concerning private vehicle use, 29.5% of the study population declared that they have already limited car usage for daily urban travel and instead choose public transit or active transport modes, while an additional 9.3% has been thinking about performing the same. On the contrary, one-quarter of the participants expressed no interest in reducing automobile use.

Data also demonstrated that a small percentage, 12.4%, has been considering opting for cycling or walking in place of public transport. Finally, very few participants (4.7%) stated that they have been thinking of substituting public transit with private car.

The single most conspicuous observation to emerge from the data comparison is the trend of reduced car use. As shown in Table 4.7, in the post-lockdown period, approximately 6% more citizens' reported having decreased private vehicle use, while the percentage of interviewees that are thinking about performing so increased by 2.2%. In the same vein, 11% fewer participants appeared reluctant to limit automobile use and opt for other transport modes.

Furthermore, it is fundamental to note that there might be a decline in public transit ridership since 2% more people consider limiting the use of public transport and walk or cycle instead. Moreover, the fact that 2.8% more commuters prefer to travel by car rather than ride the bus reinforces the previously mentioned speculation.

Table 4.7 Citizens' travel behaviour

	Phase 1	**Phase 2**
No intention of reducing car use	**35.4**	24.4
Thinking about reducing car use	7.1	**9.3**
I have already reduced car use	23.7	**29.5**
Thinking about reducing public transport use and walk or cycle instead	10.4	**12.4**
Thinking about reducing public transport use and travel by car instead	1.9	**4.7**

4.4.5 Participants' attitudes on restricted movement measures

a. Phase 1

An under investigation topic was the consequences that had the restrictive measures on citizens' commute.

According to data, 22.1% of the study population did not travel at all and stayed at home. Furthermore, half of the participants reduced their weekly transportation by 75%, while a smaller number, 17.5%, limited commuting by half. Approximately 8% of those interviewed reported limiting travelling by only 25%, whereas very few respondents (1.9%) maintained their usual travel schedule, and they did not restrict their daily commutes at all (Figure 4.12).

Nonetheless, it should be mentioned that according to findings, the overwhelming majority of the participants abide by the novel regulations since seven out of ten persons limited their daily trips by 75% or more.

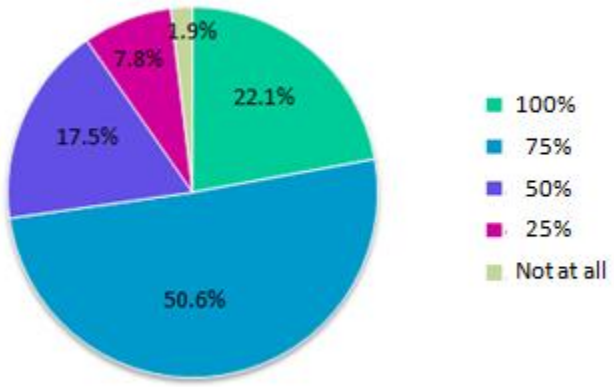

Figure 4.12 Decrease in commuting (week 16/3-22/3)

Nevertheless, are there noticeable variances between the cities of Rethymno and Chania? The graph below (Figure 4.13) indicates that overall there are no significant differences between the two populations concerning commuting reduction by 100% and 75%. However, a difference of 7.5% can be seen between the persons who reduced their transportation by half. More precisely, in Rethymno, fewer citizens limited commuting by 50% than in Chania. In addition, a slighter difference of almost 6% can be observed for the transportations that were cut down by one-quarter. In that case, residents of Rethymno restricted more the travelling opposed to citizens of Chania.

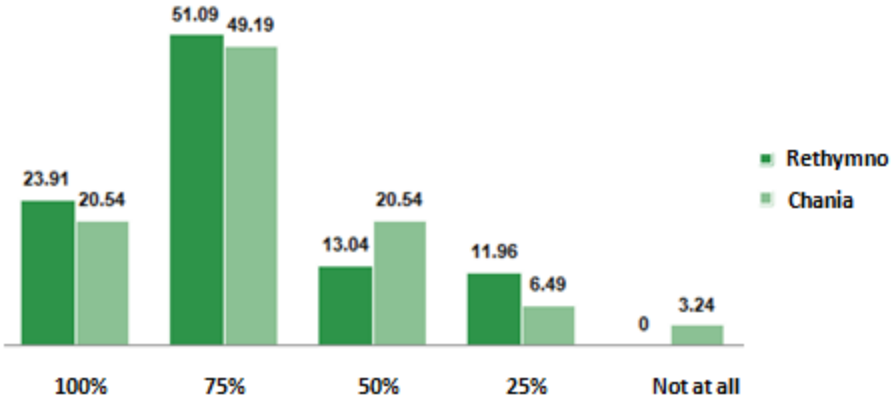

Figure 4.13 Decrease in commuting (%) during the week 16/3-22/3 in the cities of Rethymno and Chania

Another interesting finding is associated with the different attitude on the restricted movement measures according to age. Which age group limited more its daily commuting? Although all age groups are at risk of the virus, experts underscore the fact that older people are facing the most threats and challenges. Hence, it is imperative for them to stay at home as long as possible. On the other hand, sometimes the younger generation has lower risk perception on a given situation, and further young people are used to commute and socialize a lot; thus, it might be more challenging for them to stay indoors.

