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Development of an interactive platform for green transport policy evaluation

by

IOANNIS TSOUROS

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PhD Committee:

Amalia Polydoropoulou
Professor
Department of Shipping, Trade and Transport
University of the Aegean

Seraphim Kapros
Professor
Department of Shipping, Trade and Transport
University of the Aegean

Konstadinos G. Goulias
Professor
Department of Geography
University of California, Santa Barbara (UCSB)

PhD Extented Committee:

Evangelos Sambracos
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Department of Economics
University of Piraeus

Nikitas Nikitakos
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University of the Aegean

Constantinos Antoniou
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Technical University of Munich

Anna Kotrikla
Assistant Professor
Department of Shipping, Trade and Transport
University of the Aegean

Konstadinos G. Goulias
Professor
Department of Geography
University of California, Santa Barbara (UCSB)

Seraphim Kapros
Professor,
Department of Shipping, Trade and Transport
University of the Aegean

Amalia Polydoropoulou
Professor, Department of Shipping, Trade and Transport
University of the Aegean

ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΙΓΑΙΟΥ
ΣΧΟΛΗ ΕΠΙΣΤΗΜΩΝ ΤΗΣ ΔΙΟΙΚΗΣΗΣ

ΔΙΔΑΚΤΟΡΙΚΗ ΔΙΑΤΡΙΒΗ

Αξιολόγηση πράσινων πολιτικών στις μεταφορές με τη χρήση οικονομετρικών προτύπων και προσομοίωσης

ΙΩΑΝΝΗΣ ΤΣΟΥΡΟΣ

για την απόκτηση διδακτορικού διπλώματος
του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών

Συμβουλευτική Επιτροπή:

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Καθηγήτρια
Τμήμα Ναυτιλίας και
Επιχειρηματικών Υπηρεσιών
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Καθηγητής
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Καθηγήτης
Τμήμα Γεωγραφίας
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Τμήμα Ναυτιλίας και
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Κωνσταντίνος Αντωνίου
Καθηγητής
Technical University of Munich

Άννα Κοτρίκλα,
Επίκουρη Καθηγήτρια
Τμήμα Ναυτιλίας και
Επιχειρηματικών Υπηρεσιών
Πανεπιστήμιο Αιγαίου

Κωνσταντινος Γκουλίας
Καθηγήτης
Τμήμα Γεωγραφίας
Πανεπιστήμιο California – Santa Barbara

Σεραφείμ Κάπρος
Καθηγητής
Τμήμα Ναυτιλίας και
Επιχειρηματικών Υπηρεσιών
Πανεπιστήμιο Αιγαίου

Αμαλία Πολυδωροπούλου
Καθηγήτρια
Τμήμα Ναυτιλίας και
Επιχειρηματικών Υπηρεσιών
Πανεπιστήμιο Αιγαίου

Επιβλέπουσα διδακτορικής διατριβής...
Αμαλία Πολυδωροπούλου, Καθηγήτρια

“The story so far: In the beginning the Universe was created. This has made a lot of people very angry and been widely regarded as a bad move”

-Douglas Adams, The hitchhiker's guide to the galaxy

“Philosophers have hitherto only interpreted the world in various ways; the point is to change it.”

-Karl Marx, Eleven Theses on Feuerbach

Ευχαριστίες

Abstract

Climate change is one of the most prominent concerns for the future of humanity in the 21st century. The presence of humanity in the planet may be viewed as precarious, especially when considering the adverse effects of human activity and development. The current scenario predictions for year 2100 is a 4°C temperature growth. A 4 degree change has not happened in the global climate since 20.000 BC. Growing emissions from the use of fossil fuels negatively affects a series of environmental factors and is affects human life from every-day quality of life to long-term health effects, macroeconomic change, movement in human population, social equity and of course, the quality of the environement and life as a whole. A major contributor of these emissions is the transportation sector. For this reason, a multitude of international and national organizations have proposed an answer to the growing emissions, which can be grouped under the term sustainable or "green" transportation.

This thesis explores the notion of green, sustainable transportation in depth. The thesis creates an innovative framework for the analysis of decision-making process in transport and activity related matters and it designs and crafts an interactive policy assesment tool that is based on econometric modelling. The econometric modelling is done in three different tiers, the everyday rhythms tier, that is concerned with the everyday activity and transport choices of individuals and how their lifestyle can affect these choices, the light infrastructure tier that explores the effect of active transport friendly interventions in the transport system via measurable key performance indicators and the future fleet purchase tier that provides insight into the future fleet mixture and the effect it will have on the emissions and fuel cost.

The daily rhtyhms tier includes the effect of lifestyle by comparing the sample from collected data in Chios island to a database from Athens, Greece. This comparison effectively demostrates the heterogeneity of the two areas, the differences in spatial and temporal choices and the effect that lifestyle has on them. Policy-wise it presents justification for tailor-made, location-based solutions and careful consideration of norms, rhythms and lifestyle choices of the study area when applying policy bundles.

The chapter discussing the effect of active transport promoting measures uses a simulation of the study area to measure the effect of the creation of bike lanes and the pedestrianization of certain links in the study area. The analysis provides

measurable outcome through the usage of various KPIs, such as passenger kilometers, share of active transport, daily accidents and traffic levels.
The third analysis tier is concerned with future fleet purchase. It utilizes a menu-based, build-your-own, experiment approach allowing survey respondents to create their ideal vehicle using various attributes (including alternative fuel and automation level) while presenting a reasonable pricing to them. The analysis is conducted using a hybrid choice model, with latent variables aiming to reduce uncertainty and errors in the decrypting of the decision-making process.
The thesis also provides insight into the creation, design and implementation of the policy platform tool. The tool is interactive in the sense that the user can control various variables and view the output, comparing the different policy measures and scenarios. It is coded in R and developed as a webpage, in a user-friendly user interface that does not require special understanding to operate.
The thesis uses a sample of 1288, roughly 2% of the population of individuals from the island of Chios, Greece. The data collection is realized through a series of electronic questionnaires including a household and an individual questionnaire, a stated-preference experiment, an activity diary and accompanied by GPS devices to assist the activity diary.
The contribution of the thesis can be found on several topics. First, the thesis explores the notion of sustainable transport and the human behavior that is related to it using a multi-tier analysis that spans from every-day life of individuals to future, long-term decisions. Secondly, it uses a series of analytical tools to answer the research questions, innovative econometric models, transport simulation and a in-house developed interactive decision-making tool. It is a spherical exploration of the available analytical tools, each of which used provides the specific insight for which it was used. Additionally, the case study that is conducted in an insular, island area provides insight into the behavior, choices and particularities of an area that smaller scale, smoother interventions may be more succesful than abrupt, sudden changes. The lifestyle of the study area plays a significant role in the conducted analysis. Findings from this analysis contribute to the transferability of models. Finally, the thesis provides useful insight into various policy measures that should be considered for changing the human behavior, attracting more citizens to using sustainable means of transport and improving the stanard of living while minimizing the external cost of transportation.

Keywords: econometric modelling, green transport, sustainability, transport policy, decision-making, insular areas, island areas, latent variables, latent classes, hybrid choice modelling, active transportation, cycling, walking, alternative fuels.

PhD Thesis Supervisor: Amalia Polydoropoulou.
Title: Professor, Vice-Rector of Research, Development, Finance and Infrastructure of the University of the Aegean

Περίληψη στα ελληνικά

Η κλιματική αλλαγή είναι μια από τις σημαντικότερες ανησυχίες για το μέλλον της ανθρωπότητας τον 21ο αιώνα. Ακόμα και η παρουσία της ανθρωπότητας στον πλανήτη μπορεί να θεωρηθεί επισφαλής, ειδικά όταν εξετάσουμε σε βάθος τη δυσμενή επίδραση της ανθρώπινης δραστηριότητας και της ανάπτυξης στο περιβάλλον. Οι προβλέψεις του τρέχοντος σεναρίου για το έτος 2100 αναφέρουν αύξηση της θερμοκρασίας κατά 4 ° C. Τέτοιας τάξης αλλαγή δεν έχει συμβεί στο παγκόσμιο κλίμα από το 20.000 π.Χ. Οι αυξανόμενες εκπομπές από τη χρήση ορυκτών καυσίμων επηρεάζουν αρνητικά μια σειρά περιβαλλοντικών παραγόντων και επηρεάζουν την ανθρώπινη ζωή: από την ποιότητα ζωής έως μακροπρόθεσμες επιπτώσεις στην υγεία, μακροοικονομικές μεταβολές, μετακίνηση ανθρώπινων πληθυσμών (πρόσφυγες κλιματικής αλλαγής), την κοινωνική δικαιοσύνη και βεβαίως την ποιότητα του περιβάλλοντος και της ζωής ως συνόλου. Ο τομέας των μεταφορών συντείνει σημαντικά στις εκπομπές αερίων. Για το λόγο αυτό, μια πληθώρα διεθνών και εθνικών οργανώσεων οργανώνουν τις «απαντήσεις» στις αυξανόμενες αυτές εκπομπές, οι οποίες μπορούν να ομαδοποιηθούν κάτω από τον όρο «βιώσιμες» ή «πράσινες» μεταφορές.

Η εργασία αυτή διερευνά την έννοια της πράσινης, βιώσιμης μεταφοράς σε βάθος. Η διατριβή δημιουργεί ένα καινοτόμο πλαίσιο για την ανάλυση της διαδικασίας λήψης αποφάσεων σε θέματα μεταφορών και δραστηριοτήτων και σχεδιάζει και κατασκευάζει ένα διαδραστικό εργαλείο αξιολόγησης πολιτικής που βασίζεται στην οικονομετρική μοντελοποίηση. Η οικονομετρική μοντελοποίηση γίνεται σε τρεις διαφορετικές βαθμίδες. Το καθημερινό επίπεδο ρυθμών, που ασχολείται με την καθημερινή δραστηριότητα και τις μεταφορικές επιλογές των ατόμων και τον τρόπο με τον οποίο ο τρόπος ζωής τους μπορεί να επηρεάσει αυτές τις επιλογές. Το δεύτερο επίπεδο εξετάζει μέτρα «ελαφρών» υποδομών (ποδηλατόδρομοι, πεζοδρομήσεις) και διερευνά το αποτέλεσμα των παρεμβάσεων στο σύστημα μεταφορών μέσω μετρήσιμων βασικών δεικτών απόδοσης και προσομοίωσης. Το τρίτο επίπεδο εξετάζει την μελλοντική αγορά οχήματος, ειδικότερα οχημάτων με εναλλακτικά καύσιμα και αυτόνομων οχημάτων και παρέχει πληροφορίες για το μελλοντικό μείγμα στόλου και το αποτέλεσμα που θα έχει στις εκπομπές και το κόστος καυσίμων.

Το επίπεδο ρυθμών περιλαμβάνει την επίδραση του τρόπου ζωής, συγκρίνοντας το δείγμα από τα δεδομένα που συλλέχθηκαν στη Χίο με μια βάση δεδομένων από την Αθήνα. Αυτή η σύγκριση δείχνει αποτελεσματικά την ετερογένεια των δύο περιοχών, τις διαφορές στις χωρικές και χρονικές επιλογές και την επίδραση που έχει ο τρόπος ζωής σε αυτές. Από πολιτική άποψη παρουσιάζει αιτιολόγηση για εξειδικευμένες λύσεις βάσει τοποθεσίας και προσεκτική εξέταση των κανόνων, των ρυθμών και των επιλογών του τρόπου ζωής στην περιοχή μελέτης κατά την εφαρμογή των δεσμών πολιτικής και μέτρων.

Το κεφάλαιο που εξετάζει την επίδραση των μέτρων προώθησης της ενεργητικής μετακίνησης χρησιμοποιεί μια προσομοίωση της περιοχής μελέτης για να μετρήσει το αποτέλεσμα της δημιουργίας ποδηλατοδρόμων και πεζοδρομήσεων ορισμένων συνδέσμων στην περιοχή μελέτης. Η ανάλυση παρέχει μετρήσιμα αποτελέσματα μέσω της χρήσης διαφόρων δεικτών απόδοσης (KPIs), όπως επιβατοχιλιόμετρα, μερίδιο ενεργών μεταφορών, καθημερινά ατυχήματα και ροών κυκλοφορίας.

Το τρίτο επίπεδο ανάλυσης αφορά την μελλοντική αγορά στόλου. Χρησιμοποιεί μια προσέγγιση με πειράματα δεδηλωμένης προτίμησης, η οποία επιτρέπει στους ερωτηθέντες να δημιουργούν το ιδανικό τους όχημα χρησιμοποιώντας διάφορα χαρακτηριστικά (συμπεριλαμβανομένου του εναλλακτικού καυσίμου και του επιπέδου αυτοματισμού), ενώ παράλληλα παρουσιάζουν μια λογική τιμολόγηση σε αυτά. Η ανάλυση διεξάγεται χρησιμοποιώντας ένα μοντέλο υβριδικής επιλογής (hybrid choice model), με λανθάνουσες μεταβλητές που αποσκοπούν από τη μία στην διερεύνηση της επίδρασης των στάσεων και των αντιλήψεων στη διαδικασία λήψης απόφασης και από την άλλη στη μείωση της αβεβαιότητας και των σφαλμάτων κατά την μοντελοποίηση.

Η διατριβή παρέχει επίσης παρουσιάζει τη δημιουργία, το σχεδιασμό και την υλοποίηση του εργαλείου πλατφόρμας πολιτικής. Το εργαλείο είναι διαδραστικό με την έννοια ότι ο χρήστης μπορεί να ελέγξει διάφορες μεταβλητές και να δει τα αποτελέσματα, συγκρίνοντας τα διάφορα μέτρα πολιτικής και σενάρια. Είναι κωδικοποιημένο σε R και αναπτύσσεται ως μια ιστοσελίδα, με μια φιλική προς το χρήστη διεπαφή που δεν απαιτεί ειδικές γνώσεις για να λειτουργήσει.

Η διατριβή χρησιμοποιεί δείγμα 1288 ατόμων, περίπου το 2% του πληθυσμού της Χίου. Η συλλογή στοιχείων πραγματοποιείται μέσω μιας σειράς ηλεκτρονικών ερωτηματολογίων που περιλαμβάνουν ένα οικογενειακό και ατομικό ερωτηματολόγιο, ένα πείραμα δηλωμένης προτίμησης, ένα ημερολόγιο δραστηριοτήτων και συνοδεύεται από συσκευές GPS για να υποστηρίξουν το ημερολόγιο δραστηριοτήτων.

Η συμβολή της διατριβής εντοπίζεται σε πολλά σημεία. Πρώτον, η εργασία εξετάζει την έννοια των βιώσιμων μεταφορών και της ανθρώπινης συμπεριφοράς που σχετίζεται με αυτήν χρησιμοποιώντας μια πολυεπίπεδη ανάλυση που εκτείνεται από την καθημερινή ζωή των ατόμων ως τις μελλοντικές, μακροπρόθεσμες αποφάσεις. Δεύτερον, χρησιμοποιεί μια σειρά αναλυτικών εργαλείων για να απαντήσει στα ερευνητικά ερωτήματα: καινοτόμα οικονομετρικά μοντέλα, προσομοίωση των μεταφορών και δημιουργεί ένα εργαλείο διαδραστικής υποστήριξης της λήψης αποφάσεων που αναπτύχθηκε εξολοκλήρου στα πλαίσια της διατριβής. Αποτελέι μια σφαιρική εξερεύνηση και επίδειξη των διαθέσιμων αναλυτικών εργαλείων. Επιπλέον, η μελέτη περίπτωσης που διεξάγεται σε μια νησιωτική περιοχή παρέχει μια εικόνα για τη συμπεριφορά, τις επιλογές και τις ιδιαιτερότητες μιας περιοχής που η μικρότερη κλίμακα, οι ομαλότερες επεμβάσεις μπορεί να είναι πιο επιτυχείς από τις απότομες, ξαφνικές αλλαγές. Ο τρόπος ζωής της περιοχής μελέτης διαδραματίζει σημαντικό ρόλο στη διεξαχθείσα ανάλυση. Τα ευρήματα από την ανάλυση αυτή συμβάλλουν στη δυνατότητα μεταφοράς των μοντέλων σε άλλες περιοχές και κλίμακες. Τέλος, η διατριβή παρέχει χρήσιμες πληροφορίες για τα μέτρα πολιτικής που πρέπει να ληφθούν υπόψη για την αλλαγή της ανθρώπινης συμπεριφοράς, την προσέλκυση περισσότερων πολιτών στη χρήση αειφόρων μέσων μεταφοράς και τη βελτίωση του βιοτικού επιπέδου, ελαχιστοποιώντας παράλληλα το εξωτερικό κόστος των μεταφορών.

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List of Abbreviations

ABM: Activity-based models

AFV: Alternative fuel vehicles

CAV: Connected and Automated vehicles

DCM: Discrete-choice models

HCM: Hybrid-choice models

LCM: Latent-class models

MNL: Multinomial logit

Chapter 1: Introduction

For anyone concerned with modern societies, the impact of human economic activities has on the environment is an issue that he or she will inevitably encounter. This impact has serious negative effects and is perceived differently by various agents and stakeholders. These effects range from decreased life quality to uncertain global climatic futures. Peter Frase, in his book "Four Futures" states: "Two specters are haunting Earth in the twenty-first century: the specters of ecological catastrophe and automation… Human carbon emissions are warming the atmosphere, leading to hotter temperatures, extreme weather, and shortages of water and other essential resources. Differences of opinion chiefly concern how serious the effects will be, how disruptive they will be to human civilization, and how (or whether) it will be possible to adjust to those disruptions." (Frase, 2016)

A significant contributor to these emissions and the only industry sector whose emissions are growing is transportation. The transport sector is responsible for 23% of total energy-related CO_2 emissions as of 2010; without focused and bold mitigation measures this number could reach 12 gigatons of emissions per year by 2050. According to the Intergovernmental Panel on Climate Change (IPCC, 2013): "Avoided journeys and modal shifts due to behavioral change, uptake of improved vehicle and engine performance technologies, low-carbon fuels, investments in related infrastructure, and changes in the built environment, together offer high mitigation potential."

The research presented in this thesis is concerned with the evaluation of green transport policies. The thesis attempts to address the issues involved in measuring travelers' choices within a specific economic and social environment; simulate present and future transport scenarios; and assess a bundle of green policies based on a series of key parameters and indicators. The thesis presents an innovative framework for the analysis of decision-making processes with respect to activities and transport, and develops an interactive policy assessment tool based on econometric and simulation models. The modeling is done in three different tiers: 1. the everyday rhythms tier, representing the daily activity and transport choices of individuals and how their lifestyle can affect those choices; 2. the light infrastructure tier which explores the effect of active transport friendly interventions in the transport system via measurable key performance indicators; and 3. the future fleet purchase tier which provides insight into the future fleet mixture and its effect on emissions and fuel costs.

This initial chapter presents the motivation for the research, the thesis objectives, and structure, the basic definitions and contributions.

1.1 Motivation

Motivation for this thesis comes from three factors, two concerning sustainable policy and one concerning the omnipresence of useful data in contemporary society. The first factor is closely related to the major issue of environmental instability caused by human activities and more precisely the transportation industry. Green transport is a proposed answer to some of the problems, but is it the cure? What is a solid definition of green transport and which are the barriers between making unsustainable personal transport choices and on the other hand acting irresponsibly towards the environment while being an international corporation or a country's government? This research examines the first one: people's choices based on their behavior and the social and economic environment they live in. The second factor of motivation is exactly the effect social and economic factors have on people's everyday activity choices, beliefs, and perceptions that may change or remain solid in a changing environment and the people's real perception and weight on green transport. The third, independent, factor is the new concepts, tools, and techniques in data collection process, many of which have come to address existent problems such as low response rates and large cost in surveys, while providing an immense pool of useful data that will reshape the way decisions are modelled and the way econometrics, simulation and other decision-support tools work.