Notwithstanding, unexpectedly, the age group 18-24 showed the highest rates of 100% and 75% decrease in commuting with percentages 32.3% and 56.2%, respectively (Table 4.8). This finding should be linked with the fact that universities and educational institutions have been closed since March 10, 2020, in an attempt to contain the spread of the pandemic. Still, it should be noted that youngsters followed the regulations strictly and kept social-distancing.

Table 4.8 Decrease in commuting (%) during the week 16/3-22/3 with regard to age

	18-24 years old	25-34 years old	35-44 years old	45-54 years old	55-64 years old	>=65 years old
100%	32.3	21.8	16.0	17.6	12	16.7
75%	56.2	43.7	50.6	47.1	52	50
50%	8.3	21.8	22.7	21.6	16	33.3
25%	1.1	10.9	8.0	11.8	20	-
Not at all	2.1	1.8	2.7	1.9	-	-

Furthermore, as Figure 4.14 illustrates, at least half of the participants of almost all age groups limited their commuting by 75%. Regarding older people, the data revealed that only 12% of those aged 55-64 did not transport at all, a percentage that is considerably lower than that of the age group 18-24 (32.3%). Moreover, one-third of the oldest age group, >=65 years old, restricted daily travelling by half.

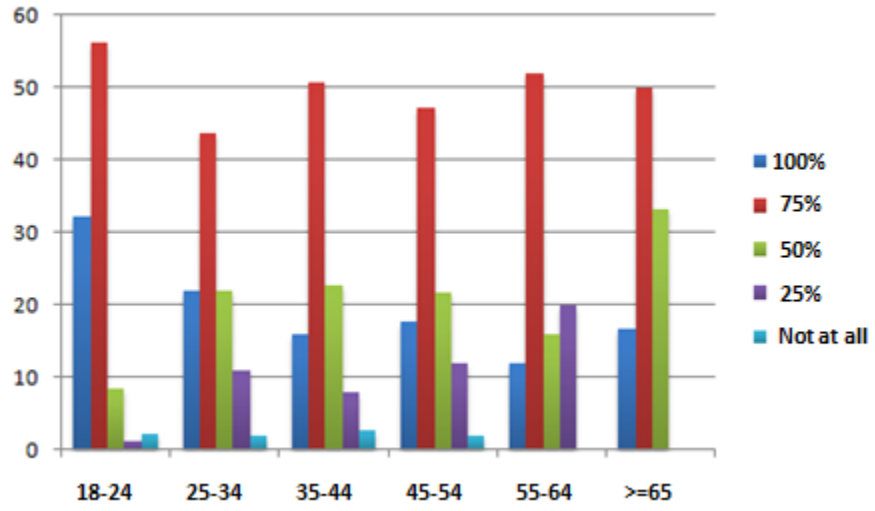

Figure 4.14 Decrease in commuting (%) during the week 16/3-22/3 with regard to age

A result that cannot be disregarded is the different adoption of the measures between men and women. As can be seen in Table 4.9, women generally abided more by the rules. More precisely, the rate for non-transportation was almost 7% higher for women (25.3% women, versus 17.9% men). In addition, while 53.4% of the female study population reduced its daily commute by 75%, the equivalent figure for men was 47%. On the contrary, the percentage of men that limited its transportation by half was double compared with that of women (23.9% versus to 12.6%).

Table 4.9 Decrease in commuting during the week 16/3-22/3 with regard to gender

			100%	75%	50%	25%	Not at all	Total
Gender	Male	Count	24	63	32	12	3	134
		% within Gender	17.9%	47.0%	23.9%	9.0%	2.2%	100.0%
	Female	Count	44	93	22	12	3	174
		% within Gender	25.3%	53.4%	12.6%	6.9%	1.7%	100.0%
Total		Count	68	156	54	24	6	308
		% within Gender	22.1%	50.6%	17.5%	7.8%	1.9%	100.0%

Moreover, in the framework of social-distancing, remote working policies were implemented. Consequently, almost one-quarter of those surveyed reported that they ceased daily commuting to the workplace, taking advantage of teleworking. Notwithstanding, the above mentioned practice is not feasible for various professions, and for that reason, 22.1% of the participants limited in general their transportation, except the trips to and from the workplace. Moreover, 25.6% of the study population stated that their daily travelling restricted considerably due to university closure and general lockdown. Furthermore, a minority (8.4%) commented that limited its daily commute to work due to reduced workload/service demand. Finally, very few participants (4.2%) indicated that they would like to reduce commuting, but at this moment, it is not feasible due to professional, family, and other obligations.

b. Phase 2

One month after the lifting of the strict quarantine and while the lockdown measures lessen continuously, have the citizens returned to their regular travel schedule?

Data analysis revealed that 22.8% of the respondents increased their weekly transportation by 100%, while almost 27% declared that the week 1/6-7/6 travelled 75% more than in April (Figure 4.15). Furthermore, approximately one-quarter of the study population increased their transportation by half. On the other hand, 17.6% of the participants reported no substantial alteration in their urban travelling, provided that they transported only 25% more than in the curfew period (April).Nonetheless, a small percentage of interviewees, 8.8, stated that there was no change in their travel pattrens between the two periods.

Thus, we can conclude that three-quarter of the citizens travel significantly more in the post-lockdown period since they at least doubled their urban transportaion.

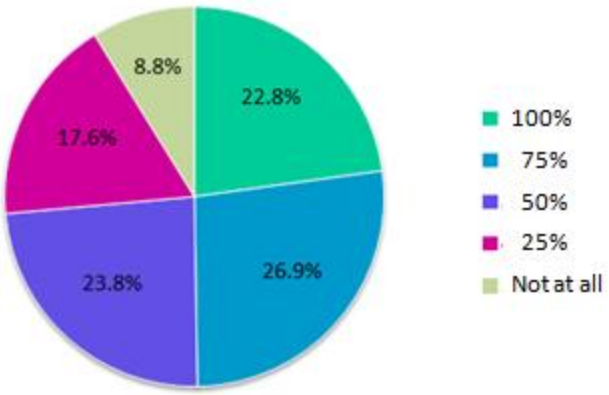

Figure 4.15 Increase in commuting (compare between April and the week 1/6-7/6)

It is noteworthy that almost one-quarter of the study population stated that commutes only to the workplace/university or for basic needs and avoids unessential transportation. On the contrary, 34.2% of the participants have returned to their regular travel schedule, and transport as much for the necessary activities as for entertainment. Notwithstanding, a small minority, 8.8%, suggested that their transportation remains limited due to teleworking/e-learning. Last, it is critical to note that 15.5% opted for traveling by private car, while 12.4% preferred active transportation (walking, cycling).

4.4.6 Shared mobility and safety

In shared mobility (e.g., carpooling, public transport, taxi), safety plays a predominant role, given that it is a major concern for travellers and frequently a deterrent factor for opting for this transport mode. How safe do people feel to share a car ride or take the bus?

a. Phase 1

The survey's results indicate that 62.3% and 45.5% of the study population feel safe to share a car ride as a driver and as a passenger, respectively. On the contrary, 8.1% expressed safety concerns regarding carsharing as a driver, percentage that doubles for the passenger role. Furthermore, two-thirds of the respondents reported feeling safe using public transport (bus), and a minority, 12%, stated the opposite. Finally, 42.9% appeared to have no safety concerns for commuting by taxi, and only 17.9% mentioned feeling unsafe to travel by that means of transport.

Nonetheless, (statistically) significant differences can be observed according to gender. An interesting yet expected finding is that women feel less secure to carshare. More specifically, while 16.8% of female travellers feel unsafe to share a car ride as a driver, only a small figure of men (2.6%) feel the same (Table 4.10). The equivalent rates for carsharing as a passenger are 19.3% (women) versus 13.7% (men) (difference not statistically significant).

Notwithstanding, it should be noted that the degree of safety feeling decreases considerably for both males and females commuters for carsharing as a passenger than as a driver. More precisely, regarding men, a decline of 37% can be observed between the driver and the passenger role (86.1% versus 49.2%). As for women, the reduction is lower (23.4%), given that while 71% of them feel safe to share a car ride as a passenger, 47.6% expressed the opposite.

Furthermore, the safety feeling as a passenger seems to decrease with age. From 63.5% for the age group of 18-24, it declines to 40.5% for the age group 55-64.

Table 4.10 Feeling safe of shared mobility (%) with regard to gender (phase 1)

	Car with others as a driver		**Car with others as a passenger**		**Bus**		**Taxi**	
	♂	♀	♂	♀	♂	♀	♂	♀
Yes	86.1	71.0	49.2	47.6	78.4	72.6	57.0	46.5
No	2.6	16.8	13.7	19.3	11.2	15.3	21.9	20.8
I am not sure	11.3	12.2	37.1	33.1	10.3	12.1	21.1	32.6

Concerning public transport, females also feel less safe than males. As shown in the table above, 78.4% of men suggested feeling safe to commute by bus versus 72.6% of women. In contrast, 11.2% of the male population declared a sense of insecurity using public transit, whereas the equivalent figure for women was 15.3%. Regarding opting for a taxi for transportation, almost six out of ten men stated feeling secure, versus 46.5% of women (differences not statistically significant in both cases). Hence, it is apparent that men feel safer than women about shared mobility. In addition, the safety feeling, for the taxi, seems to increase with age, from 46.6% for the age group of 18-24 to 80% for the age group >=65.

Furthermore, the results obtained from data analysis showed that 73% of the study population feels safe to share a car ride as a driver with persons they already know (Figure 4.16).