1.1.1 Green transport as an answer to the impact of transportation on the environment

Green transport means sustainable transport and it is a part of the broader sustainable development idea. The term sustainable development was first defined in "Our common future" UN Commission on Environment and Development which was published in 1987. The definition is: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (UN Commission on Environment and Development, 1987). However, there is not yet a clear universally accepted definition of green transport. (Castillo and Pitfield, 2010).

Transport accounts for 26% of global CO2 emissions, being one of the few fields that these emissions are still growing. There is a fundamental difference between the researchers that view sustainable development and transport as an alternative path to economic growth (Amekudzi et al., 2009) and those who support a rather radical criticism on development itself (Bianco et al., 1977). The conception these two approaches have in common is the strong critique of the consequences of transportation has on the environment and the inconsistency of the present and past policies with the ideas of intergenerational equity (accessibility, social equity, transport externalities) and intergenerational equity (handing over a healthy habitat for the next generations). There is almost universal agreement between researchers that, even in the worst-case scenarios, the earth will not become inhabitable. The main question is not whether we will survive climate change but rather who will survive it.

To prevent the dilution of the topic's consistency, one should prioritize the key aspects of the perceived dimensions of green transport. An initial scale could be based on the UN report (UN Commission on Environment and Development, 1987) which presents four main dimensions: safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intra- and intergenerational equity. These can act as pillars, not with a strict hierarchy between them but with the acceptance that the absence of any of them in a green transport definition would eventually lead to errors or misconceptions about the true meaning of the term.

In this frame, the present thesis will not address and try to evaluate green policies that lead or support economic growth. It will rather try to measure and quantify the effect that a changing economic environment has on these policies, and on the people's perception of the ideas, policies, and measures that support green transport. The argument for this is that the contemporary economic crisis poses a threat to certain green policy measures, either physical policies such as infrastructure development or increase in the use of public transport, or economic measures such as tax policies. This fact creates an opportunity window for the "soft" policies category (Santos et al., 2010) which may include car sharing, teleworking and education concentrated on behavioral change.

1.1.2 People's behavior, choices, and perceptions towards green transport

Urban mobility has been a topic of major discussion and debate for policymakers, stakeholders, and citizens for decades. The growing popular belief that we should act to protect the environment, supported by the scientific evidence of morbid future scenarios, has pushed policymakers to act and to propose measures of green policy that vary from education to strict economic measures.

The contemporary global economic crisis, which leads to international fiscal austerity has put the strict economic measures, at least for the passengers, temporary out of the frame. It has also made more difficult the transition to a market of hybrid or electric vehicles. One could regard these policies or modes of transport not as temporarily inactive but rather as wishful thinking for the time being. This argument can lead to researching and analyzing another aspect of travel behavior, the role that social reality, personal choices and opinions, contemporary lifestyle and perceived dimensions of transport play. Steg, (Steg, 2005) has developed a framework for the "Instrumental, symbolic and affective motives for car use." Of course, not everything in the previous sentence links to economic factors which are an indicator that social norms, lifestyle, and symbols outrank income or economic factors, which otherwise is a main governing factor of the society. It also gives a hint towards to which direction one should turn, affect and positively change travel behavior by understanding, educating and finally shifting views and perceptions.

People's involvement in the evaluation or the proposal of green policies is positive. Not only new policies require public support in order to be at least marginal successful, but also studies have shown that public involvement, either public consultations including experts (reference to public consultation paper) or the public itself (Xenias and Whitmarsh, 2013) has shown that the public may not fully accept policies designed by an expert committee. Subsequently, early public

involvement may be necessary for later acceptance but also for the location of problems and the evaluation of solutions.
Individual decision-making analysis, especially when concerned with discrete choices, has been associated with the usage of specific econometric models. Discrete choice models have been associated with this kind of analysis for many decades, especially in the transportation field. Daniel McFadden, who was awarded the Nobel Memorial Prize in Economic Sciences in 2000 for his work in the field, presents a 30-year review of the evolution of discrete choice modelling (McFadden, 2001) and the usage of random utility models (RUMs). The quintessence of random utility models is the concept that all economic agents act in a rational manner to ensure maximum utility is gained through their decisions. This may not be the general case, as a series of authors have pointed-out, and agents' decisions may vary "systematically or idiosyncatically". Hess and Daly (Hess et al., 2018), provide an extensive and thorough review of the RUMs properties, its paradigm and various anomalies and a review of the methodology used to overcome anomalies and incosistensies of RUM.
In this context, scientific tools have been developed to stress the role of psychological and behavioral factors in the decision-making process. McFadden, (McFadden, 1999) locates attitudes, affects, motives as the indicators of preferences. Information and preferences build the individual perceptions and beliefs which in order react with the process of decision making. While Random Utility Theory has been criticized for violating rationality, new models such as the Hybrid Choice Model (Ben-Akiva et al., 2002) which combines the theory of Random Utility with latent variables which can add the interpretation of unobserved (latent) psychological or behavioral characteristics which are, otherwise, regarded as an error or random variance. Latent variables range from happiness (Abou-Zeid and Ben-Akiva, 2011) and travel well-being to perceived safety (Kamargianni and Polydoropoulou, 2014). There is an ongoing academic debate in the transport community about the usefulness of such modelling frameworks and the inclusion of latent variables in them (Chorus and Kroesen, 2014; Vij and Walker, 2016).
Apart from the effect of personality and individual decisions, transport related decisions are made in the context of the economic and political environment of the 21st century and de-facto have socially inherited traits of individualism, egotism and indifference for the effects of one's actions towards the society. Measurement of social altruism, the growing sense of community in various geographical and social areas and technological advances lead to new mobility types, innovative business models

that the ever-changing social, economic and political landscape may harvest in order to reach environmental, social-equity or systems optimization goals.
Examples of the new mobility types and business models include the introduction of the "sharing economy" (see Uber in transport related ventures), the concept and development of "autonomous, inter-connected vehicles" and the "Mobility-as-a-Service" business model concept. The common element in the recent developments, magnified by the growing availability and richness of available data, is the passage from ownership to usership. This attempted passage has a series of serious implications both to economy and society.

1.1.3 Innovative data collection

In data collection, many new technological and data fusion advancements allow the establishment of a closer communication to the respondents in surveys, decrease respondent burden, and increase the amount and quality of information. For example, when we collect data through GPS-enabled devices and internet communication we avoid asking repetitive questions about the timing of travel and location and can ask strategically with high value (e.g., type of activity engaged and the presence of other persons at activity locations). In this way, one can ask questions about revealed behavior in more detail and verify answers using secondary data. They also allow the creation of "experiments" in the form of hypothetical questions comparing different options that are called stated preference studies. These studies allow examining potential actions from policies that cannot be put to test in the real world. Moreover, merging of data from revealed preference data and stated preference enrich behavioral models in a way that can help us answer policy questions with increased flexibility.
It is now evident that response rates in household travel surveys are dropping (Stopher and Greaves, 2007; Wilson, 2004). In fact, the households that are hard to contact (and because of that they represent the highest non-response rates) are the ones that travel the most. In these cases, the travel survey or the travel diary are considered an extra burden on the already stretched household schedule. An additional issue is the tendency of the respondents to omit trips in the travel diaries, either when contacted by phone surveys (Wolf et al., 2003) or even in face to face interviews (Stopher and Collins, 2005).

In simulation models, when data are available the day in the life of an entire country can be represented with extreme detail in time (second by second) to account for the execution of activity agendas of persons and at the level of longitude and latitude (point to point). These advancements are heavily based on observations of residents in the major metropolitan areas, and their subject is the daily life of these residents. We did not experience similar advancement in the area known as "long distance travel' that includes traveling for tourism (either as a pure leisure travel or a combination of business and leisure). There are examples of research activities dedicated first to collect data on this behavior. The data can be used to inform an activity-based approach that is tailored to this type of behavior.
Of course, all these advancements increase the need for higher quality data, computational power, and familiarity with more sophisticated data analysis and visualization techniques. This is often influenced by the tour operators' marketing campaigns which steer the tourism flows to specific island destinations. On the other hand, though, a rising number of "active" and "aware" travelers seek destinations which meet their criteria for environment protection and management, similar to practices applied in their hometown or country. The implementation of similar practices at the island destination is very likely to attract tourists keen to visit a destination with a high environmental awareness.

1.2 "Shades" of green transport

Since there is not a strict definition of sustainable transport or sustainability in general, there is much discussion as to which are the limits or the true content of sustainable transport. It is a difficult subject, as it should be viewed within the context of the political, social and economic system it is a part of. Bibri and Krogstie (Bibri and Krogstie, 2017), in their extensive literature review of sustainability and future cities, state that " In general terms, sustainability can be conceived of as a state in which society doesn't undermine the natural and social systems, i.e. where the natural system is not subject to resource depletion and intensive consumption, hazardous substances, and concomitant environmental risks, and, as of equal importance, where the social system doesn't render people subject to conditions that inhibit their ability to satisfy their needs and aspirations. Undermining natural and social systems can occur through pollution, environmental degradation/ecological deprivation, health decrease, social instability, social injustice, and social hazard." In the long discussion about sustainability, there is some critique to the notion or the application of sustainable transport policy.

One of the most used terms in green transport criticism is "Greenwash."(Lightfoot and Burchell, 2004) The term is used as a spin to promote a product or a service as environmentally friendly deceptively. The tell-tale sign is that an organization or a company spends significantly more amount of money advertising their "green" product than helping the environment. It is used more in food products and energy but has also appeared in transportation issues (Leahy, 2004).

More to the core approaches present green or sustainable transport as an ineffective concept, or even worse false and unfeasible, delaying the urgent changes needed, as for instance in the case of global climate change. (Eliasson and Proost, 2015) There is also the question of who is affected by specific policy measures. For example, market solutions such as taxing carbon may result in economically strong individuals or corporations abusing regulation and using influence and money to disrupt the goals of sustainable transport policy.

A radical criticism views the problem of emissions in from a whole different perspective. Criticism of development as an economic strategy, proposing actual de-growth not as a means of destruction but more as "a fundamental change of key references such as the collective imagination" (Martínez-Alier et al., 2010) and as a strategy for a society built on the quality and not quantity. A final topic of criticism is the conception of lifestyle as a fundamental and obligatory variable in promoting green transport (Gilg et al., 2005) or the behavioral shift to a greener lifestyle as an inefficient and counter-intuitive. (Roy & Pal, 2009).

1.3 Objectives

Based on the above introduction and discussion on the definition, usefulness, and need for sustainable transport, this thesis aims to explore, understand, quantify and compare different policy measures that are widely regarded as being part of green or sustainable transport. This exploration is conducted using different tools. The main analysis of the thesis is conducted using quantitative tools; mostly econometric discrete choice modeling and simulation. However, a lesser but equally important portion of the thesis is materialized by using qualitative tools of analysis and synthesis, such as the discussion of the proposed measures with the local, case study stakeholders and community.

The objectives of the thesis can be grouped into four main axes:

1. Explore the notion, form, and content, of sustainable or green transport and review the state-of-the-art and fruitful practices
2. Develop and test econometric models that focus on the transportation-related choices of individuals in three different time frames:
    a. Everyday life
    b. Mid-term decisions
    c. Long-term decisions
3. Design and develop a web application (from now on: **the platform**) that will use the modeling results to quantify the effect of different policy measures to the overall transport network performance, carbon emissions and standard of living.
4. Use the above to critically discuss the usability, need, and effectiveness of various policy measures.

1.4 Contribution

Sustainable transportation is a topic widely discussed and useful in the 21st century. As already discussed in the introduction, climate change is a very real threat to humanity, and any response tactic or strategy should be carefully considered and implemented for it to be efficient and decisive. There is extensive literature discussing green policy regarding transportation, ranging from innovative measures and tools to adoption rates of new fuel technology and critical discussion of results. The main contribution of this thesis is that it tests and assess the effect of various policy measures in the same population group (with distinct particularities) using different tools and different time horizons.

First, this thesis develops three groups of models; that each explores a different aspect of sustainable transport in a different time frame. The models that are developed in each model group provide specific results that can be transferred to the final product, the platform and act as complementary or competitive agents with each other. Some of the model results are model specific and other are comparable with other models. For example, the construction of a bicycle lane in the study area affects the modal split and raises the portion of bicycle users. This result affects the passenger kilometers traveled by motorized vehicles thus affecting the daily emissions. Daily emissions are also affected by another policy measure: the introduction of alternative fuel vehicles in the local vehicle market. The two measures share the result of the reduction of daily emissions, which is comparable, but each of them has different results that are not directly comparable.

Secondly, the developed models are based on sound modeling techniques that are utilized and reinforced in the last years, adding new layers of understanding the decision-making process. Each model formulated in this thesis has a distinct contribution to the literature. For example, the 4-step modeling process, which is a widely-used transport simulation model for decades, is extended by altering the first step of the model to include disaggregated information using synthetic population and by using crowd-sourced information in step 2.

The integrated approach of policy assessment followed in this study is expected to extend the existing frameworks and tools of policy evaluation and to lead to integrated, in-depth analysis of proposed measures, taking into account the particularities of the study area without compromising the transferability of the models and methods.

1.5 Overall methodology

To address the challenges described in the previous sections, this thesis develops a policy evaluation tool, the *Platform*. The platform uses a multitude of different data, a combination of econometric and simulation models and a specialized database and GUI structure to deliver an in-depth, spherical and critical evaluation of sustainable mobility policy measures in the study area.

The collected sample consists of 560 households and 1290 individuals. The data collection process took place from August 2013 to April 2014 in monthly intervals and consisted of four questionnaires. The first questionnaire included questions about the household structure and vehicle ownership. The second questionnaire contained questions about individual household members and some attitudinal questions. The third questionnaire was an activity diary – accompanied with a GPS device to log the respondent's travel schedule. The fourth questionnaire was a Stated Preferences experiments regarding future vehicle choice. The final questionnaire was accompanied by a series of different psychometric questions to collect the respondents' attitudes and perceptions.

As Figure 1 shows, the survey data come from a variety of different sources. The personal survey database consists of 1,290 respondents, roughly 2.5% of the island's population and 5% of the population of Chios town, which was the main focus of the data collection. 720 of these respondents successfully completed a 2-day activity diary while 100 of them accompanied the diary with a handheld GPS device that recorded their activity and travel. Also, 250 respondents from the sample completed a menu-based stated preference experiment, using a modular approach, concerning future vehicle purchase. The same respondents also completed an attitudinal and psychometric questionnaire.

Secondary data sources are online APIs, geocoded databases and shapefiles and social media data. Data from Google places (points of interest, land use, commercial establishments, work areas) contribute to an up-to-date and crowdsourced gravity model for the spatial interactions of the study area, described in more detail in the next section of the paper. The collected and publicly available GPS data of the study area are useful for evaluating the transport network characteristics, updating missing links and assessing mean speeds in a more pragmatic sense (Tsouros et al., 2015b; Tsouros and Polydoropoulou, 2014). Shapefiles of the study area along with other geocoded information successfully contributed to obtaining a valid transport network and land use classification and as an exploratory tool for handling various socio-demographic variables. The latter is a process aided by the use of Twitter data (Goulias et al., n.d.), using geocoded text analytics, and resulted in a much better and in-depth exploratory analysis of the study area which, in turn, served as a more stable basis for the conception and design of the modeling framework.

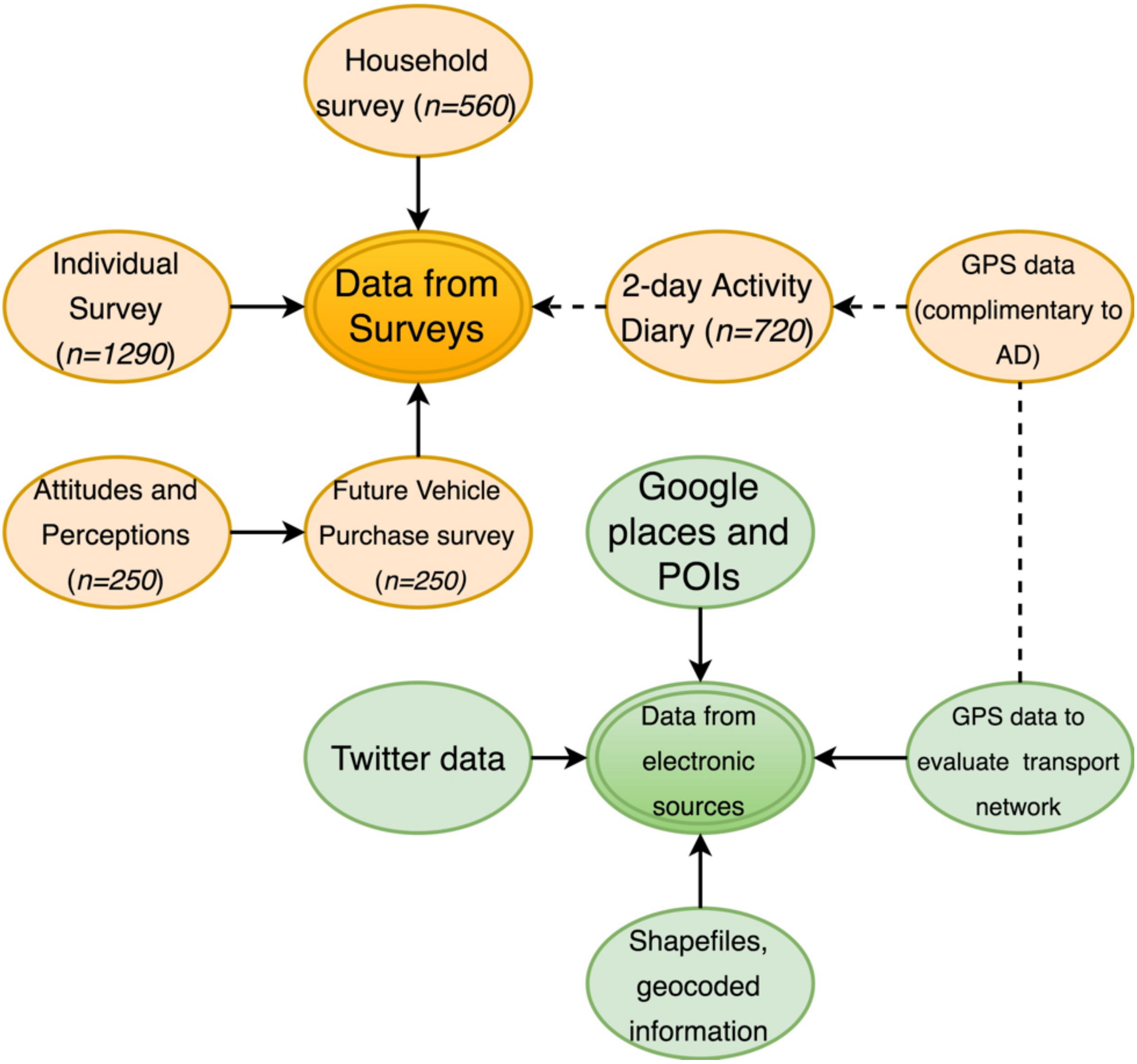


Figure 1 Data Sources

MODELS

This section presents the models comprising the engine of the policy tool. Figure 2 presents the overall model structure.