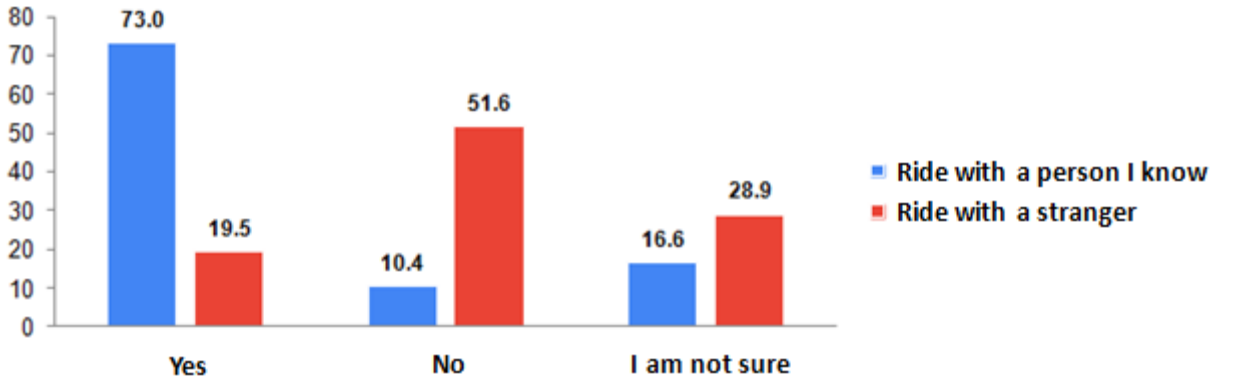

Figure 4.16 Feeling safe to share a car ride as a driver (%) (phase 1)

Nevertheless, only 19.5% declared feeling safe to carshare as a driver with a stranger, and the percentage is even lower, 11.4%, for car commute with strangers as a passenger (Figure 4.17). Moreover, just over half of those surveyed and six out of ten persons reported feeling unsafe to share a car ride with unknown persons as a driver and as a passenger, respectively.

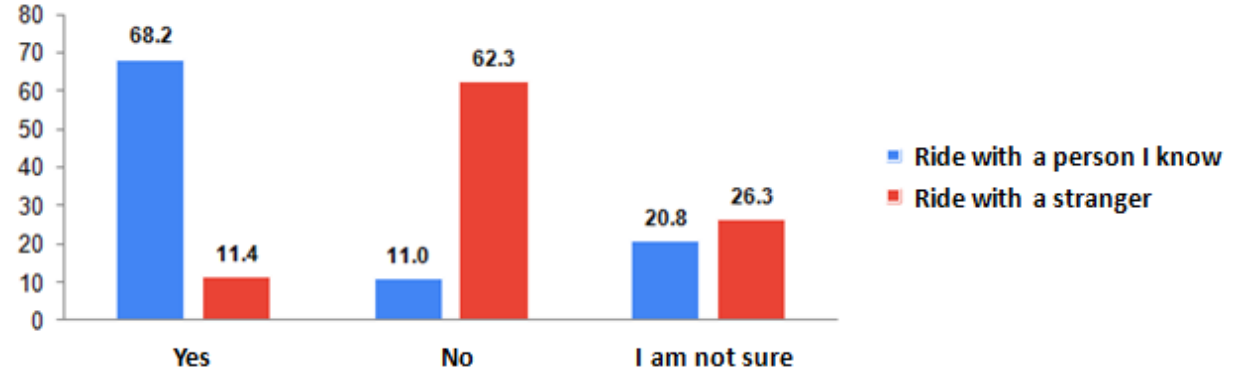

Figure 4.17 Feeling safe to share a car ride as a passenger (%) (phase1)

Enlighting was the further statistical analysis of the data safety concerning gender. As expected, generally, female travellers feel less safe than men sharing a car trip either as a driver or as a passenger with persons they know (e.g., 63.2% women versus 85.8% men, feel safe as a driver, difference statistically significant). Moreover, their safety concerns are even higher when travelling with unknown persons. For instance, while safety reasons deter 16.1% of women from driving a vehicle with someone they know, that percentage increases significantly, reaching 59.8% when the passenger is a stranger (x^2=13.794., p-value=0.001).