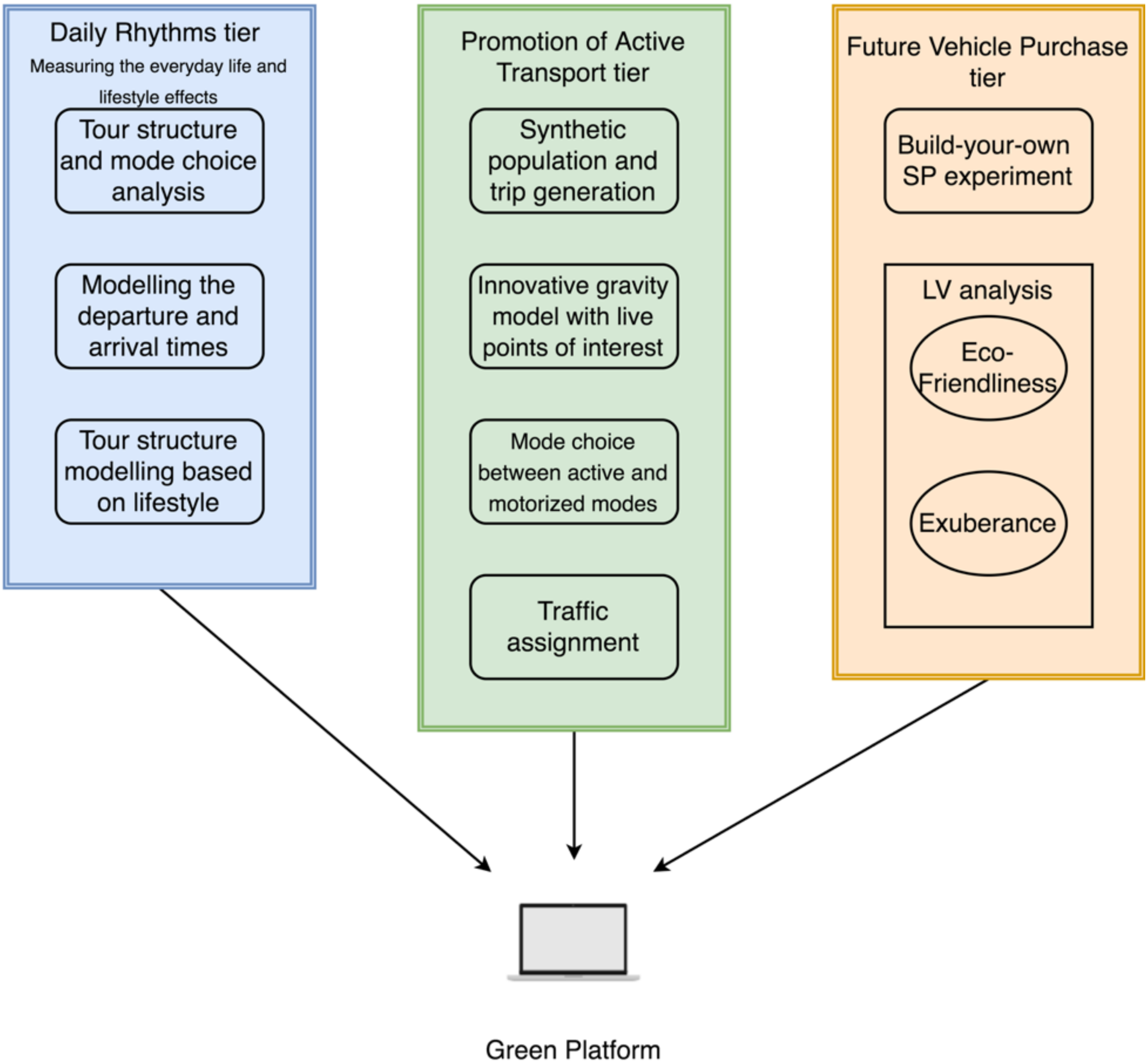


Figure 2 Overall model structure

Daily rhythms tier

The platform compares island daily rhythms by examining departure and arrival times, mode choice, the correlation between times and activities and tour structure. First, the average morning departure times and work activity durations are compared. Then, tour structure is analyzed. Tours are identified and grouped into primary and secondary tours, with primary tours containing work, education, shopping, leisure and other activities as the main trip purpose. Intermediate stops are also noted. Thus, the tour structure can be one of the following types: primary tour (with no intermediate stop or secondary tour), primary tour and secondary tour (with no intermediate stops), primary tour with an intermediate stop but no secondary tour, and finally primary tour with both an intermediate stop and a secondary tour. The next step is the analysis of the tour structure, depending on the temporal positions of the intermediate stop(s). Four groups are identified: HMH (home – main activity – home), HiMH (home – intermediate stop – main activity – home), HMiH (home – main activity – intermediate stop – home), and HiMiH (home – intermediate stop – main activity – intermediate stop – home). The final step of this analysis is a comparison of the modal split in the two areas, into general and activity-specific. This is followed by an examination of the bivariate correlation between the morning departure time and the duration of the various activities, and the statistical significance of this correlation. The departure time is measured as time elapsed from midnight (in minutes) so that the two variables are comparable. Correlation tests include work, leisure, education and shopping activities, measured across the appropriate sample clusters.

Stochastic frontiers were developed for models of production. A production function is an ideal amount a unit can produce for a given set of inputs. In empirical settings, observed outputs are not ideal (maximum), due to unknown random factors and measurement error (v) specific to each observed unit and caused by productive inefficiency, which also varies with each observed unit (u). Applying this model to the departure from home can reveal the factors affecting the "ideal" departure time; and similarly, for the last arrival at home in a day. To examine the relationship between output variables (arrival at home) and input variables (characteristics of the person and her household) a regression model is created with the dependent variable being the indicator of output and the independent variables being the array of variables we wish to test for their significance in influencing arrival time.

A latent class choice model is developed to examine tour structure further (Tsouros et al., 2015a). The initial assumption underlying this model is that the latent trait *Lifestyle* divides the sample into two distinct classes, each class having its own utility function for tour structure. Lifestyle seems to play a major role in all results. The more flexible timetable of the islanders, aided by a mixture of smaller travel times, relaxed work schedule, and proximity of various activity locations, leads to the more independent organization of daily patterns. In fact, only leisure duration seems to affect morning departure times in the island. A more favorable urban environment may not result in the adoption of an active transport lifestyle or trend but can lead to a more relaxed and independent management of the daily time schedules and activity patterns.

Promotion of active transport tier

This tier consists of a five modules transport simulation model of the study area. The simulation model is used to assess the performance of the proposed measures and scenarios as well as, mainly, the performance of the active transport policy measures – the creation of bike lanes and the pedestrianization of certain links in the city center. The initial module of the model consists of the creation of the synthetic population of the study area. Using data from the household and individual surveys and the synthetic population software PopGen (Goulias et al., 2012), the first module recreates the entire population of the island and allocates it to 43 specified analysis zones. The second module of the model consists of calculating the generated and attracted trips for every zone, for each trip purpose and socio-demographic group. This is done by using a mixture of regression models and trip rates, depending on the type of zone and the analysis level that we need. The zone attraction sub-component is supported by the use of the Google Places API in order to determine the presence of points of interest, commercial establishments and other places that could influence the attraction level of a zone. The API is used statically in this analysis, but it can also be utilized dynamically, incorporating into the modeling process the hours of service of the zone points of interest and also the crowd sizes, popularity, and rankings. The third module creates the OD matrices of the simulation model by using an innovative gravity model which incorporates sense of place via Twitter analysis as a factor in determining spatial interaction and zone relationships. The fourth module of the transport simulation model is the mode choice module. In this particular mode choice model, a binary choice logit between active and motorized transport is realized. Walking and cycling are included in the active modes (around 41% of the modal split), and mainly cars and motorcycles in the motorized modes (almost all the remaining modal split; the presence of public transport in the study area is virtually non-existent). The final module of the model is concerned with the traffic assignment in the network. It is applied after all the above modules and reflects the predicted traffic flows. The equilibrium of demand and supply is achieved.

The assessed policy measures include three different bike lane routes (from Chios city center to 3 neighboring locations – Vrontados, Karfas, and Kampos), two pedestrianization scenarios, and two scenarios that include all the bike lanes and both the pedestrianizations. Results of the model indicate that all the proposed policy measures and scenarios (detailed results in Table 35) have a positive impact on the policy goal, which is the modal shift to active transport. The simulation model provides more information, such as passenger kilometers, vehicle kilometers, mean trip distance and travel time and other useful information that can be used to calculate additional KPIs (such as emissions and fuel cost) or that further assists the evaluation process.

Future vehicle choice tier

This tier examines the future car purchase choice, using modules and different levels of attributes that construct a car, and measures the effect on purchase choice of personality traits such as ecological consciousness and symbolic/exuberant attitudes towards vehicles. The results should enable policy-makers to focus on certain market segmentation modes for the promotion of alternative fuel and automated vehicles. The tier presents a hybrid choice model, with latent variables capturing the pro-environmental and exuberant attitudes of individuals. The questionnaire presented to the respondents was in the form of a menu, from which participants could choose five different types of vehicle characteristics (engine size, type of car, fuel type, car edition and level of automation) to construct their ideal vehicle. The developed model is a hybrid choice model (Tsouros et al., 2015d; Tsouros and Polydoropoulou, 2017). Results indicate that there is a negative correlation between having symbolic, exuberant attitudes towards automobiles, and the purchase of a hybrid or a small engine sized gasoline car. Also, pro-environmental attitudes positively correlate with the purchase of a hybrid vehicle but not of an electric one.

Through the application of the hybrid choice model, the future fleet mixture of the study area is calculated. The calculation is conducted on the basis of two scenarios concerning the macro-economic situation of the country: an optimistic one and a neutral one which is an extrapolation of the current situation (as of 2017) of the macroeconomic indicators.

1.6 Structure

The thesis structure is the following: In the initial chapter introduces the subject of the thesis, states the preliminary definitions and clarifies which one and in which context will be used for the rest of the thesis. It presents the objectives, contribution and the structure of the thesis.

Chapter 2 is an extended literature review, concentrating on three axes: Literature on contemporary, innovative data collection methods and tools. A spherical research on these methods focused on the use of mobile devices, such as GPS, smartphones, and sensors, and their incisional role on the data collection procedures. It also presents surveys and projects that are relevant to green policy and sustainable transport, which use this kind of methods and tools. Then worldwide and European policy practices and state-of-the-art example are presented. This acts both as a literature review of successful practices, supporting the argument that green policy is not just wishful thinking and as a thought pool for policies to be adjusted, fit to the island area context and evaluated through the platform this thesis builds. The final axis of the literature review is a peek through the contemporary models and methods for travel behavior analysis. Hybrid choice models, with latent variables attempting to explain views and perceptions, activity-based models to develop a real-time simulation of activities and travel and secondary but required modules such as population generators, long-term choices evaluation, and spatial analysis.

Chapter 3 introduces the methodology of the thesis. It introduces the study area and the local context within which the thesis will try to assess policies by running models and simulating travel behavior. A current situation analysis of the study area presents facts and figures useful to the reader. It then introduces the framework for the survey design, the data needed and the exact methods and tools for data collection. GreTIA (GReen Transport in Island Areas) research project is presented, along with the modules and work packages that this thesis will use data from, ranging from tourists' behavior to environmental and financial analysis. The analytical presentation of the methodological framework of Chapters 4, 5 and 6 concludes Chapter 3.

Chapter 4 is about the every-day life tier. The effect of lifestyle is evaluated by comparing the study area, which has an island lifestyle, to the large urban center of Athens by using a similar database. Significant results presenting the differences between the two areas are discussed and policy implications from location specific analysis are also part of Chapter 4.

Chapter 5 is about the simulation of the study area and the effect of light infrastructure interventions – promoting active transport. It describes the procedure of coding and calibrating the city's network, the choice of zones and the grouping in main zones and clarifies the models that will act as input for the simulation. Population generator, spatial data, and long-term choices build up to a simulation model that has two main running periods, winter and summer, respecting the seasonality shifts of the local area social and transport conditions. Traffic data collected at main nodes is used as a calibration means. Initial future scenarios are discussed.

Chapter 6 is concerned with the strategic decisions tier; the future car purchase decisions which affect the future fleet mixture. The SP experiment that the survey participants responded to are presented. The SP experiment has a modular approach, allowing each participant to create their ideal vehicle. The methodology of a hybrid choice model is discussed. The latent variables that the model use is the Symbolic or Exuberant use of vehicles, the Environmental friendliness and the Tech-Savviness of users/respondents.

Chapter 7 explores the development of the platform. Data and models from Chapter 4 along with the simulation provide the input data for the one input channel of the platform that is based on simulation and transport conditions. The other two are environmental and financial analysis. The platform has the capability to evaluate green policies based on a series of factors and models that fit the study area particularities, addresses economic background and learns and respects people's perceptions, views, and behavior.

Chapter 8 concludes the thesis by summarizing results, discussing policy implications and providing insight for future research.

Chapter 2: Literature review

In the introduction, it was made clear that this thesis aims to develop a green policy evaluation platform, using advanced model techniques and simulation. This chapter contains the literature review, split into three main categories. The first category is concerned with data collection methods, completing the discussion opened in the first chapter. New approaches and tools for data collection are reviewed, and findings from the similar research are presented. The second category presents green transport policy practice and state-of-the-art examples from around the world. It is the knowledge pool from which radical, "soft" and education policy will be picked and later evaluated in the platform. The final category is a peek through new model classifications, the inefficiencies of Random Utility models and the capabilities of modeling behavior the Hybrid Choice Models add. It is also a review of simulation practices in respect with their fit to the study area this thesis is going to address.

2.1 Data collection

One of the first references to GPS based methods is the survey of Murakami and Wagner, (1999) which studied the reliability of GPS devices to verify the number of trips reported by the respondent, the actual trip times and any other characteristic that may be recorded erroneously in the trip diary of the survey. This research, being published over 13 years ago, used mobile devices much larger and more expensive ($1350 of a GPS device) than the devices used today. The findings verified that the research participants tend to forget or to over-estimate the number of daily trips, and a GPS device can contribute to the correct trip data collection and correction of possible mistakes.

Stopher and Greaves, (2007) suggested the elimination of travel diaries along with data fusion techniques, panel surveys and continuous measurement as an answer to the gradually dropping response rates, and increasing costs of surveys. However, it is noted that these fusion techniques depend highly on the acceptance of the respondents to carry a GPS device with them all day. This fact may raise concerns on personal security or even fear. An answer to this may be the use of smartphones with integrated GPS function, which even solves the problem of reaching young people and busy professionals (which have always been the most difficult to reach). Another issue identified by Wolf et. al., (2001) was that this survey design lacks the ability to precisely determine the means of transport (raw GPS speed data from a motorbike and a car are very much alike). Moreover, it does not actively engage the respondent in the survey procedure. Moreover, activities of participants are not recorded and need to be predicted using other methods.

Bricka et.al., (2012) present an analysis of the factors that influence the differences between what is written down in the trip diaries and the actual trips verified by the GPS devices. They point out the different nature of these two methods of data collection, especially when a survey is conducted solely by GPS devices, without a trip diary present. They also attempted an analysis of the factors influencing the differences in survey-reported and GPS-recorded trips. From a sample of 265 individuals, which reported a total of 1533 trips, only the 49% reported exactly the number of trips that the devices record. The results of the descriptive analysis and the model estimations revealed that the HBW trips are less likely to be under-reported. The research also pointed out the "Friday effect." People who travel on Fridays tend to travel more for non-work purposes than work purposes.

Papinsky et.al., (2009) attempted to explore the route-choice decision-making process, actually by comparing the planned routes (stated in a travel diary) and the observed ones, revealing that the GPS devices can be used in studies containing quantitative factors, like travel time, route directness or congestion.

Stopher and Collins (2005) suggested a probability matrix to determine mode choice. Average travel times and speeds provided by GPS devices for every mode were recorded in a matrix and other factors (such as bicycle ownership) determined the probability of a certain mode choice. This study used GIS maps to calibrate the matrices.

Cortés et.al., (2011) attempted the evaluation and verification of travel times of public transportation (mainly bus) by using GPS devices. The research recorded the bus's speed by using mobile devices and with the aid of geo-coding and GIS software-defined the location of the areas in the network that suffer more from traffic congestion or categorized the bus lines according to their efficiency, speed and time accuracy. These data were then used to locate the bus stops that cause more traffic

congestion problems. It was concluded that this methodology is not limited to bus lines with fixed schedule but can also be used in hop on – hop off bus lines or in cases of taxis and mini-buses making stops at the passenger's demand.
In 2013 survey authors (Şimşek et al., 2013) used the data collected by mobile GPS devices to evaluate drivers performance and behavior. The methodology of the research, apart from defining the correct (or the socially expected) driving behavior, used the GPS tracks, to measure speed and route choice, and then compared the data with the legal/posted speed limits. Finally, three quantitative factors were evaluated: driving speed off the legal limits, waiting times at traffic lights and fuel use on every trip (depending on the vehicle).
Du and Aultman-Hall (2007) focused on the correct identification of trip-ends using GPS devices and presented a methodology for data analysis when arranging many logging data. They found out that after an automatic identification of trip-ends, 94% of the trips were correctly identified (on a passive stream of GPS data).
In a 2010 research paper, authors (Herrera et al., 2010) attempted traffic monitoring using GPS-enabled cell phones. Exploiting the "extensive coverage provided by mobile phones and the high accuracy in position and velocity measurements provided by GPS units" the prototype demonstrated a successful way to monitor traffic.
Asensio et. al., (2009) used the GPS devices to collect speed data for road traffic noise mapping. This is another case of expensive and challenging data collection that GPS technologies may make it cheaper and easier to collect.
GPS devices have been recently used in studies constructing a pedestrian network algorithm derived from multiple GPS traces (Kasemsuppakorn and Karimi, 2013); and in route choice models developed with Revealed Preferences data from the devices studying cyclists' behavior (Broach, 2004) (Broach et al., 2012). Both studies show that the use of such devices can be instrumental when trying to evaluate green modes of transport.
Schönfelder et al., (2002) conducted a research considering the differences in travel behavior and mobility patterns when addressing the intra-personal level and the inter-personal level. The research also focused on the potentials of automatically collected GPS data and the known drawbacks of this type of data collection methodology. The identification of problems with the data led to a proposed methodology of data editing procedure to maximize data quality. In the conclusions, they propose future research with GPS to be focused on route choice analysis as a better way of representing behavioral analysis.

In another paper focusing on the combination of GIS and GPS, (Gong and Chen, 2012) attempt to apply a method for travel mode detection from GPS traces with the collaboration of GIS software in New York City. In a complex urban environment such as that of New York transportation networks are complicated. Technical details such as logging frequency or satellite signal problems are discussed. GIS software can identify transport modes such as subway, rail or bus lines (fixed route). Problems occur when walking mode traces mix with slow moving car traces (stuck in traffic). A complete algorithm and methodology for data processing are proposed, specially designed to handle big amount of data. This research uses GPS devices similar to the present research and the methodology proposed the limits for data logging frequency of timetable of logs in a way that can fit the needs of the present research.

Moreover, Badland et al., (2010) examined commute routes with the aid of GPS devices. University employees were used as the study subjects, using a 7-day self-report travel log only for work related trips. The paper aimed to identify whether the shortest route is the main factor affecting the decision of route choice.

Reumers, et al., (2012) attempted to create a semantic annotation procedure for GPS traces. The research focused on extracting data from GPS and then assign a probability for each activity being a certain one depending on factors such as time of the day, time of the activity, the day of the week, characteristics of the household. The same was attempted for mode identification with factors such as speed, GIS interactions (i.e. bus stops), and speed graphs.

Ellison and Daniels, (2012) used data from GPS devices which were part of a broader study on travel behavior to capture speeding behavior in school zones. This study included a psychological sub-study to record the personality traits, risk perception and driver behavior (aggressiveness) of the participants. The devices were used to measure the speed around school areas and to pinpoint locations to locate the speed limit in these areas manually.

Henriques and Bento, (2013) attempted the integration of GPS traces, and Digital elevation maps to improve bicycle traffic. The system architecture of this research uses GPX (GPS exchange files) and terrain elevation data to simulate bicycle traffic in a simulation software like VISSIM.

Broach, et al., (2012) used bicycle mounted GPS devices to developing a route choice model. They used only non-exercise trips. In this paper, it is stated, that GPS traces can also work as a base network, mapping the network as the traces flow through the urban area. The model considered distance, slope and turns as main

factors for the route choice analysis. The results of the model revealed that commuting cyclists are more likely to be affected by distance as a factor.
One of the aims of the literature review is to point out the richness of information that a GPS device can collect in an easy and low – cost way. An individual using a GPS logging device correctly along with his/her daily travel schedule can provide information not only about the trip ends and the routes but also for speed, travel time, slopes and altitude or certain routes, delays at junctions or traffic lights, evaluation of public transport services and other interesting information. This can become a breakthrough in data collection, both because of the minimum burden and the low cost but also relative acceptance to use the GPS devices by respondents. Data collection can be made even more accurate by using a web interface where respondents can find, review and correct their trips, stops or other information (Sun et al., 2013)
The review of the literature demonstrated a growing interest in the usage of GPS as means of analyzing travelers' decision-making with single modes of transportation. The research presented in this paper capitalizes on these findings and goes one step further by utilizing GPS traces to compare alternative active transport modes and identify route choice attractiveness for bikes, electric bikes, motorcycles, and walk alternatives

2.2 Travel Behavior Research – Activity-based models

Activity engagement constitutes the backbone of human behavior (Devillaine et al., 2012). Activity-based approaches explicitly recognize the fact that individuals travel to fulfill their need to engage in activities. An activity-based model should predict activity participation and time allocation, with explicit consideration given to spatial, temporal and social constraints, while accounting for inter-dependency among individuals in a household and trips (Goulias and Kim, 2001).
The development of activity-based models as a tool to analyze travel behavior and forecast transport demand has been motivated by the growing complexity of activity patterns. The developments result in socio-economic changes, growing congestion, and negative externalities, as well as the need to estimate changes in travel behavior

in response to innovative policies designed to achieve sustainability (Shiftan and Ben-Akiva, 2011).

Several successful implementations of the activity-based models have already demonstrated that the activity-based concept is workable. Operational modeling systems at the regional level can be constructed that are both practical (reasonable running time, reasonable size and scope of the travel/activity surveys required to support the model estimation), and that also incorporate the best components from the frontier-line research on activity and travel behavior (Davidson et al., 2007). Overall, when describing the new generation of regional travel demand models, three basic features should be highlighted:

1. An activity-based platform that implies that modeled travel is derived within a general framework of the daily activities undertaken by households and persons.

2. A tour-based structure of travel where the tour is used as the unit of modeling travel instead of the elemental trip; this structure preserves a consistency across trips included into the same tour, by such travel dimensions as destination, mode, and time of day.

3. Microsimulation modeling techniques that are applied at the fully-disaggregate level of persons and households, which convert activity and travel related choices from fractional-probability model outcomes into a series of crisp decisions among the discrete choices.

While complimentary, these features are essentially independent, and having one of them in place in the modeling system does not automatically require the others. Recognition of the activity-based nature of travel and attempts to derive travel from the comprehensive analysis of the individual daily activity agenda started long ago without any explicit linkage to a tour-based technique or micro-simulation (Bhat and Koppelman, 2000).

Similarly, the tour-based concept of modeling travel is rooted in trip-chaining models that were first developed independently of the activity-based paradigm, until it was recognized after the works of Bowman and Ben-Akiva, (1999; 2001) that the tour may serve as an efficient unit to construct daily activity patterns.

Microsimulation techniques first opened the way to apply activity-based effectively and tour-based constructs in a realistic regional modeling setting (Bradley et al., 1999; Vovsha et al., 2002; Bradley et al., 2001; Jonnalagadda et al., 2001). Several activity-based models, incorporating all three of these salient features of the new activity-based models, are summarized and presented below.

Goulias et al. (2012) developed a large-scale spatiotemporal simulator of activities Greenhouse Emissions, Networks, and Travel (SimAGENT) for Southern California. The simulator includes population synthesis that recreates the entire resident population of this region, provides locations for residences, workplaces, and schools for each person, estimates car ownership and type as well as the main driver of each vehicle, and provides other key personal and household characteristics. Then, a synthetic schedule generator recreates for each resident person in the simulated region a schedule of activities and travel that reflects intra- household activity coordination for a day. This synthetic activity and daily travel schedules are then converted to multiple Origin-Destination (OD) matrices at different times in a day. These are in turn combined with other OD matrices (representing truck travel, travel from and to ports and airports, and travel generated outside the region) and assigned to the network in multiple periods in a day. The assignment output is then used in another software to produce estimates of fuel consumed and pollutants emitted (including CO2) by different classes of vehicles. The overall model system also includes provision for finer spatial and temporal resolutions.

Auld (2012) developed the Agent-based Dynamic Activity Planning and Travel Scheduling (ADAPTS) model, which implemented for the Chicago region for validation. ADAPTS is a new activity-based travel demand model which has been developed (Auld, 2011) to demonstrate the direct integration of travel demand modeling with traffic assignment. The fundamental concept underlying the development of the ADAPTS is to treat activity planning and scheduling events as individual discrete events within the overall simulation framework. Consequently, an activity is created and modified over time and eventually executed (i.e. assigned to the network) in one unified simulation. The model is dynamic in the sense that activities are generated and passed to the network assignment as they are scheduled, rather than pre-defining daily activity schedules for agents to assign at one time. This allows for dynamic interaction effects within the demand model and network simulator, including such things as opportunistic scheduling, en-route replanning or other effects.

Pendyala et al. (2010; 2012) designed an integrated model system, SimTRAVEL. The model involves the microsimulation of location choices within the land use domain, of activity-travel choices within the travel demand domain, and of individual vehicles on networks within the network supply modeling domain with a view to more tightly tying together component model systems in a behaviorally consistent fashion. The proposed alternate design adopts an event-based paradigm in which every activity-travel episode is an event that is simulated along a continuous time axis. The land use microsimulation model is run first to simulate the locations of households and businesses. In the activity-based model system, time-space prism constraints are identified based on the scheduling of necessary activities of the individual as well as of those household members who may be dependent on the person for transportation. In any unconstrained period, activities (and travel to the activities) may be undertaken. The choice of mode and destination for any activity is determined using a common mode/destination choice model. The mode choice set includes only those modes that are available to the individual at the time that an activity is going to be undertaken, and the destination choice set includes only those destinations that can be reached by the fastest mode possible without violating time-space prism constraints. Therefore, the joint mode/destination choice model requires an initial set of network level of service attribute to simulate these choices. The set of initial network level of service attributes may be obtained from a validated four-step model or by applying a bootstrapping procedure. A prototype has been developed and tested on a three-city subarea in the southeast region of the Phoenix metropolitan area.

Bowman et al. (2006) developed a regional travel forecasting model system called SacSim (developed in 2005 and implemented in 2006) for the Sacramento (California) Area Council of Governments. The system includes an integrated econometric microsimulation of personal activities and travel (DaySim) with a highly disaggregate treatment of the purpose, time of day and location dimensions of the modeled outcomes. Initially, the Population Synthesizer creates a synthetic population, comprised of households drawn from the region's U.S. Census Public Use Microdata Sample (PUMS) and allocated to parcels. Long-term choices (work location, school location, and auto ownership) are simulated for all members of the population. The Person Day Activity and Travel Simulator then creates a one-day activity and travel schedule for each person in the population, including a list of their tours and the trips on each tour. These components, comprising DaySim and implemented jointly in a single software program, consist of a hierarchy of multinomial logit and nested logit models. The models within DaySim are connected by adherence to an assumed conditional hierarchy and using accessibility log sums. The trips predicted by DaySim are aggregated into trip matrices and combined with predicted trips for special generators, external trips and commercial traffic into time- and mode-specific trip matrices. The network traffic assignment models load the trips onto the network. Traffic assignment is iteratively equilibrated with DaySim and the other demand models. SACSIM was calibrated and tested for the base year of 2000 and forecasts to the years 2005 and 2035 (Bradley et al., 2010). It was used to provide forecasts for the Regional Transportation Plan (RTP) and continues to be used for various policy analyses.

With regards non-motorized trips, Sacramento's SacSim activity-based model uses parcel/point level land use data (Bradley et al., 2010), potentially providing the finer resolution needed for more accurate non-motorized modeling (Liu et al., 2012). Parcel/point data also allows more precise representation of transit proximity as the distance from each parcel/point to the nearest transit station or stop, and more accurate measurement of intra-zonal walk time and drive time. These continuous, micro-level representations of land use and walk accessibility and intra-zonal accessibility permit improved modeling of non-motorized travel. Walk and bike are modeled in the tour and trip mode choice models, which include two land use variables – mixed use density and intersection density. The former is defined as the geometric average of retail and service employment and households within a half mile of the origin or destination parcel, while the latter is measured as the number of 4-way intersections plus one-half the number of 3-way intersections minus the number of 1-way intersections (dead ends and cul de sac) within a half mile of the origin or destination parcel. Other models in SACSIM, such as the destination choice models, also include land use and urban form variables defined within a given distance of a parcel/point, such as density variables and street pattern variables.

The San Francisco County Chained Activity Modeling Process (SF-CHAMP) was developed for the San Francisco County Transportation Authority (SFCTA) to provide detailed forecasts of travel demand for various planning applications (Outwater and Charlton, 2006). These applications include developing countywide plans, providing input to microsimulation modeling for the corridor and project-level evaluations, transit planning, and neighborhood planning. The objective is to accurately represent the complexity of the destination, temporal and modal options and provide detailed information on travelers making discrete choices. These objectives led to the development of a tour-based model that uses synthesized population as the basis for decision-making rather than zonal-level aggregate data sources. The tour-based model has nine primary components (Outwater and Charlton, 2008). Most of the model components were estimated using household survey data for San Francisco residents only, collected by the Metropolitan Transportation Commission (MTC). Each model component was calibrated using various observed data sources, and then the full model was validated using traffic count and transit ridership data for each period. However, over the years, improvements to SF- CHAMP have been primarily shaped by the questions confronting decision makers. Model improvements have addressed issues such as road pricing, parking availability and pricing, transit treatments, non-motorized infrastructure, land use decisions and the quality of the built environment (Erhardt et al., 2008; Zorn et al., 2011; Hood et al., 2011; Zorn et al., 2012). For instance, SF-CHAMP is unable to capture any benefit related to capacity expansion, crowding's effect on travel time nor or any of the real-life true capacity limitations.

Pendyala et al. (2005) developed a multimodal comprehensive activity-based travel demand forecasting system for the State of Florida, FAMOS, which consists of two main modules that together comprise a microsimulation model system for modeling activity-travel patterns of individuals: 1. Household Attributes Generation System and 2. Prism-Constrained Activity Travel Simulator (PCATS). FAMOS simulates activity-travel patterns at the level of the individual decision-maker. Thus, not only is it an activity-based model system, but it is also a microsimulation model system. This is because activity-travel patterns are simulated at the micro level, i.e., at the most disaggregate level possible. By simulating activity-travel patterns at the level of the individual decision-maker, the model provides a strong platform for modeling travel demand in a region along a continuous time axis. The output of FAMOS is essentially a series of activity-travel records for all people in the simulation. These activity-travel records can be aggregated both spatially and temporally to obtain zone-level origin-destination (O-D) matrices by trip purpose, mode, and time of day. These O-D matrices then are fed into any static or dynamic traffic assignment routines for obtaining link volumes by time of day.

The model system has been developed and estimated using household activity and travel data collected in the Southeast Florida region of Florida in 1999.

The New York activity-based model (Vovsha and Chiao, 2008) is the first comprehensive multimodal model developed for the New York Metropolitan Region, which encompasses an entire 28-county, a three-state region that includes portions of Connecticut and New Jersey, with a total population of 20 million residents. The NYMTC model's success has proven that the concept of a microsimulation activity- and tour-based model can be applied to a large metropolitan area with a unique level of complexity for the transportation system. The NYMTC model has four consecutive major modules: (1) Tour generation, which includes household synthesis, automobile ownership, and journey frequency choice models; (2) Tour mode and destination choice, which includes pre-mode choice, primary destination choice, entire-tour mode combination choice, stop-frequency choice, and stop location choice; (3) Time-of-day choice and pre-assignment processor, which includes tour time-of-day choice for outbound and inbound directions, trip mode choice, and construction of mode-specific and time-of-day period-specific trip tables; and (4) Traffic and transit simulation, which is implemented by time-of-day periods.

Roorda et al. (2009) based on the Travel Activity Scheduler for Household Agents (TASHA) (Miller and Roorda, 2003; Roorda, 2005) microsimulation framework propose an integrated model of vehicle transactions, activity scheduling and mode choice with the help of the concept of stress, which is expected to ''occur when one's current state deviates from some alternative desired/expected/optimal state (Miller, 2005). The importance of introducing the stress can be justified by the existence of irreversibility and uncertainty, especially in the long-term decision, where transaction costs might be significant. The stress could come from both a household member him/herself under study and another member(s). The authors operationalize the concept of the stress, as a measure of potential improvement in behavioral change, based on the utility loss due to the unavailability of household vehicles and the occurrence of conflicts over the use of household vehicles. In the integrated model, the stress is used as feed- back into the model of vehicle transactions and type choice. Furthermore, the integrated model explicitly represents intra- household interaction in joint activity participation, vehicle allocation, and ridesharing, chauffeuring and conflict resolution. For the model, estimation was used two sources of data. The automobile transactions model is based on the Toronto Area Car Ownership Survey (TACOS), a retrospective survey of 935 households (Roorda et al., 2000). The TASHA model of activity scheduling and mode choice is based on data from the 1-day trip diary Transportation Tomorrow Survey conducted in 1996 (DMG, 1997). The most conflicts occur over the vehicle in one-vehicle households. By buying a vehicle, a one-vehicle household reduces the number of conflicts it experiences by 0.19, on average, which is virtually all the conflicts it experiences. Similarly, a two-vehicle household can eliminate almost all the conflicts it experiences by purchasing a third vehicle. When a two-vehicle household disposes of one of its vehicles, nearly 2.5 times the number of conflicts is generated as the one-vehicle households would eliminate if it purchased a vehicle.

Bhat et al. (2004) designed the Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns (CEMDAP) to model the daily activity-travel patterns of individuals, which uses census tract–block group–block level summary tables as control totals for synthesizing households and individuals from the 2000 Public Use Microdata Samples (PUMS) data. Some of the summary tables contain the distribution of a single variable, while other tables describe the joint distribution of multiple variables. These tables are used to construct a full multiway distribution by using a recursive merge procedure and the iterative proportional fitting procedure. For the Dallas–Fort Worth (DFW) application, four household-level variables and three individual-level variables, are used as controls. The household-level variables are the household type (six categories), household size (seven categories), the presence of children (two categories), and age of householder (two categories). The individual-level variables are gender (two categories), race (seven categories), and age (10 categories). All other variables in the PUMS data that are required for the activity-travel pattern simulator, but not controlled during the population synthesis, are not directly used. Instead, their values are simulated based on a suite of models estimated by using PUMS and other sources of data (Guo et al., 2005).

In 2006, Pinjary et al. presented CEMDAP II, a new modeling system that enhances CEMDAP in several ways. First, the new system is developed at a finer spatial resolution and applied to a 4,874-zone system for the DFW area in Texas. Second, the activity-travel patterns of children (persons under 16 years of age) are now explicitly modeled and forecasted. Third, the interdependencies between the travel patterns of children and their parents (such as an escort to and from school and joint participation in optional activities) are explicitly accommodated. Finally, for estimation of the models, the raw survey data obtained for the DFW area were reprocessed to create a larger sample, and all the model components (over fifty in all) were re-estimated. The overall modeling system is broadly subdivided into the following five categories: (1) the generation-allocation model system, (2) the worker scheduling model system, (3) the non-worker scheduling model system, (4) the joint discretionary tour scheduling model system and (5) the children scheduling model system. The data used in the estimation of all the model components were obtained from three main sources: (1) the 1996 DFW household activity survey, (2) the DFW zonal land-use database, and (3) the DFW interzonal transportation level of service data. The final estimation data set comprised about 23,000 activity-travel records for 6,166 persons from 2,750 households.

PB Consult Inc. (2005) designed the Mid-Ohio Regional Planning Commission (MORPC) model, which is a disaggregate tour-based model applied with the microsimulation of each household, person or tour. The MORPC model consists of the following eight core components: 1. Household car ownership choice, 2. Coordinated choice of individual daily activity pattern type and a number of tours for mandatory purposes (work, school, university), 3. Household generation of fully joint tours for non-mandatory purposes (shopping, other maintenance, eating out, other discretionary) and person participation in them, 4. Household generation of individual tours for maintenance purposes (escorting, shopping, other maintenance) and allocation to persons; individual generation of tours for discretionary purposes (eating out, other discretionary) and at work sub- tours, 5. Primary tour destination choice, 6. Tour time-of-day choice, 7. Entire-tour mode combination choice, 8. Stop frequency, stop location, and trip mode choice. All eight model sets were validated against the surveyed population (5,555 households) with excellent results. Then the model was applied to the base year synthetic population (610,000 households) and validated against the traffic counts, transit counts, and on-board survey. The model area is divided into 1805 internal and 72 external zones. The primary inputs to the model are transportation networks and zonal data, where each zone has the standard socioeconomic characteristics.

Shiftan et al. (2003) developed an advanced activity-based model system for the City of Tel-Aviv in Israel. The model system is developed as a system of logit and nested logit models assuming a hierarchy of the model components. At the highest level of the model system, an auto availability model is predicting the probability of having a various number of autos available to the household. In additional, an aggregated auto ownership model was prepared to produce control values at the aggregated level to validate the Auto Availability Model. Following this model, the primary activity model determines a person's main activity. The alternatives include work, education, shopping, other types of activity out of the home, and staying at home. For activities outside the home, the model determines the destination of the primary activity and the main mode of the tour. In developing the model, the emphasis was put on evaluating the response to different transportation policies such as parking restrictions and pricing in addition to improved and new infrastructures and transit services. Some of the innovative aspects of this model system were based on a combination of data sources including a tour-based stated- preference survey, a three-day trip diary database enriched in communities adjacent to a rail corridor, and a detailed parking survey that includes information on parking demand and supply.