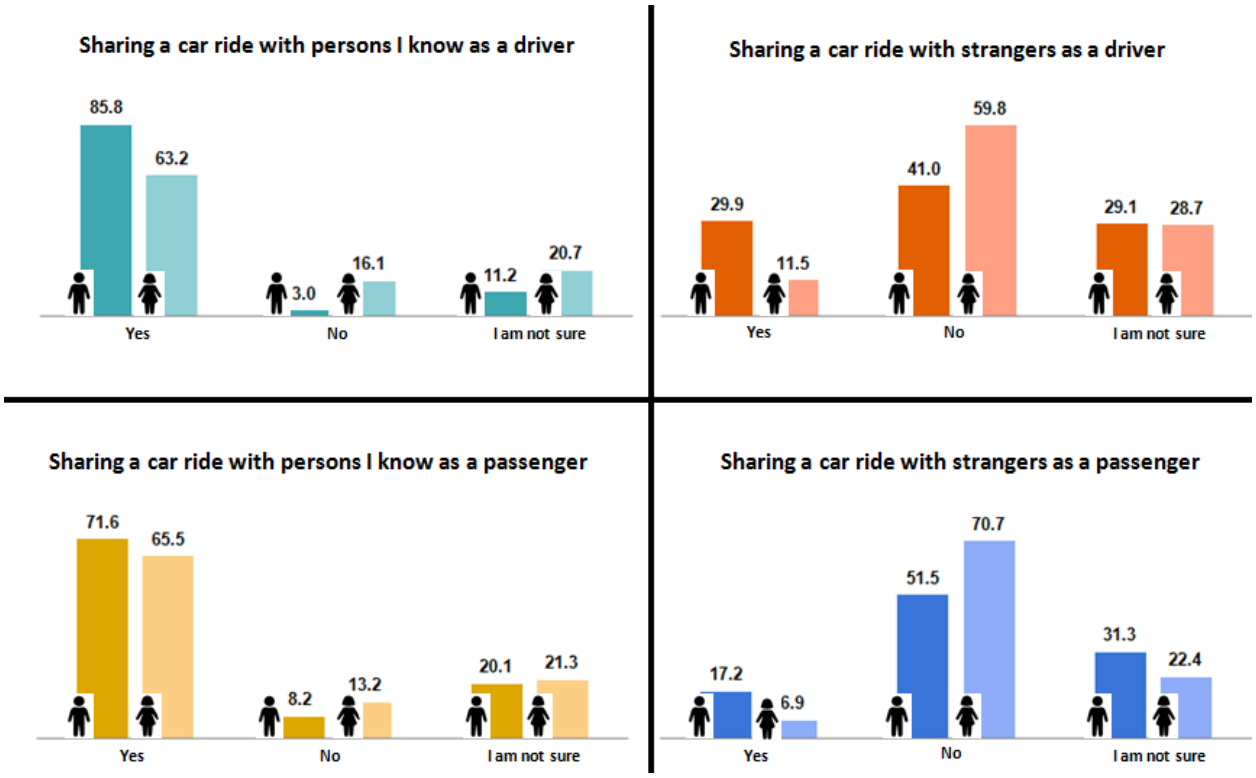

Figure 4.18 Feeling safe to share a car ride as a driver and as a passenger (%) with regard to gender (phase 1)

Nevertheless, surprisingly, while the vast majority of the male population, 85.8%, feels safe to drive a car with familiar persons, only three out of ten men feel the same in case the fellow traveller is unknown. In other words, men also appeared considerably concerned about their safety and unwilling to travel by car with unknown individuals. It is noteworthy that just over half of the male participants expressed feeling insecure about sharing a car ride with strangers as a passenger.

Another interesting finding is the differences between the driver and the passenger roles. As highlighted in Figure 4.18, men feel safer driving than being a passenger in a car ride, either when travelling with familiar persons or unknown ones. More precisely, while 85.8% and 29.9% of men declared feeling safe when driving a car with familiar persons or strangers, respectively, the equivalent percentages for the passenger role are 71.6% and 17.2%, respectively. On the one hand, that difference can be attributed to the fact that men prefer driving. On the other, they do not trust easily the driving skills of others, and sometimes they perceive women as bad drivers.

On the contrary, female travellers expressed a higher sense of security when being passengers and knowing the driver. Nevertheless, safety concerns increase when the driver is a stranger. Consequently, women in the case of travelling by car with unknown persons, they prefer driving than being a passenger.

Finally, with respect to age, the safety feeling both as a driver and passenger is of higher concern for the age group >=65.

b. Phase 2

The results of the 2nd phase of the survey support the previous findings (stage 1). Data revealed that the majority of the study population feels safe to carshare either as a driver (59.1%) or as a passenger (50.8%). Comparing with phase 1, the 5.3% increase regarding the passenger role, may be linked with the rise in the number of car passengers that we mentioned earlier (see Table 4.2). On the other hand, 8.3% and 13.5% of the participants appeared to have safety concerns about sharing a car ride as a driver and as a passenger, respectively.

Furthermore, six out of ten persons reported feeling safe commuting by public transport (bus), and just a small number, 12.4%, seemed unwilling due to safety reasons. Surprisingly, those percentages differ slightly from the ones of phase 1, which implies that the impact of COVID-19 on people's notion towards public transit was not profound. Nevertheless, the sharp decline in the regular public transport ridership suggests otherwise.

Finally, 42.5% mentioned feeling secure to use a taxi, while a minority, 18.1%, stated the opposite. In this case, there were also no significant differences between the two phases of the survey.