Srinivasan and Bhat (2008) in their descriptive study of activity patterns explored joint participation with both household and non-household members and examined the generation, location, and scheduling of joint activity episodes. Such an exploratory analysis is a necessary first step in informing the development of activity-based travel demand models that adequately capture joint participation in the activity and travel episodes. By using data from the American Time Use Survey (2003-2004) in which participated 34,693 persons, they found that about 30% of individuals undertake one or more out-of-home (OH) activity episodes with household members on weekdays, and about 50% pursue OH activity episodes with non-household companions on weekdays. The results of this analysis highlighted the high levels of joint activity–travel participation by individuals. Further, independent activities are found to be different from joint activities in systematic ways. Specifically, joint episodes are of longer durations, significantly likely to take place at the residence of other people, and often confined to certain time periods of the weekday. Also, within the class of joint episodes, significant differences are also observed based on activity type, companion type, and the day of the week. Finally, they also found a strong influence of socioeconomic characteristics (such as gender, employment characteristics, household structure, the presence of children, and income) on how individuals spend time with different types of companions.

Kato and Matsumoto (2008) propose a Tobit-type joint time allocation model in the context of a nuclear family with a child (a representative child). The model adopts a particular case of the multi-linear and iso-elastic household utility, i.e., the additive type of household utility (Zhang et al., 2002; Zhang and Fujiwara, 2006). It refines the studies in three ways (Timmermans and Zhang, 2009). First, a child is explicitly introduced into the model, even though the multi-linear and iso-elastic models can be theoretically used to represent the influence of children. Second, the newly developed model incorporates not only the constraint of available time but also that of the monetary budget. Third, the new model explicitly represents the occurrence of activity (i.e., whether an activity is performed or not) by using a non-linear Tobit-type modeling approach. For the model estimation, Kato and Matsumoto used data from a paper-based household survey that they conducted in Tokyo and Toyoma in 2003 with a total sample of 1432 participants. The empirical analysis of the model reveals the common characteristics between the two cities – with respect to the child's gender; the husband's weekly non-working days, allowance, and job; and the wife's age and job – that significantly influence the household's welfare. The analysis also reveals different characteristics between the two cities. First, the greater the number of children in a household, the higher is the significance of the husband and wife's joint out-of-home leisure activity on a weekday for household welfare in Tokyo (mega city), and the lower is the same in Toyama (local city). Second, the greater the non-working days of the husbands, the lower is the significance of their individual out-of-home leisure activities on a weekday for household welfare in Tokyo and the higher is the same in Toyama.

Wang and Li (2008) present a model of household time allocation with the consideration of hiring domestic helpers. The modeling methodology adopted is similar to the one proposed by Kato and Matsumoto (2008), but it is unique in the sense that it deals with the influence of domestic helpers on household time allocation behavior. The model assumes that the utility of hiring a domestic helper is inherently related to the time allocation behavior of household members. Such modeling approach reflects the fact that domestic helpers impose a continuing influence on the household across a given period. To estimate their model, they used trip diary data from the Hong Kong Travel Characteristics Survey conducted in 2002. The final sample used for this study involves 10,381 households, of which about 11.7% or 1210 households have live-in maids or full-time domestic helpers. Even though hiring domestic helpers is a common practice in some limited Asian countries and regions such as Singapore, Hong Kong and the mainland of China, it could also have its specific policy implications with the increase of women (especially the married women) participating in the labor market in the context of other countries and regions. The paper provides a logical and operational method to represent the influence of some specific persons on household time allocation behavior. These persons could include not only the domestic helpers but also the extended family members such as parents of household heads (Timmermans and Zhang, 2009).

Zhang et al. (2008) develop a new type of household discrete choice model by integrating different types of household choice models based on latent class modeling approach under the principle of random utility maximization, where household utility function at each model is defined to reflect its members' preferences and intra-household interaction theoretically. A latent class corresponds to a group decision-making mechanism. The proposed model can deal with not only the choice situations where multiple household members involved in the joint decision are known a priori but also the situations where the involved members are unknown. As a case study, three types of household utility functions are dealt with: multi-linear, maximum and minimum types, in the context of couples’ car ownership behaviors. Using the data collected from household members over 15 years old in two Japanese cities (Hiroshima City and one of its satellite cities, Higashi-Hiroshima City) in 2004, they found that changes of utility combinations result in very complicated variations in

both signs and values of the model parameters and choice probabilities by multi-linear utility show small variations across different combinations.
Arentze and Timmermans (2008) describe the household behavior based on the concept of need in the context of multi-day, multi-person activity participation. The need of household or its member is the source of motivations to perform various activities, and the change of need consequently generates the utility. The authors introduce the concept of potential to illustrate how and how much activity could satisfy the certain need of a household and its member(s). Intra-household interaction is represented in several ways. First, it is proposed to use a weight that a household assigns to the household needs about the weight that a household member assigns to his/her personal needs. Accordingly, altruism-selfishness is implicitly incorporated. Then, an exchange procedure is further proposed to reflect the fact that the household members "use joint decision rules first to make their agendas consistent and next to see whether personal re-allocations could improve the group result. The joint decision rules are introduced to properly evaluate the influence of disagreement between household members on the selection of household activities and the allocation to members. Since the need may vary over time, a dynamic microsimulation approach is proposed.
Spissu et al. (2008) presented an analysis and modeling of weekly activity-travel behavior using a multi-week activity-travel behavior data set with 5,561 discretionary activities on 5,936 days, collected in and around Zurich, Switzerland. Her survey focuses on six categories of discretionary activity participation (namely: 1. OH social, 2. OH meals, 3. OH sports, 4. OH cultural, 5. OH leisure, 6. OH personal business, and 7. Other) to understand the determinants of and the interpersonal and intra-personal variability in weekly activity engagement at a detailed level. A panel version of the Mixed Multiple Discrete-Continuous Extreme Value Model (MMDCEV) that explicitly accounts for the panel (or repeated observations) nature of the multi-week activity-travel behavior data set was developed and estimated on the data set. The panel MMDCEV model allowed the researchers to quantify and assess the relative magnitudes of within-individual week-to-week variation and between individual variation in the preference for discretionary activities. The analysis revealed that week-to-week intra-individual variation is greater than inter-individual variation in discretionary activity participation for virtually all activity categories, suggesting the importance of collecting and analyzing multi-period activity-travel data in the context of discretionary activity participation. The greatest inter-individual variance occurred in sports activity participation.

A unified model of activity type choice (generation), time of day choice, mode choice, destination choice, and time use allocation (duration) was proposed by Eluru et al. (2010) and estimated on a survey sample data set drawn from the 2000 San Francisco Bay Area Travel Survey (BATS). The model system constitutes a joint multiple discrete-continuous extreme value (MDCEV) - multinomial logit (MNL) model. In the model, all discrete choices, except for destination choice, and the continuous duration dimension are modeled using the MDCEV, and destination choice is modeled as an MNL (with a sampling of alternatives) nested and therefore integrated with the MDCEV model component. The parameter estimates of the joint model offer behaviorally intuitive results that support the integrated treatment of these choice dimensions as a choice bundle.

Ferdous et al. (2010) proposed a multivariate ordered-response system framework to model the interactions in non-work activity episode decisions across household and non-household members at the level of activity generation. Such interactions in activity decisions across household and non-household members are important to consider for accurate activity- travel pattern modeling and policy evaluation. They address this estimation problem by resorting to the technique of composite marginal likelihood (CML) that is based on the classical frequentist approach. The empirical analysis uses data drawn from the 2007 American Time Use Survey (ATUS). The results underscore the strong linkages in the activity episode generation of adults based on activity purpose and accompaniment type. More specific, the results indicate the presence of distinct gender effects in activity type participation and accompaniment. Men are less likely than women to participate, across all companion types, in family care activities, maintenance activities, and non-maintenance shopping activities. The extent of this linkage varies by individual demographics, household demographics, the day of the week, and season of the year. The results also highlight the flexibility of the CML approach to specify and estimate behaviorally rich structures to analyze inter-individual interactions in activity episode generation.

In another survey, Choo et al. (2012) focused on weekend trips and compared travel characteristics on weekends with a weekday. Their study explored characteristics of travel behavior on weekends through descriptive analyses such as t-tests and ANOVA tests on socio-demographic variables. Also, they developed three Tobit models for trip frequencies (number of daily trips) of weekday and weekends to identify key factors that significantly affect travel behavior. Data for this study came from a 24-hour household travel diary survey conducted in the Seoul Metropolitan region through face-to-face interviews in 2006. The sample size of the survey is

230,900 households, while the survey for weekend travel was performed on 11,545 households in the same week. Findings reveal that travel characteristics are significantly different between weekday and weekends. Youngers have more trips on weekdays and Saturday but fewer trips on Sunday. Also, results indicate that weekend travel is affected by various household (household size, number of cars in a household, household income, residence area, type of house, and presence of preschoolers) and personal (gender, age, occupation, employment status, workweek type, and presence of a driver's license) attributes. Finally, they found that weekend travel behavior is more strongly affected by geographical and cultural characteristics of the country or the city than socio-economics and demographics, and they suggested that travel demand models for weekends need to be different from weekday as well as by region or country.

Liu and Deng (2008) presented an on-going effort undertaken by New Jersey Department of Transportation (NJDOT) to develop statewide weekend travel demand forecast and mode choice models for New Jersey by balancing state of the art research and practical modeling applications for multiple agencies. They examined the unique characteristics of weekend travel with several travel survey data sources (e.g. RT-HIS, NPTA and NHTS); reviewed existing travel demand forecast models by various organizations in New Jersey (e.g. NJTPA, SJTPO, DVRPC, NYMTC, NJ Transit and NJ DOT); and developed a statewide weekend travel demand forecast model that can be incorporated into the existing long-range transportation planning process at both metropolitan and state levels.

Bhat and Misra (1999) studied a utility-maximizing resource allocation problem for the allocation of total weekly discretionary time of individuals between in-home and out-of-home locations and between weekdays and weekends. A model was formulated and applied to an empirical analysis using 1985 time-use survey results conducted in the Netherlands. The analysis considered household socio-demographics, individual socio-demographics, and work-related characteristics as the explanatory variables. The age of the individual was regarded as the most important factor determining discretionary time split with older people having a strong in-home orientation. Other factors such as the number of young children, adults and autos in the household, gender, work duration on weekends and travel time to work also affected discretionary time split.

Sall and Bhat (2007) developed a model to examine the spatial and temporal characteristics of weekend work episodes. Empirical analyses were conducted using 2000 San Francisco Bay Area Travel Survey data. The results indicate the important effects of day of the week, individual demographics, work-related variables, household characteristics, and location variables on weekend work participation characteristics. Females were less likely to work over the weekend compared to males, avoiding starting work early in the morning or late in the evening. Self-employed individuals were more likely to work at home and individuals working with a flexible work schedule showed less preference to work on weekends. Persons who worked at home were likely to work shorter durations and start their work activity later in the day. The seasonal and location effects were not statistically significant.

Bhat and Srinivasan (2005) analyzed the frequency of participation of individuals in out-of-home non-work and non-school episodes over the weekends. A multivariate mixed ordered response model accommodating the effects of explanatory variables and capturing the dependence among the propensity to participate in different activity types was developed and applied to the 2000 San Francisco Bay Area Travel Survey data. Single parents and adults in households were more likely to participate in physically active recreational episodes. Individuals who lived alone and adults in couple families were more likely to participate in recreational activities than another non-single parent. Adults in households with children participated less in maintenance shopping and personal business activities on weekends and more in community and pick-up/drop-off activities.

Ashish (2004) provided a comprehensive analysis of weekday and weekend travel patterns, utilizing the 2001 NHTS data. Urban area size identified differences and similarities between the two patterns. Weekend and weekday travel behavior models were developed to capture the relationships of socio-demographics, activity durations, and travel duration, based on the structural equations modeling that provide various direct and indirect effects inhibited in the relationships among them. Females were found to make more trips and activities than males on weekdays, while a reverse trend was shown on weekends. High income led to less time on weekend subsistence activities, and the number of children had a positive effect on the social activity duration. Slightly more person miles occurred on weekends than weekdays. However, the total vehicles miles traveled by household were longer on weekdays because higher occupancy vehicles (SOVs) were preferred for longer trips on weekends.

Kim et al. (2004) analyzed the weekend travel behavior changes due to a 5-day workweek instead of a 6-day one. Activity participation and travel behavior were compared between two population groups, those currently working five days and six days a week. Multilevel structural equation models were developed using the

2002 Seoul Metropolitan Area Transportation Survey. The relationships among socio-demographics, activity participation, and travel behavior within households as well as between household models were found. The effects of variables were significantly different between two groups. In the within-household model, single women and those with a high level of education spent more time on leisure activities on Saturday. In the between-household model, households having more students participated in fewer recreational activities, while household income growth resulted in leisure activity and travel time increases.

A few modeling approaches were attempted using the 2000 San Francisco Bay Area Travel Survey data. Bhat and Gossen (2004) formulated a mixed multinomial logit model for the type of recreational activity episodes of individuals on weekends. The choices include in-home, out-of-home, and pure recreational episodes. The effects of household and individual socio-demographics, land-use and density variables, and episode participation attributes were analyzed in detail. Individuals preferred recreational episodes in the morning and pursued in-home recreation on Sundays. Land-use and density' impacts on weekend recreation choice were not substantial.

With regard, the activities and mode choice, Guojun Jiang et al. (2012) investigated the interdependency between bicycle usage and activity patterns and capture the decision order between them. To achieve the research objective, data was extracted from the household travel survey in the urban area of Bengbu, China. The final sample contains 5632 valid cases. The co-evolutionary approach combined with MNL model was used to capture the interrelationship between bicycle usage and activity patterns. The analytical procedure included five steps: sort of bicycle usage and activity patterns, statistical analysis, MNL model specification, co-evolutionary modeling process and the final model evaluation. It turned out that on average 4.25 cycles were needed to reach a final decision for both bicycle usage and activity pattern choice facets. The model estimation results showed that in most the cases, activity pattern is made in before mode choice. In other words, travelers took the decision on bicycling or not according to the pattern of their daily activities. Furthermore, this study also found that the patterns of subsistence activities had larger impacts on the choice of a bicycle compared to the maintenance and recreational activities. The coefficient of gender indicates that compared to women, the probability of bicycling among men is higher. People with the age of 20 to 60 seem to be the most frequent bicyclists. Compared with employees and students, self-employed or retired people are less likely to bicycle. The probability of bicycling also decreases if an individual holds a public transport card. Annual household income and car ownership are negatively related to bicycle usage. It implies that maintenance or recreational activities would be more determined or influenced by bicycle choice than work related activities.

Ye et al. (2007) considered three different causal structures for links between trip chaining and mode choice. The first structure assumed that trip chaining pattern was determined first and influenced mode choice while the second structure was the either. In the third structure, both trip chaining and mode choice were determined simultaneously. The first two structures are estimated within a recursive bivariate probit modeling framework that accommodates error covariance. The simultaneous logit model is estimated for the third structure that allows a bidirectional simultaneous causality. The analysis and model estimation are performed separately for work tour and non-work tour samples drawn from the 2000 Swiss Microcensus travel survey, which trip dataset includes 103,376 trips reported by 29,407 interviewed persons. Model estimation results showed that the need to make a complex tour increases dependency on the auto mode. In addition, it was found that demographic and socio-economic characteristics, the tour's primary purpose, and time-of-day significantly influence mode choice and tour complexity. It was found that the causal structure in which trip chain complexity precedes mode choice performs best for both work and non-work tour samples.

Ben-Akiva (2007) gave a new extension to activity-based modeling by investigating the happiness of the travelers. The prevailing hypothesis is that activities are planned and undertaken to satisfy needs so as to maintain or enhance subjective well-being (Abou-Zeid and Ben-Akiva, 2009). In 2012, Abou-Zeid and Ben-Akiva (2012a; 2012b) presented an empirical analysis and a theoretical analysis of the relationship between well-being and activities. The empirical analysis consisted of an exploratory model of the effects of activity and travel well-being on the propensity to participate in activities. Using a convenience universal sample of highly-educated commuters, they found significant correlations between activity/travel well-being and activity participation for several different activity types: the greater the happiness while performing an activity and the greater the satisfaction with travel to the activity, the more frequently an activity is conducted. The theoretical analysis consisted of developing a model framework for the extension of activity pattern models based on the activity schedule approach (Ben-Akiva et al., 1996) which structures the day into an overarching activity pattern and then determines the timing, destination, and modes of tours and trips comprising the pattern. They presented two extensions to these models. The first extension was econometric and attempted to better estimate the utility of an activity pattern by adding a measurement equation where satisfaction with a pattern was used as an indicator of its utility. The second extension was behavioral and attempted to formulate the activity pattern utility to account for the behavioral process of activity generation, based on the idea that activities are conducted to satisfy needs (Murukami & Wagner, 1999).

2.3 Travel Behavior Research – Choice models

A series of previous studies have pointed out the importance of the symbolic-driven and instrumental perception of vehicles, pro-environmental stance and other personality traits in the car or fuel type preference.
One of the first scientific works modeling vehicle choice can be traced back to the 80s (Manski and Sherman, 1980). Using an MNL model they described households' choice probabilistically on a yearly basis. Variables used in the experiment design include: "vehicle seating capacity, luggage capacity, weight, acceleration time, noise level, scrappage probability, price, operating cost and of a search-transactions cost associated with entering the vehicle market." At this early stage of vehicle choice models, environmental issues are not regarded as utility estimators. However, one can attest to the presence of noise level, although it remains unclear throughout the paper whether the noise level is the perception of the in-vehicle passengers about the engine noise or if it's the noise the vehicle produces to its vicinity. A prominent result of this early study is the correlation of household size with the optimal seating capability of the vehicle. A non-expected result was the strong preference for slower vehicles over faster ones.
Subsequently to these early approaches, researchers began to re-focus their attention to various aspects of purchasing behavior and alternative fuel vehicles choice. This created a fused category of vehicle choice models: the models aiming to predict who is more probable to buy an alternative fuel vehicle. Potoglou and Kanaroglou, (2007) investigate "household demand and willingness to pay for cleaner vehicles.

In their literature review, they report that most of the papers they reviewed had California set as their study area (Dagsvik et al., 2002) limiting, the variety of input. Potoglou and Kanaroglou, (2007) offer results from the Canadian urban context, using a discrete choice experiment with three choices and with attributes including fuel type, purchase price, annual fuel, and maintenance cost, fuel availability, acceleration, incentives (HOV lanes, low taxes, parking), and pollution level. The estimated model (nested mnl) reveals a strong influence of individual preferences in stimulating demand for Alternative Fuel Vehicles (AFVs). Tax-free purchases and vehicles with reduced emission levels are strong incentives while access to HOV lanes and free parking do not affect preference towards cleaner vehicles.
Shafiei et al. develop an agent-based model., (Shafiei et al., 2012) in Iceland to investigate the market share evolution of passenger vehicles in the country. The paper uses an integrated form of MNL which "includes the utility of consumers and the effects of social exposures," incorporating the stimulation of the processes of word-of-mouth, social influences, imitation and trend setting. Using a synthetic population and a repetitive algorithm containing choice branches about an individual's purchase possibility as determined by social groups and the lifetime of the existing vehicle, the model predicts an agent's probability of buying a specific type of vehicle. Vehicle attributes on the experiment include Vehicle name and manufacturer, fuel type, purchase price, fuel consumption, luggage capacity and acceleration. The results of the model predict that electric vehicles can be adopted in a 20-year horizon and have a 1:1 ratio to ICE (internal combustion engines) in the moderate and favorable scenarios developed in that paper. The greatest concerns for the adoption (or not?) of electric vehicles are the reduction in import taxes and recharging issues. Finally, the paper strongly correlates the vehicle choice with the driving patterns of an individual, revealing that it is harder for someone with a long daily driving range to overcome the anxiety involved with recharging his vehicle, in the electric vehicle case.
He et al. attempt a similar examination of the relation between vehicle usage and consumer choice of hybrid electric vehicles., (He et al., 2012). Using a hierarchical choice modeling framework, they identify market segmentation through principal components analysis and they designate certain individuals as hybrid drivers based on the hybrid attribute of the vehicle they were driving at that time, creating thus, an additional weight for this portion of the sample. Results reveal that the vehicle attribute of interest is driven distance; the paper concludes that vehicle usage is another

dimension of the overall consumers' choice, in addition to the consumer profile attributes which cannot fully explain differences in vehicle use.
The question of the possible buyer of AFV vehicles is further answered in two papers. Plötz et al., (2014) attempt to identify potential early adopters of electric vehicles in Germany. Results of the paper reveal that, most likely, early adopters of Electric Vehicles in Germany are the middle-aged men, with technical professions, living in rural or suburban, multi-person households.
Petschnig et al., (2014) use a form of Theory of Innovation Adoption to create an integrative AFV adoption model where perceived innovation characteristics affect attitude towards an AFV which combined with personal and subjective norms affect the intention to adopt such a vehicle. Perceived innovation characteristics such as ease of use, observability, ecology, image, design, profitability, physical and functional risk, trialability, compatibility and relative advantage are examined allocating a positive or adverse effect on the intention to adopt depending on various indicators for each perceived innovation characteristic. Structural model results allocate a value depending on the importance of each characteristic to formulating an attitude. Compatibility turned out to be the most prominent characteristic of attitude formation followed by design and image. Compatibility includes the consistency of hybrid vehicles with previous driving habits, as well as, availability of necessary refueling infrastructure. Trialability and Observability were not found to be as influential as previous research indicated. In addition, functional and physical risk were not found to be as influential as it could be expected. Authors argue that in other studies when risk is modeled with other characteristics it does not have a strong effect on resistant behavior and consequently, does not represent a strong barrier in the choice of adopting a hybrid vehicle.
Ziegler, (2012) examines the preferences for alternative-fuel vehicles in Germany, a country that has set goals of transition to electro-mobility within a short period. The paper uses data from car dealerships and technical inspection agencies from 35 different locations around Germany, using a Computer Aided Phone Interview survey. The experiment presents purchase price, motor power, fuel costs, CO2 emissions and service station availability as attributes. The fuel types available in the experiment are more than the average paper: Gasoline, Diesel, Hybrid, Gas (LNG or LPG), Biofuel, Hydrogen, and Electric. In the descriptive statistics of the paper, Electric ranked at the bottom of the choices (8.67%) with Gas and Diesel being at the top. The first, significant, finding of this paper is that through the MNL estimation it is revealed that even if all attributes are equal (horsepower, purchase price, other), the

respondents have lower utility for AFVs. This has major policy implications, as the policy makers should initially focus on making electric vehicles, or AFVs in general, susceptible of being widely accepted by the public. The second finding is that horsepower and service station availability have a positive effect while fuel costs and price have a negative effect regardless of the type of vehicle. This supports the popular opinion that policy measures such as "green taxation" could be successful promoting AFVs. The paper concludes by pointing out that the goal to release 1 million electric vehicles on the street by 2020 in Germany was difficult to reach, and policy makers should focus on certain related policies in order to promote the use of AFVs. It also points out that potential buyers of AFVs can be found within the younger age groups and evaluates the high positive impact of environmental awareness on the SP of biofuel vehicles.

Daziano and Bolduc, (2011) go a step further and attempt to incorporate pro-environmental attitudes in the decision-making process of buying an AFV through a Bayesian Hybrid Choice Model (HCM). They use a latent variable (EC – Environmental Concern) with two categories of indicators. One with statements on the support of certain transport policies (Bike lanes, HOV, Road Tolls, Gas taxes, etc.) and another with statements on the gravity of transport problems (Traffic noise, Traffic congestion, etc.). The alternatives to the model are a Standard gas vehicle, AF vehicle, Hybrid vehicle and Hydrogen vehicle. Unsurprisingly, the latent variable has a significant positive effect on the choice of an alternative fuel vehicle and has the highest effect on the Hydrogen fuel cell vehicle. Results of the structural equation model link PT users with the latent variable than carpool users. Measurement model results shed light into which precise transport policies and problems are related to the latent variable: expanding and upgrading roads has a negative relation but HOV and transit priorities a positive one. In addition, environmentally conscious individuals consider poor air quality to be the biggest transport problem.

The symbolic attributes of AFVs were the center of the attention for a UK study (Skippon and Garwood, 2011), which used a Real-Life experience of electric vehicles to "reduce psychological distance" of the participants. The participants who widely acknowledged the environmental benefits of using AFVs. The study discusses several instrumental attributes such as willingness to pay higher capital costs for lower running costs, performance issues, recharging time and place and other relevant vehicle attributes. However, it is pointed out that the symbolic attributes of the respondents that would make them ideal candidates to purchase an AFV were: Openness, Conscientiousness, and Agreeableness. This pattern unfolds in many relevant studies, and it could be defined as an alternative symbolic perception of vehicles, the symbolic perception of AFVs.

Instrumental perception has been discussed in many studies, focusing on the limitations of AFVs, such as higher costs and lower autonomy. The interpretation of vehicle performance is considered by Skippon (2014) who presents an extensive literature review on how different instrumental factors are evaluated and groups them into independent dimensions: dynamic and cruising performance. Factors are grouped into independent dimensions: dynamic and cruising performance; in dynamic performance, the driver engages actively in the change of status of the vehicle, while in cruising performance the driver maintains the condition of the vehicle. Once again, the openness to ideas, pro-environmental and pro-social values pattern are related to the preference of electric vehicles. EVs are perceived having a good cruising performance.

Pro-environmental attitudes are one of the most popular attitudes to be linked to the favorability of AFVs. Tsouros et.al. (2015c) use a hybrid choice model to investigate the relationship of pro-environmental attitudes with a future car purchase. Results indicate that people holding pro-environmental values are more likely to buy a hybrid car independently of macroeconomic scenarios or incentives such as green taxation. However, Potoglou and Kanaroglou (2007) find that various incentives such as free parking are not significant, but other such as tax relieves are.

Axsen et.al. (2015) study preference and lifestyle heterogeneity between potential Plug-in electric vehicle (PEV)s users in Canada. Interesting findings include that household income does not significantly differ between the lifestyle constructed lifestyle classes, while a variation of interest in vehicle types, valuation of fuel savings, environmental concern and level of education were far more determining factors. Members of the most pro-EV class have the highest standards of technology and environmental oriented lifestyle. This is an indicator that potential PEV buyers can be hardline pro-environmentalists but also technology and gadget enthusiasts, two social clusters that are not always overlapping.

Correlation between technology enthusiasts and AFVs is discussed in other research papers also. Noppers et.al. (2015) link earlier innovation adopters with a stronger intention to purchase an electric vehicle. Also, early adopters tend to value more the symbolic attributes of an electric car, much more that later adopters.

Schuitema et.al., (2013) investigate the relationship of instrumental, hedonic and symbolic attributes with the choice to purchase an electric vehicle using OLS linear regression analysis. Study results reveal that while previous research had concluded

that instrumental attributes of electric vehicles such as driving range are the most important factors affecting the purchase decision, symbolic and hedonic attributes are more important. However, the perception of the instrumental and symbolic attributes are vehicle specific, for example, people in this survey tend to regard Battery Electric Vehicles as having less instrumental value (particularly their driving range) which results to less joy and consequently more negative symbolic attributes.
In their recent work, Zoepf and Keith (2016) study and model user decision making in the car-sharing context using stated preference experiments. Among other findings, they find that car-sharing users widely prefer hybrid vehicles, more precisely a much larger exposure of car sharing users to hybrid vehicle technology (400 to 1) from regular, household owned vehicle users.
The future penetration of CAVs is also a very frequently research topic, especially during the last years. As Kyriakidis et.al., (2015)reveal, using a 5000 respondent internet survey, almost 70% respondents think that fully automated vehicles will reach 50% of the market by 2050. To model the level of automation they use the levels designed by Wending (2014) and Smith (2014). A contribution of this study is the presentation of the public opinion of CAVs in a global perspective, not only in western countries as most of the previous studies (for example see: (Howard, 2014; Payre et al., 2014)) do. Findings include the popularity of manual driving, seen as the most enjoyable mode of driving by individuals but also the fascination about automated vehicles. Key concerns are about hacking and misuse of vehicles. Finally, people are most willing to pay for a fully automated driving car, while the step from "partially to highly automated driving was not considered worth extra money."
In another CAV study, Bansal et.al., (2016) assess the public opinion about automated vehicles and new vehicle technologies in general in Austin, Texas. Regarding adoption timing of automated vehicles, the researchers found out that older people, leaving far from work are more likely to adopt an AV when most of their friends do, while younger aged people living in urban areas are likely to adopt with less dependence on their friends' behavior. Also, results indicate, that individuals who drive more are more apt to adopt automated vehicles and to spend more money on a fully automated product. Finally, higher-income, tech-savvy males in urban areas are found to be more interested in CAVs. This finding may be a hint towards to what context of the latent variable will be useful to measure attitudinal stances towards CAVs.

2.4 Conclusions

Concluding, sustainable transportation is often considered a big city issue. However, to maintain economic and environmental health, and ensure equitable access to key services such as employment, educational institutions, and medical services, smaller, rural and insular communities also need to find solutions to increase mobility options for their citizens. The case studies in this section presented the best practices of some capital cities, but more attention was paid to the best practices of medium and small-sized European cities, which in the past faced similar transport situations with Chios island and through simple transport planning, policies and campaigns managed to become sustainable and green.

The review of the best practices indicates that the planning of green transportation policies, begin by conducting a review of relevant existing facilities and a survey for collecting accurate data about citizens' transport needs. The data analysis could provide to local authorities a valuable source of information in order to develop their policies. Once the policies are developed and applied the establishment of monitoring and evaluation procedures is necessary. In this context, a green transportation plan and system should:

- Encourage the modal shift from private cars towards public transport and non-motorized.
- Increase the share of non-motorized transport (walking and cycling).
- Avoid or reduce unnecessary or undesired mobility.
- Facilitate access to a regular, frequent, comfortable, modern, competitively priced, well-linked network of public transportation.
- Promote the selective and rational use of private cars with a preference for clean, quiet, energy-efficient vehicles powered by renewable or alternative fuels.
- Provide an accessible environment suitable for everyone. Accessibility does mean not only easy to reach but also easy to use. When talking about accessibility, every citizen is concerned not only disabled and older people. Also, children, an often forgotten target group, need to be considered, as they still need to learn how to move around independently and safely.
- Provide safe routes to all road users (pedestrians, cyclists, drivers).
- Provide accurate and real-time information and orientation to all road users.

- Consistently educate and train the road users of all ages about green transportation issues.
- Make the most efficient use of land.
- Be actively managed in an integrated manner with the participation of all the stakeholders and public consultation.
- Have short, medium and long-term objectives with an effective monitoring system.

Several conclusions regarding the experience to date with activity-based modeling can be drawn:

- There are a growing interest and an increasing number of applications of travel demand models of the new generation. These important properties of the new models include an activity-based conceptual platform, the focus of the tour as the base unit for the modeling of travel, and the use of a microsimulation technique that operates on households and persons at the fully-disaggregate level. The new generation of models brings much stronger behavioral realism to the travel demand forecasting process, by ensuring an internal logical consistency among the various activity/travel components for each household, person, and tour.
- Although these new modeling structures are evolving rapidly, following somewhat different specific paths of developments, it is already possible to summarize the important new structural features of these models. Among them is the explicit incorporation of intra-household interactions, a significant and important new component that has been entirely missing in the conventional travel demand models (Davidson et al., 2007).
- The new generation of models is based on the detailed classification of activities and travel segmentation. In particular, activities are grouped by type (mandatory, maintenance, discretionary) and setting (individual, allocated, joint) where a special modeling technique is applied to each particular type and setting.
- The skeleton of the new travel demand model can be outlined as a sequence of conditional choices that include long-term level decisions, daily pattern/schedule level, tour level, and trip level.
- The disaggregate travel diary information obtained through home interview surveys remain the empirical foundation for the estimation of the travel demand model, including activity-based models. However, given the increased

emphasis on activities themselves, and the need for the data to clearly identify household interactions, certain aspects of the home interview survey data collection deserve more attention to assure completeness and accuracy. This is especially relevant for activities undertaken jointly by several household members and also in-home activities.

- The analytical structure of the new generation of activity-based tour-based models in the application is fundamentally different from the conventional aggregate models. Instead of fractional-probability calculations at the level of origin–destination pairs of zones, the model is applied at the level of individual households, persons, and tours with no explicit restrictions on the number of variables or population/travel segments.
- It is important to effectively promote the development and application of activity-based models and demonstrate their clear advantages to practical planners in a meaningful way. Demonstrating clearly their practical benefits for planners and decision-makers seems to be the best strategy for the promotion and eventual widespread acceptance of the new generation of travel demand models.

Summarizing, individuals' daily activities structure and temporal organization have been studied extensively. Trip chains and tour structure, time-of-day analysis, and departure time models have been employed to examine variables influencing spatiotemporal variations. Our thesis shows that different lifestyles among places influence the daily schedules of individuals, contributing to the literature regarding new methods and perceptions of time allocation at different levels, both spatial and temporal. We find this to be of value because both methodologies used, stochastic frontier models concentrating on the temporal differences and latent class choice model on spatial differences, providing useful insight on the effects that lifestyle has on the observed variance. This includes identifying differences in the complexity of tours and mode share in Chios and Athens and similarities in other aspects of behavior.

The literature review on the future purchase choice of an AFV or a CAV revealed a broad range of information and knowledge and some gaps that are not yet filled due to the very recent developments in both technologies. The relationship of attitudes and perceptions, the effect that latent, psychological traits have on the final purchase choice of the vehicle is the core subject of many of the studies cited in this section. Ecological conscious individuals are more likely to be associated with the purchase of an AFV. Also, individuals that hold a symbolic perception of cars are also found in most studies to be prone to purchase an AFV. The initial investigation of public opinion on CAVs reveals that tech-friendly individuals are more likely to state that they would adopt an automated vehicle. These findings from the literature lead us to the decision to use three latent variables to model the intention to purchase a vehicle: Eco-Friendliness, Exuberance, and Tech-Savviness. Chapter 6 describes a model framework for these three latent variables and tests a part of it, using one latent variable in a case study on Chios.

Chapter 3: Methodology

3.1 Introduction

3.1.1 The Island of Chios

Chios Island is in the Aegean Sea, seven miles off the coast of Asia Minor. It is the fifth largest of the Greek islands, 51320[1] people live in the main city or the villages and the towns of Chios. The port of Chios is the main freight and passenger hub, connecting the island with the neighboring islands of Samos, Lesvos, and Limnos (itineraries vary, especially in the summer), the cities of Kavala and Thessaloniki and Greece's main port, the port of Piraeus. There is also a daily connection between Chios and Cesme, mainly for tourist purpose (recently also for freight transport).

Chios Airport connects the island with the islands of Lesvos, Samos and Rhodes, and the cities of Athens and Thessaloniki. Connection with Athens is daily, with Thessaloniki most days of the week and weekly for the islands. In the summer months, some charter flights are connecting Chios with some (mostly northern European) cities.

Chios attracts tourists mainly during the summer season when a lot of Greek Americans visit their homes. This is an added burden on the island's road network, considering that many of them bring their cars together.

3.1.2 Particularities of Chios

Chios Island has some particularities worth mentioning in this study. Chios town, the capital of the island (also called Chora, mostly by natives) is the center of the island's transport flows, commercial activity and has a population of approx. 30.000 people. There is not a second large population concentration in Chios (contrary to what hap-

[1] 2011 temporary census results

pens in other islands), and the second most populous town is the neighboring Vrontados with 5000 population, which is becoming almost a suburb of Chios town, because of the recent intense urbanization of both areas and their spatial proximity. Chios town is situated in the middle of a north – south axis which is a prominent geographical separation of the island areas. As a result, the traffic flowing from north to south or backward (transit) also flows through Chios town (there is a longer alternative, with much worse road condition)

Chios town has developed around the main core of Chios port and along the main road arteries. The center of the town is developing mainly around the municipal garden and some traditional commercial roads. (Usual land use is for commercial, governmental and entertainment reasons).

Study Area

The study area is the whole island. It must be understood, though, that Chios town plays a leading role in the transport flows of the island. Figure 3 presents the center of Chios town. A significant portion of the road next to the port is a part of the center. This fact leads to traffic congestion, whenever a ship unloads passengers and cars in the island, the situation is worse during summer months. Considering the central square and the municipal garden as the city center, the circular road around them is almost always congested during summer months, especially the days and hours when the local stores are open.

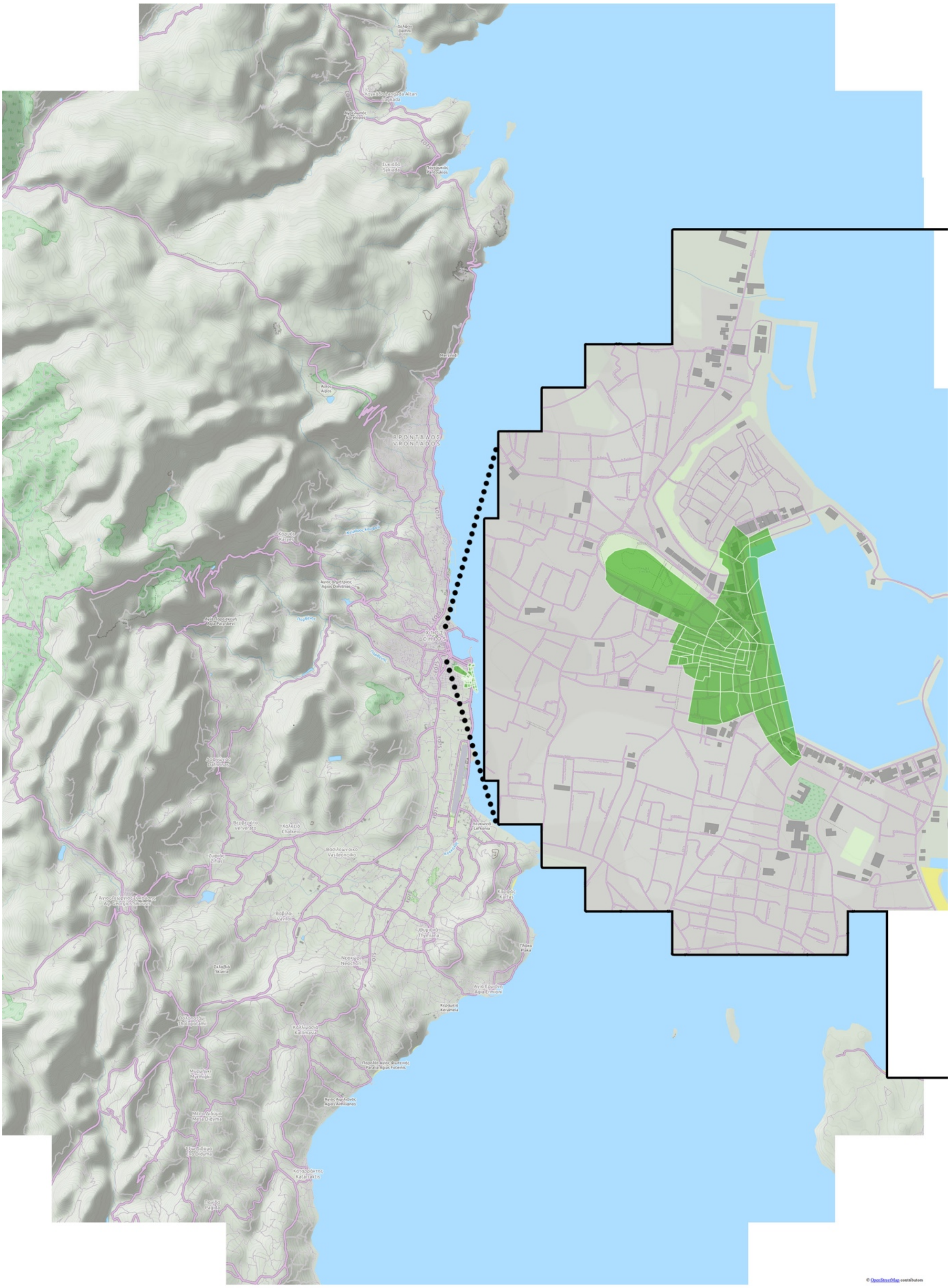


Figure 3 Center of Chios town

Socioeconomic Characteristics

In this section, the main socioeconomic characteristics of Chios Island are presented. In Table 1 the main well-being indicators are presented. In 2009, Chios was the 4th prefecture in Greece in bank savings (Lyviakis 2009), while back in 2007 it was in the 2nd place, right after Athens. The income of Chios inhabitants is ranked 3rd among the 57 Greek prefectures. Furthermore, the unemployment rate in Chios is rather low compared with the rest of Greek prefectures. Chios has a fair amount of high school students per 1000 people (ranked 17th in Greece), and also it ranks first at the university entries per population for five consecutive years.