Nonetheless, it should be mentioned that more women than in phase 1 expressed feeling safe to carshare as a passenger (increase 8.3%). Concomitantly, the number of female travellers that appeared to have no safety concerns for commuting as a car passenger decreased by 6.6% (Table 4.11). Hence, almost 15% more women feel secure to carshare as a passenger. This finding seems to be consistent with the previous comments on the increased share of car passengers.

Moreover, another interesting observation is that the percentage of the male population that declared a sense of insecurity sharing a car ride as a driver increased by 7%. Last, the proportion of females that feel secure to use public transport decreased by 12.8%.

Table 4.11 Feeling safe of shared mobility (%) with regard to gender (phase 2)

	Carshare as a driver		**Carshare as a passenger**		**Bus**		**Taxi**	
	♂	♀	♂	♀	♂	♀	♂	♀
Yes	85.1	68.0	51.9	55.9	75.6	59.8	53.4	46.5
No	9.5	12.0	16.5	12.7	7.7	17.6	16.4	20.8
I am not sure	5.4	20.0	31.6	31.4	16.7	22.5	30.1	32.6

Comparing Figure 4.19 to Figure 4.16, it can be seen that the number of participants who stated feeling unsafe to carshare as a driver with a person they already know increased by approximately 3%. Moreover, the equivalent proportion when the passenger is unknown decreased by 3.4%. However, it is obvious that are no significant differences between the two phases.

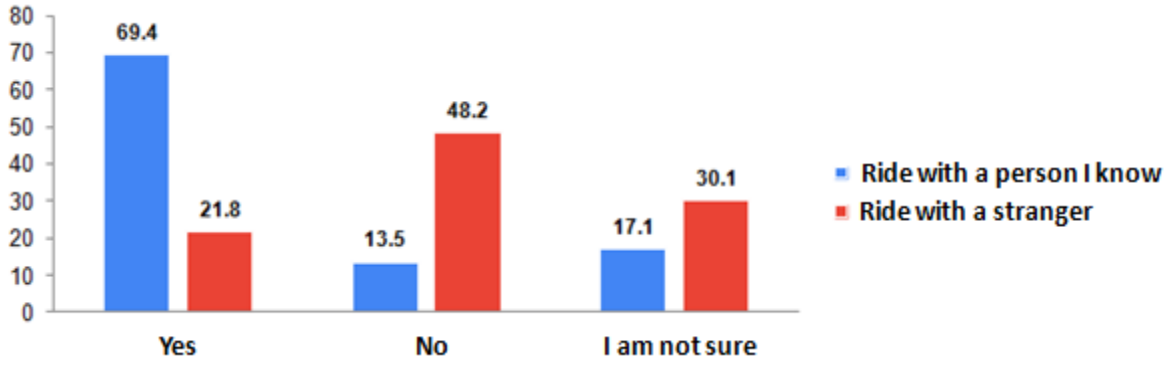

Figure 4.19 Feeling safe to share a car ride as a driver (%) (phase 2)

Regarding sharing a car ride as a passenger, an increase of 4.3% was observed for travelling with a familiar person (72.5% in phase 2, versus 68.2% in phase 1) (Figure 4.20).

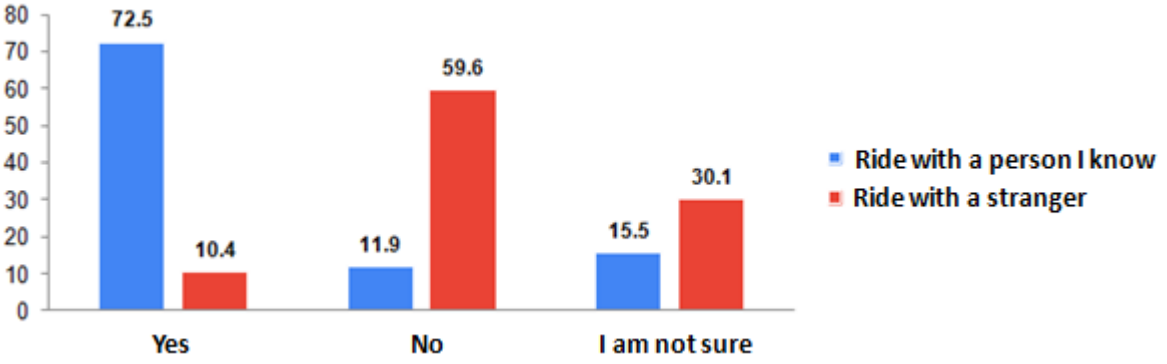

Figure 4.20 Feeling safe to share a car ride as a passenger (%) (phase 2)

As previously (phase 1), the results demonstrate that overall, men tend to feel safer than women to carshare, either as a driver or as a passenger. One unanticipated finding that derived from the comparison between the two phases showed that in stage 2, females were notably less concerned about their safety (for passenger role). More precisely, almost 10% more women

declared feeling safe to commute by automobile with persons they know, while a decrease of 9.2% regarding the feeling of insecurity when the driver is a stranger was identified as well (Figure 4.21).