Table 1 Chios economic indicators (Source Nomoi 2010)

Well-being indicator	Reference Year	Chios	Country average	Ranking in Greece (52 prefectures)
Savings accounts	2009	23,200 €	18,800 €	2
Income (pp)	2008	16,100 €	16,700 €	7
Taxes paid (pp)	2008	1,200 €	1,600 €	11
Population growth/1000 people	2008	0	0.9	19
High school students / 1000 people	2009	66	62	17
Unemployment rate	2009	3.7%	9.5%	45

In Table 2, there is a comparison with other island areas (both island states of the EU and Sicily as a big island part of an EU country). It must be noted that this is an indicative, comparative table that introduces the reader to conditions in island areas.

Table 2 Comparison with other island areas

Indicator	Chios	Malta	Cyprus	Sicily	Cor-sica	Ma-jorca	Crete
Population Density (/km^2)	57.5	1240	82	200	38	240	74.4
Area (km^2)	904	316	9,252	25,711	8,680	3,640	8,303
Cars per 1000 people (2009)	420	566	529	583	569	580	410
Total road fatalities per 100.000 population (2014)	12.8	2.29	3.76	4.1	7.2	4.5	9.5

In Figure 4 the population of the island during the last 40 years is presented. As it can be seen from Figure 4 Chios population 1971-2011there is a decline in the population in the past decade. This decrease should be attributed to the tendency of young people to leave the island searching for better work opportunities in larger national or international cities.

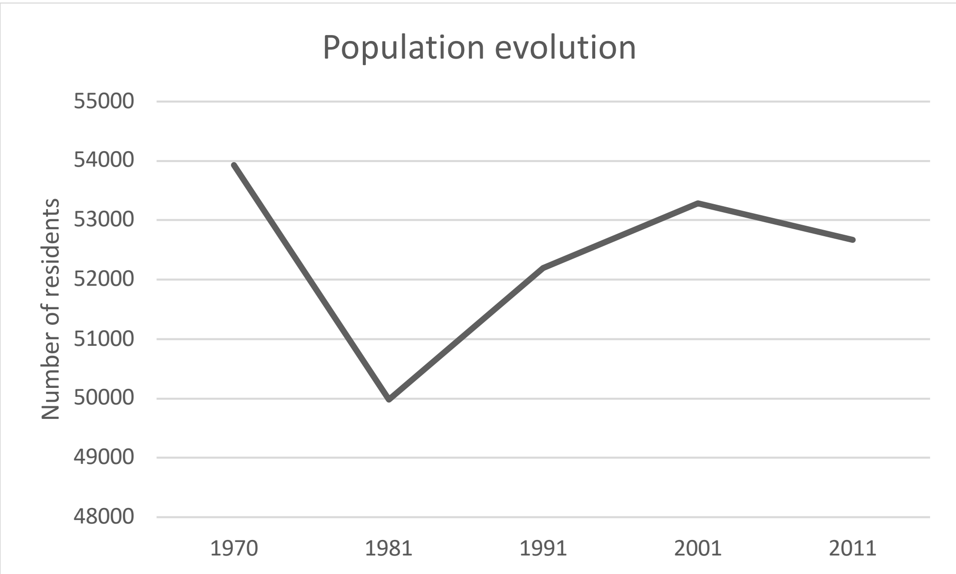


Figure 4 Chios population 1971-2011

Figure 5 presents the unemployment rates in the Chios Island. As shown in the figure below there is a small decline in the unemployment in Chios. This change is in the opposite direction of the national trend, (unemployment rise – consequence of the economic crisis and the austerity measures). The national rise can be explained by the national economic crisis that started in 2009, and the consequences are starting to show up in the unemployment statistics for 2011 (17.47% in Greece, 13,4% in Chios).

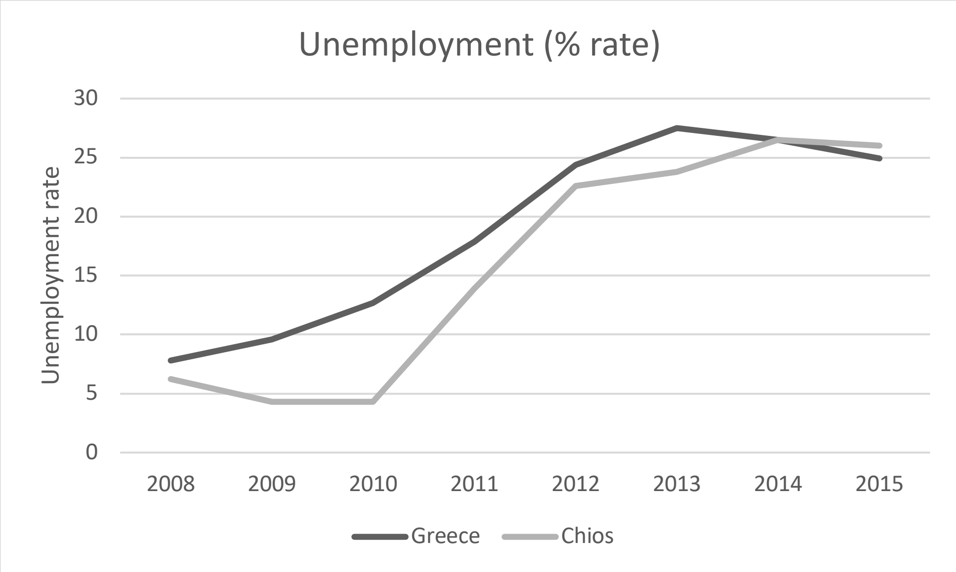


Figure 5 Unemployment in Chios in comparison with the national percentage

Transportation System Characteristics

Intra-Island Transportation System Characteristics

As already stated, Chios has many vehicles for its population. In Figure 6 a steady increase in the car ownership, from 2000 until 2009, can be noted. Back in 2007, there were 38.78 cars for every 100 people on the island (3rd place in Greek prefectures, with Athens and Thessaloniki metropolitan areas being the two first). In 2009, this number rose to 42 cars per 100 people.

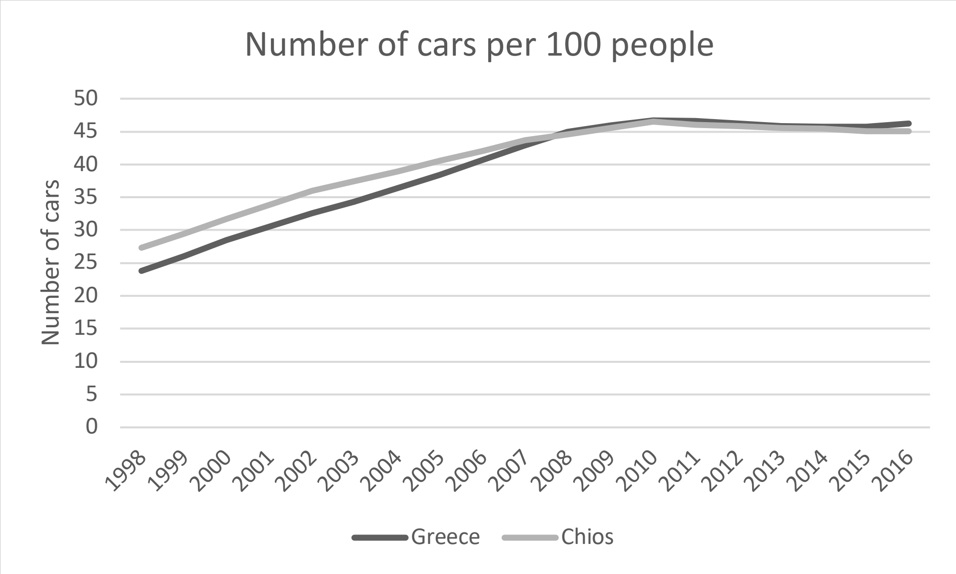


Figure 6 Cars per 100 people

The clear majority of vehicles on the island of Chios can be grouped into the following categories:

- Motorcycles (motorbikes<50cc and motorcycles over 50 cc)
- Passenger cars
- Taxis
- Buses
- Trucks

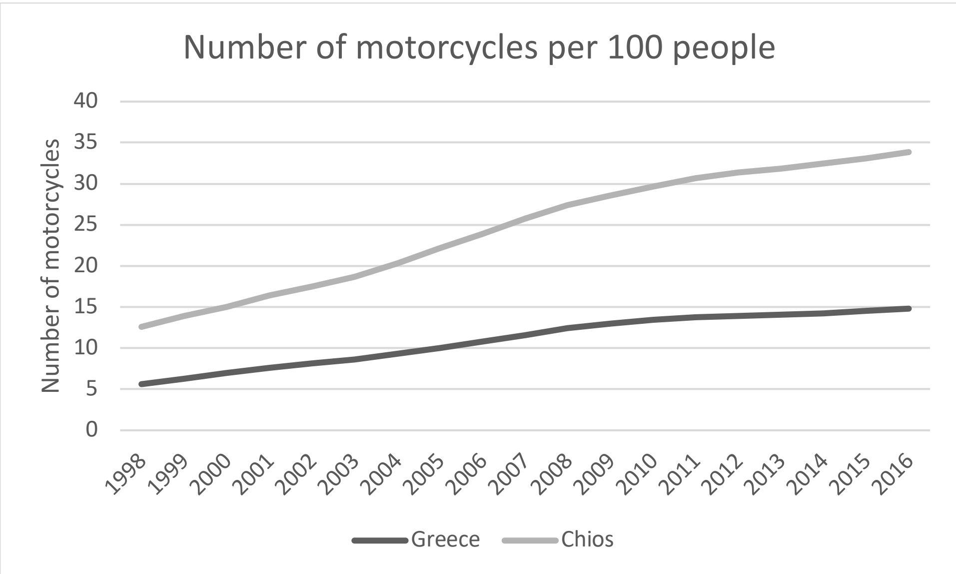


Figure 7 Motorcycles per 100 people

Motorcycles are used mostly in Chios town, and their use is popular especially among young people and teenagers, the majority of which tend to drive without having a driving license. Due to the island's rough and badly maintained road network, small motorcycles are rarely used for significant distances. However, there is a rising trend of motorcycle use on the island, as presented in Figure 7. The financial crisis started in 2010 does not seem to halt the growing trend of motorcycle ownership resulting in a more than twofold difference between Chios and the rest of the country.

Road accidents are a major problem of the transportation system characteristics (Antoniou et al., 2016). As shown in Figure 8 below, the number of traffic accidents remains at an elevated level (above 30 per year) for the last six years. An even more disappointing fact is the age of the traffic accidents victims. Over 25% of the fatalities are aged 18 to 23 years old.

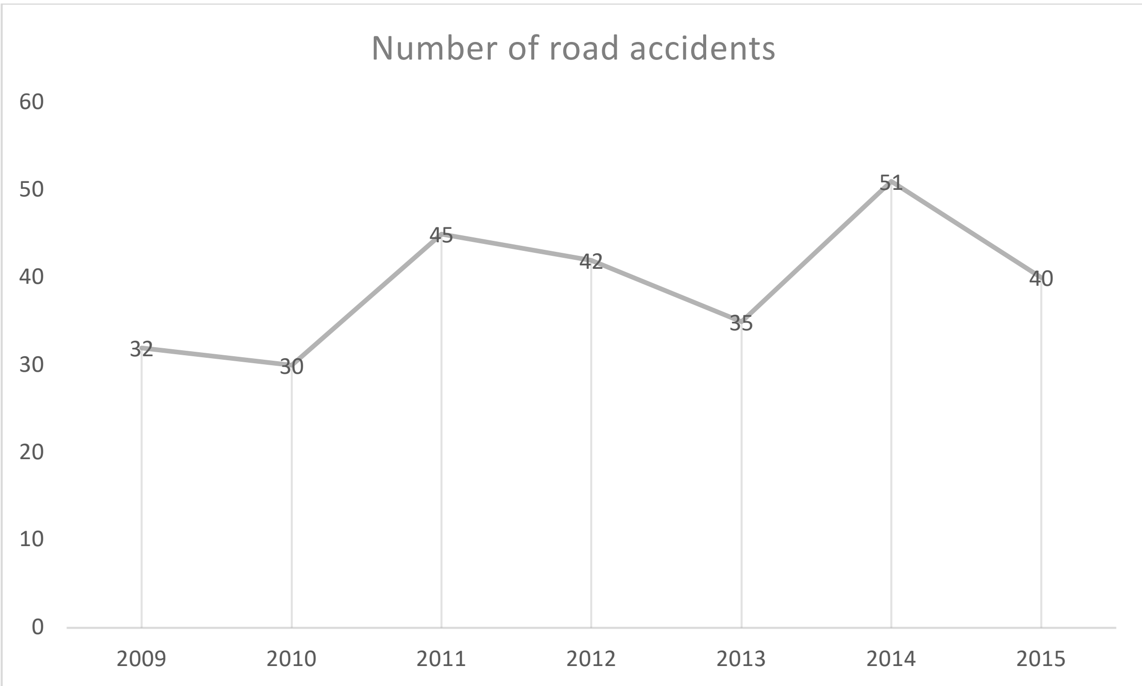


Figure 8 Road accidents in Chios

Suburban public transport in Chios (between Chios town and the villages), is organized in a simple network of stops. A fleet of 16 (privately owned) buses and 17 drivers is used. The age of the fleet is relatively young, as the old buses were recently (ktelchios.gr 2015) replaced by new ones of 40-50 seats.

Urban public transport has also been upgraded recently with the scheduling of frequent mini buses, from and to parking areas outside the center of Chios town, to improve the traffic congestion in the center. The main bus line connects areas around Chios town (from northern suburbs – Vrontados to Kampos and Nechori in the south). These urban bus lines pass through the main roads in the center adding stress to the already high traffic burden.

There is a growing trend for bicycles in Chios. While there is not much official evidence, only the observation of bicycle sales growth during the last 5 years, (to support this fact, the daily local experience shows that more people (mainly those that live in or near Chios Town) chose the bicycle as their main transport means. Road surface condition is not the ideal for bicycle use, and there has not been any recent planning for bicycle lanes.

Inter-Island Transportation System Characteristics

The passenger market structure is depicted in the following figure. A passenger has the choice of airplane or ship to move to Athens or another city. The main transport hub in and out of Chios is Chios town (airport and port), but there is the alternative of Mesta port, located in the southwest of the island (mainly preferred by southern Chios locals).

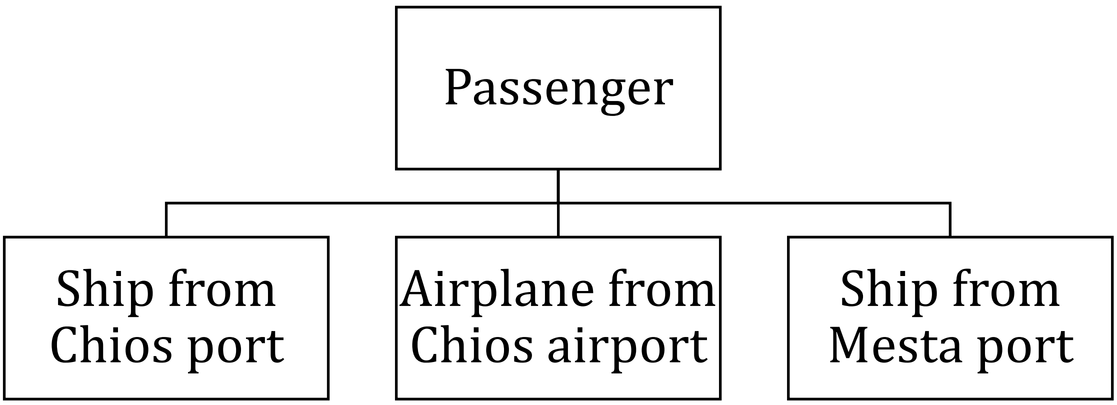


Figure 9 Passenger market structure in Chios

In the freight market case, the shipper (receiver) has the choice of airplane and plane again, but the airplane is used mostly for light and valuable cargo as well as for printed press arriving early in the morning with the first plane landing from Athens. A significant majority of truck owners chose the Mesta port alternative for cost reasons.

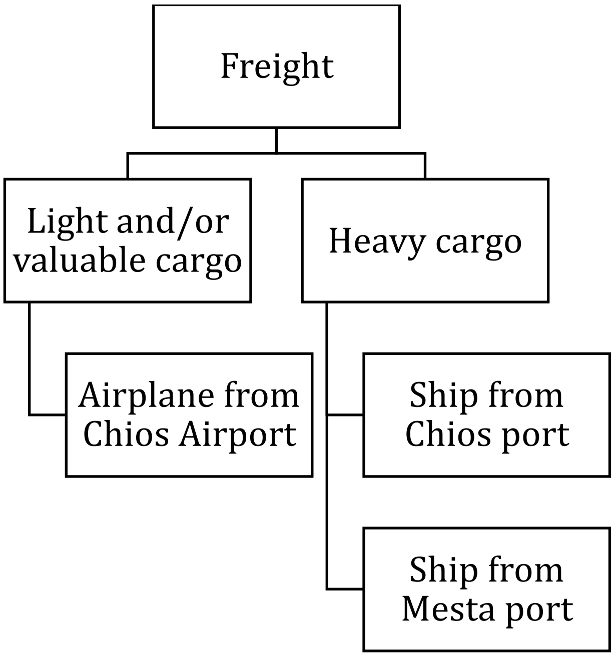


Figure 10 Freight market structure in Chios

There exists observed seasonality in the passenger movement of Chios harbor. While during the winter months passenger movement is limited to around 10.000 passengers arriving at Chios port every month, in July the island was visited by as many as 34.000 passengers (Chios Port Authority, 2016). The small peak during April is explained by the tourists and local students visiting the island for the Easter.