By contrast, the sense of insecurity in carsharing increased for the male population. According to data, men that feel safe to share a car ride as a passenger with an unknown driver decreased by approximately 7% (17.2% in phase 1, versus 10.7% in phase 2). Nevertheless, even when the driver is a familiar person, the proportion of males that expressed safety concerns increased almost by 4%. Furthermore, 10% more men feel unsafe driving their car with unknown fellow travellers.

Last, contrary to expectations, the proportion of males that feel safe to share a car journey as a driver with a stranger increased by 7%.

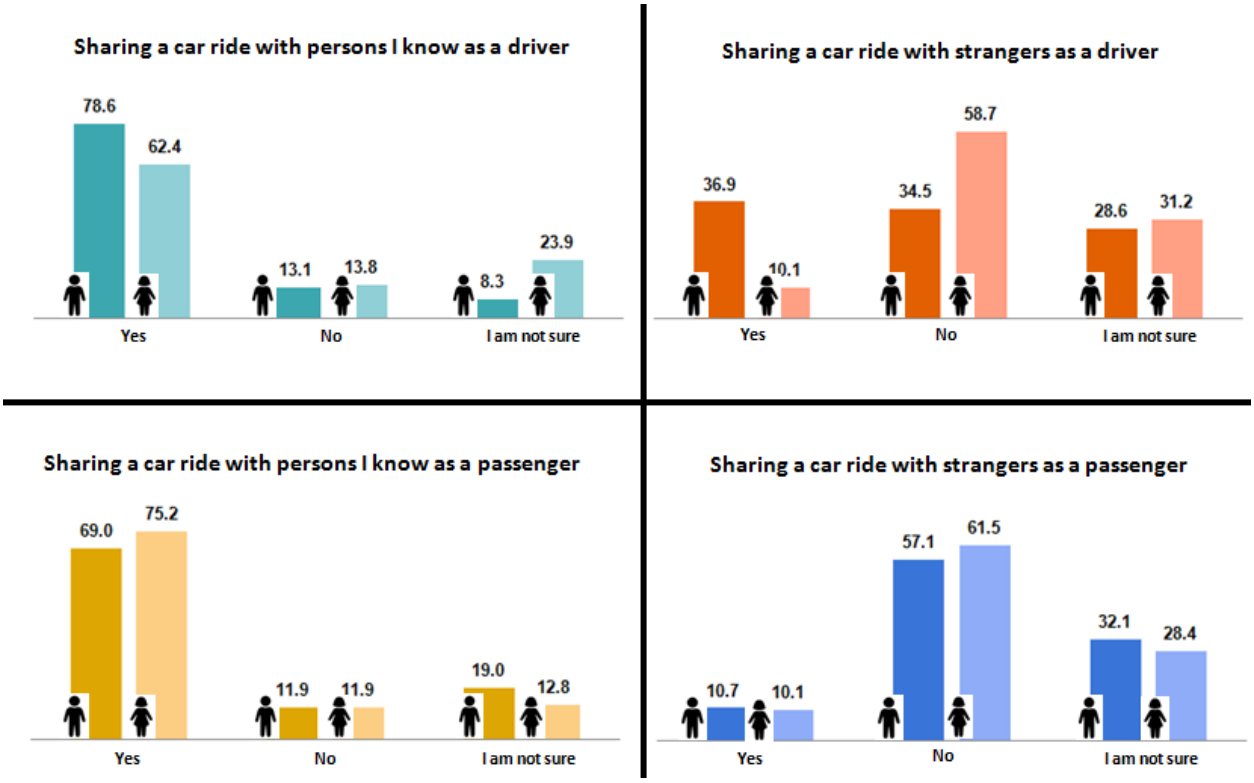

Figure 4.21 Feeling safe to share a car ride as a driver and as a passenger (%) with regard to gender (phase 2)

Chapter 5. Conclusions

This study focused on the impacts of the COVID-19 pandemic on urban mobility, and concurrently, endeavored to shed light on people's behavioral changes regarding their travel patterns.

The research revealed that both cities, Chania and Rethymno, are car-centric since almost 40% of the study population uses a private vehicle daily. Nevertheless, the small size of the cities encourages green transportation, and a significant percentage of citizens (46.1%) choose walking for their daily commuting. On the contrary, cycling is not a preferred transport mode. The lack of proper infrastructure, especially in Chania, and cultural barriers, contribute to the limited use of bicycle within the city.

As the core of the urban planning and transportation systems design is sustainable mobility, it is encouraging that a significant share (almost 30%) of citizens have already reduced car usage and opt for alternative and sustainable transport modes (walking, cycling, public transport). In addition, it is equally important that in the post-curfew period the daily car journeys decreased. However, this is not sufficient, as one-quartrer of the study population is not willing to alter their travel habits and limit car use. This reinforces the above mentioned conclusion that private automobiles dominate mode-share in the cities of Rethymno and Chania.

Another interesting finding that correlates with car dominance is the fact that ecological footprint is last on the list of travel mode choice determinants. This illustrates poor environmental awareness, which is a significant constraint for changing peoples' travel habits. On the contrary, safety is of paramount importance when choosing transport mode for the vast majority of travelers. Nevertheless, how can we ensure health and safety during a pandemic? Are shared mobility and safety compatible?

Undoubtedly, it is quite challenging to combine mass transit with physical distancing, given that human interaction is innate in public transport. Furthermore, the sharp decline in public transit ridership demonstrates that passengers are skeptical or even reluctant to use the bus. Although there are signs of recovery, the use of public transportation remains remarkably low. Consequently, transportation planners and decision makers have to unravel not only how to entice citizens back to mass transit but also how to serve public health interests. As the lockdown subsidies, it is critical that measures are taken to rebuild people's confidence in public transport and discourage car use, or traffic congestion will exacerbate. Frequent cleaning and disinfection of the public transport fleet, hand sanitizers, floor stickers to mark adequate spacing, are some measures that could minimize the risk of contagion and safeguard riders and employees.

Notwithstanding, besides the adverse impacts of the pandemic, there are also some positive effects. Lockdown due to COVID-19 reduced traffic congestion and consequently travel time. As stated earlier, travel time not only affects peoples' well-being and overall health but also,

according to respondents, it is a significant travel mode choice factor. Therefore, policymakers and transportation officials should place more emphasis on commute time.

On the other hand, although it was not observed an overall uptake in cycling, the reduced traffic caused cyclists to feel safer on the road. It should be noted that several participants declared that car-free city was ideal for commuting by bicycle safely. This underscores the need for bike lanes as the risk of accidents is a major deterrent from cycling (Cervero et al., 2019). Furthermore, participants commented on the city´s cleaner air and reduced frustration while travelling, additional benefits of limited motorized transport that cannot be disregarded.

Considering the aforementioned it becomes evident that decongested roads promoted the city's livability and improved citizens' quality of life. Those are main objectives of urban sustainable mobility; thus, it is indispensable to make the essential adjustments and take the necessary steps in order to maintain the positive side effect of the coronavirus crisis.

The transport sector, and principally ridesharing, have been profoundly affected by the COVID-19 outbreak, and the post-pandemic era is still obscure. The current mobility system proved unready to assimilate the impact of this unprecedented crisis, and defaults regarding the network's integration and public health were also unveiled. Nevertheless, the citizens' health and safety should be the priority of urban planning and transportation schemes.

The challenge we face today is COVID-19, but in the future, it may be a different kind of emergency (e.g., extreme weather phenomena due to climate change, flooding, earthquake). In order to preserve mobility and safety in times of crisis, it is imperative to reinforce the transport's system resilience. The more flexible, autonomous, and robust a system is, the more resilient it becomes. Hence, it is essential the development of a multi-modal transportation network that provides a variety of mobility options. Furthermore, the network should be composed of more connections enabling the use of alternative routes. On the other hand, the deployment of micromobility (e-scooters, bikes) and the construction of the required lanes is regarded as vital.

In the aftermath of the pandemic, cities should be reshaped in favor of active transport (walking, cycling), since returning to pre-COVID-19 traffic and air pollution levels is not a sustainable option. Already, several cities around the globe have been reallocating temporarily road space from cars to cyclists and pedestrians, while others, like Milan, have set in action ambitious plans to make these changes permanent (Laker, 2020). In addition, as city officials are trying to fend off a resurgence in car use, they encourage cycling by providing economic incentives for the purchase/repair of bicycles (Connolly, 2020).

Nonetheless, the establishment of the 'green shift' in mobility habits requires not only infrastructures but also a coordinated and integrated urban transportation system. Citizens should be able to safely navigate the city and have easy access to local and regional public transit. Furthermore, this is the opportune moment to overcome the cultural barriers and redirect people towards eco-friendly modal choices. As lockdowns ease and people start slowly commuting again, it is easier to encourage them to adopt active transport modes and adhere to them, given that due to curfews, they drifted apart from their previous mobility behaviours.

Moreover, ‘soft interventions’ such as environmental awareness campaigns are regarded as crucial to promoting sustainable urban mobility.

Nowadays, we are in a transition period. Life as we knew it has altered dramatically, and we are obliged to start fresh. As we are entering the post-COVID-19 era and cities are trying to build the ‘new normality’, it is interesting to investigate further the consequences of the pandemic on urban transport. Future studies could examine whether people perceive the long-term benefits of limiting private car use and are willing to swift towards active transportation.

Furthermore, as the urban commuting gradually restarts and the ‘new normality’ begins to take form, it would be useful to register the alterations in citizens’ mobility patterns and compare them with pre-pandemic, quarantine and post-curfew ones, in order to identify the mobility trends. In addition, profound research on citizen’s mobility behaviour from a psychological perspective could be as well valuable. Lastly, an intriguing research field is the assessment of coronavirus impacts on urban mobility in correlation with the tourism period. The analysis and modeling of the data would be useful in the future design of more flexible, sustainable, and resilient mobility strategies and systems..

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