Land Use Characteristics

Table 3 presents the changes of land use in Chios from 1991 to 2001. The most rapid change is observed in the growth of land used for residential purposes. Private pastures shrink while there is a small rise in public ones. Forest land is decreased mainly due to the big fires (primarily during the summer season).

Table 3 Land use in Chios

	Pasture Private	Pasture Public	Crops	Forest	Residen-tial	Other
2001	14610	42980	16530	9700	4530	2070
2011	13820	44150	16540	9550	5024	1316
Change	-5.41	2.65	0.06	-1.55	9.83	-36.43

Table 3 is based on Greek national statistics service – 2011 census data for the land use in Chios, the island area is 90.400 hectares, and the distribution of the land use is the following:

- Forests 9,550 hectares
- Public pasture – Bushes – 44,150 hectares
- Private pasture – grasslands - 13,820 hectares
- Arid land (rocks) – 1,316 hectares
- Crops – 16,540 hectares
- Residential areas – 5,024 hectares

Chios commercial chamber splits the 3.790 businesses on the island in the following categories:

- Commercial
- Small industry
- Professionals
- Tourism

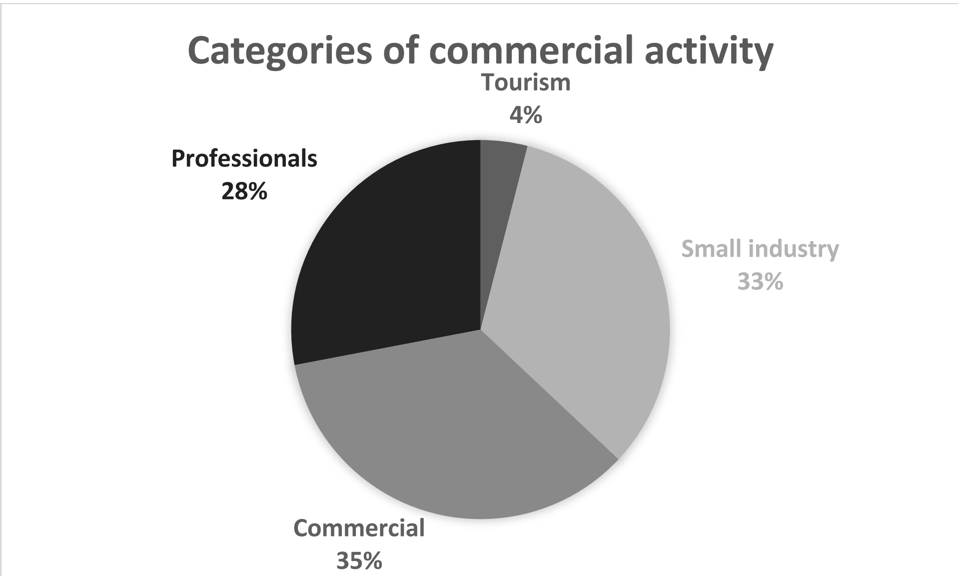


Figure 11 Commercial activity in Chios

3.2 GreTIA – Green transport in islands areas

This thesis is conducted in the framework of the THALES funded "Green Transport in island areas – GreTIA" research project. The research project funds the thesis. An abstract briefly outlining GreTIA follows:

Green development is heavily dependent on transportation through the strong seasonality of transportation demand by residents and tourists exacerbating the impact of traffic on congestion, noise, and pollution. This project creates a comprehensive green transport policy, research and development action plan for Aegean island areas, accounting for the unique characteristics and growth prospects of the area in its multiple dimensions. This is done through the fusion of ideas, data, and models in four pillars: œtravel behavior of the resident population, tourist preferences, œenvironmental analysis, and economic and financial evaluation.

The project identifies the factors that affect the study area development by:

- defining the requirements of decision makers;
- investigating the individual activity and travel patterns; and
- exploring island destination choice for tourists.

Data collection includes network and land use data that characterize living and traveling environments, surveys for residents and tourists, and atmospheric pollution data. Based on this information we develop advanced integrated discrete and latent variable choice models for both tourists and residents to simulate their travel behavior. We also develop environmental and economic models to analyze and evaluate the impact of green transport policies.

The final product is a policy platform which includes environmental analysis, travel simulation, and economic analysis. In this way, the project used approaches that are multidisciplinary (e.g., data collection informed by geography, engineering, and environmental science) and based on interdisciplinary research (e.g., discrete choice travel models from economics and engineering) moving one step further in research. Fusion of these ideas, data, and models lead to novel (transdisciplinary) research directions and methods that function as gateways of many other research directions in transportation and environmental science and engineering.

More information about GreTIA, results, presentations and published scientific papers can be found on the project's website (Gretia, 2017)

3.3 The data collection

One of the aims of the thesis is to point out the richness of information that a GPS device can collect in an easy and low – cost way. An individual using a GPS logging device correctly along with his/her daily travel schedule can provide information not only about the trip ends and the routes but also for speed, travel time, slopes and altitude or certain routes, delays at junctions or traffic lights, evaluation of public transport services, and other information.

This can become a breakthrough in data collection, both because of the minimum burden and the low cost but also relative acceptance to use the GPS devices by respondents. Data collection can be made even more accurate by using a web interface where respondents can find, review and correct their trips, stops or other information Sun et al., 2017 (*27*)

3.3.1 Data quality

The GPS devices used in data collection are Q-Starz – BT1000XT travel logger. The devices, along with the majority of GPS logging devices can be configured in a custom way regarding the frequency of logs with parameters ranging from time-frequency (log every x second), speed parameter (log over x km/hour), and distance (log every x meters). Every study reviewed has its optimum customization for data collection. The data used for the present paper is collected as a part of the "GreTIA – Green transport in island areas" travel survey. The devices are used as a supplement to a two – day activity diary and are customized to log all the modes of transport. Thus they are not optimized to log bicycle traces. This results in a small deduction (loss) in data quality for bicycles but at the same time permits the comparison of different modes. However, GPS devices used solely for bicycle travel should be configured in a different way, resulting in optimum data quality. The following settings are recommended for each mode, based on empirical observation and trial-and-error techniques:

- Car/Motorcycle: Log every 2 seconds or log every 10 meters and log over 3km/h
- Bicycle/E-Bicycle: Log every 4 seconds or log every 5 meters
- Walking: Log every 10 seconds or log every 1 meter

If data can frequently be uploaded, on a daily basis, a choice of logging every second is optimal. This frequent upload results in best data quality, minimum data loss and minimizes errors that occur due to storage capacity. In cases of travel diary studies, compromises must be made to capture all modes. In this research the settings are the following: Log every 2 seconds and log over 2km/h.

Data provided by the devices has to be edited through a data mining procedure and a specific algorithm that is adapted to the study area. Often data quality issues show up either in the form of signal loss or drifting problems, provided the device be correctly configured for the research and its needs. The data mining algorithm for this study is:

1. The software provided by the GPS devices company Qstarz 2013 (*28*) has an automatic "remove drifting points" task, which eliminates a large number of drifting points;
2. After the initial procedure, all the GPS traces with 0 distance traveled should be eliminated. These are mainly satellite signal errors;
3. The final task is to remove tracks that contain irregular traveled distance for the study area of the respective research. In the present research tracks containing distance greater than 500 km were removed. This error is called drift, caused by signal loss. The GPS logs a track in a long distance from the main trace;
4. An extra step that can be taken to ensure data quality is to remove traces or part of traces that contain irregular speeds. In the present study tracks containing speeds greater than 180km/hour were removed. These speeds are usually much larger than a regular vehicle can travel with.

3.3.2 Data Collection Methodology

GPS devices provide traces from which certain useful information can be extracted. With the help of GIS software, this information can be geocoded and presented on maps of the study area. In this way speeds, travel time, slopes and all other data can be analyzed for every different road segment, from a small link to the whole route.

Four routes with a significant amount of traces were selected as the main routes for evaluation. Two of these routes pass through the urban area of Chios town, and two of them are outside the city center. This distinction between the urban area and the area outside the city center is important for many reasons that will be discussed later on but mainly because a lot of trips conducted in the "rural" area are leisure trips. Both routes outside the city center are coastal routes that have a nice scenery which positively influences bicyclists' perception of enjoyment.

The route characteristics examined are: distance, maximum slope and mean slope. The slope is a factor affecting the use of bicycle and walking, as routes with steep slopes are considered difficult to walk or bike. Both maximum and mean slope affect the trip.

Mode characteristics include Mean speed, the standard deviation of speed, travel time and maximum recorded speed. Travel time is an influential factor in mode choice. Top speed for electric bicycles is around 30 km/hour, but in some cases, higher speeds are observed when the bicycles run downhill.

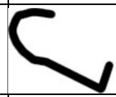
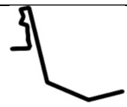
The data mining procedure is done manually for every trace collected. Every track that passes through one of the routes is examined for the above characteristics for each respective mode. Then averages and standard deviations are calculated, and the results are used in the following section's tables.

3.3.3 Route Evaluation

The initial route choice was made on the elimination of the routes that lack data for one or more modes. Then the decision that has been made is to choose two internal routes, passing through the center of the city, and two external ones with one of their trip ends in the city and the other outside it.

Table 4 GPS measured route characteristics

Route 1	Airport route (coastal)				
Mode characteristics	Car	Motor-bike	Regular bicycle	Electric bicycle	Walking
Mean speed (km/hour)	52.4	49.3	14.4	22.3	5.05
Travel time (minutes)	3:28	3:41	12:37	8:09	36
Maximum recorded speed (km/hour)	93	80	23	30	11.8 (jogging)
Speed standard deviation	4.39	7.18	1.64	1.68	1.42
Route 2	Coastal route to Vrontados				

Mode characteristics	Car	Motor-bike	Regular bicycle	Electric bicycle	Walking
Mean speed (km/hour)	47.8	51.4	15.1	20.4	-
Travel time (minutes)	3:51	3:35	12:14	9:04	-
Maximum recorded speed (km/hour)	88.1	80.5	26.1	34.2	-
Speed standard deviation	7.76	8.20	2.81	6.09	
Route 3	Round route of Chios garden				
Mode characteristics	Car	Motor-bike	Regular bicycle	Electric bicycle	Walking
Mean speed (km/hour)	29.4	23.5	15.4	21.8	4.0
Travel time (minutes)	0:49	1:01	1:33	1:05	6.0
Maximum recorded speed (km/hour)	45.9	44.6	25	33	5.2
Speed standard deviation	4.32	4.38	2.05	4.35	0.76
Route 4	Route from the harbor to the main shopping area				
Mode characteristics	Car	Motor-bike	Regular bicycle	Electric bicycle	Walking
Mean speed (km/hour)	27.3	23.7	14.2	17.3	4.1
Travel time (minutes)	2:38	3:02	5:04	4:10	17:34
Maximum recorded speed (km/hour)	53	60	22	27	5.9
Speed standard deviation	4.77	4.69	5.23	3.98	0.99
Route characteristics	**Route 1**	**Route 2**	**Route 3**	**Route 4**	
Maximum Slope	3.0% / -2.1%	3.9% / -5.4%	3.0% / -3.7%	6.0% / -5.2%	
Mean Slope	0.8% / 0.7%	1.4% / -1.3%	2.2% / -2.8 %	2% / -1.7%	

Distance(km)	3.03	3.08	0.4	1.2	

External routes

Route 1 is one of the main routes from the center of the city to the south of the island. Also the main route for the tourist region of Karfas and Chios airport. There are two alternative routes, not passing by the coast. As seen from the results in Table 4, it has the lowest slope from all the routes in this study. It is a popular route amongst the local population, used for both workout and leisure walking and biking. The results, regarding the speed of the modes, reveal that even electric bicycles struggle to compete with motorized modes' speeds and travel times. However, the nice scenery and the relatively wide road can make up for the longer travel times. It is the route with the most GPS traces passing through it. The standard deviation of the electric bicycle speeds reveals that a large percentage of the users were biking with speed over 20 km/hour, most probably using the assisting power of the electric bicycle.

Route 2 is the main route from Chios city to the neighboring town of Vrontados and the north part of the island. As route 1, this is a busy road, with many different land uses around it. There are two alternative routes, the one with similar characteristics, not passing by the coast and the other being the new ring road, longer but with better technical features and designed for larger capacity. From the results an average slope is revealed, shown in detail in Figure 13, green bars represent almost zero slope and as the color shifts to yellow more abrupt slope is represented, comparing figures 1 and 2, it can be seen that for the part of the route that has a bigger slope the bicycles speeds are the lowest. For the most of the route, the road is almost flat, with slopes at both ends of the route. Regarding the mode characteristics, this is, like the first one, a long route, and bicycle speeds cannot be compared with those of the motorized modes. As shown in Figure 12 the speed of the car trace is almost double for the most of the route than other modes. Regarding the car traces, there are not many abrupt peaks and valleys, same happening with bicycle traces. This is also a road with many accidents, and in contradiction with the first one has narrow roads. The latter in addition to the almost double travel times reveal that this is not a very active transport friendly route and needs (physical) intervention in order to be more attractive. There are no walking traces for this route.

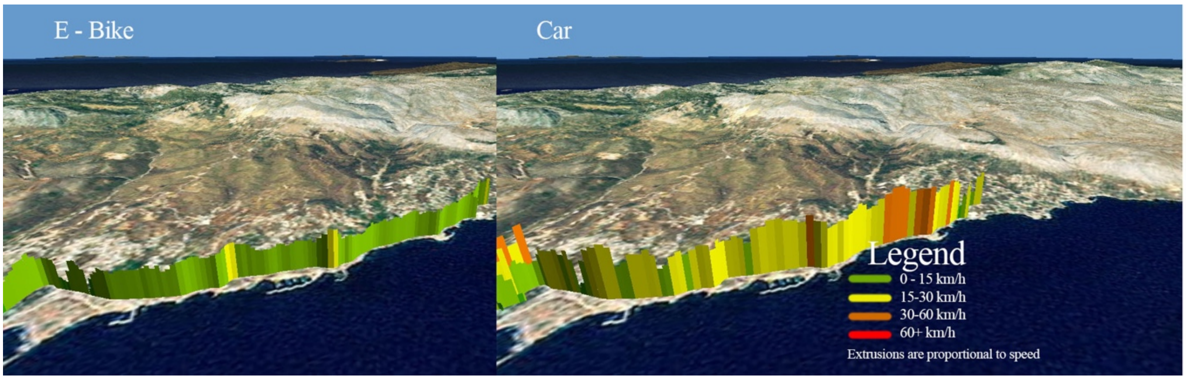


Figure 12 Comparison between car and e-bike speeds in Route 2

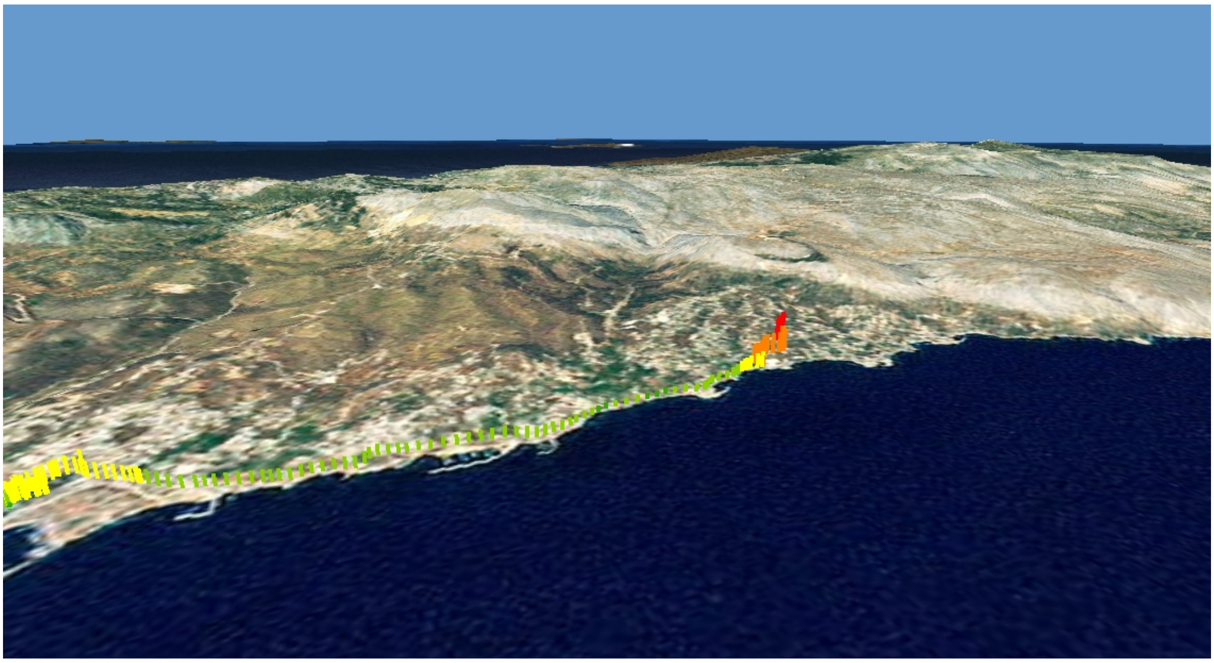


Figure 13 Altitude change (slope) in Route 2

Internal routes

In Figure 14 internal routes are depicted in yellow line (round route of Chios garden) and the red line (route from the harbor to the main shopping area). Figure 14 presents the location of the routes and the population density in zones around the city center. The darker the color, the denser the zone. Figure 14 also depicts the location of the routes and the number of shops (business establishments) per zone in the area. The darker the color, the larger the number of the shops.

Figure 14 Internal routes and population density (gray) and number of shops (red)

Route 3 passes right through the center of Chios city, one of the most congested road links during summer months. In comparison with the external routes, the maximum slopes are comparable, but the mean slope is noticeably higher. Empirical evidence reveals that this has been a consistent complaint of the residents, that the slopes in the city center discourage them from biking or walking (see Polydoropoulou et al., 2013). This route, as well as the next one, are one of the more congested during the summer months. Chios island, as a tourist destination, is highly influenced by seasonality which affects the traffic congestion. Along these routes, most users experience considerable delays with cars experiencing this more often and motorbikes less often.

Route 4 also passes through the city center, linking Chios harbor with the main shopping alley, Aplotarias str. As seen in Figures 3 and 4 these routes connect neighborhoods with high population density with areas with a large number of shops, passing through the busy Chios port or the municipal garden – the center of Chios city. The maximum slope is quite greater than the other three routes, and the mean slope is second to the other external route. It must be noted as of June 2013, the main shopping alley of Chios is permanently a pedestrian road. Both routes 3 and 4 end near the shopping alley and users of motorized modes cannot continue into it without parking their vehicle.

Comparison of speed and travel time reveals an interesting fact. There is no noticeable difference between the electric bicycles and the motorcycles. For route 3 the difference between these two is marginal. Also, the standard deviation for Route 3 is almost identical. The small standard deviation for all routes, regarding electric bicycles, is a positive result. No extreme speeds are logged, meaning that no individuals are struggling with their bikes and recording very low speeds, but there are also no very high speeds that can lead to accidents, especially in the external routes that have minimum protection for the cyclists. Electric bicycles can overcome the disadvantage of the steep slopes, and the competition between the two modes becomes fair. This can lead to many conclusions, and it certainly points out to a basic scenario design for stated preference experiments. Are the residents willing to switch their motorcycles with an eco-friendly mode of transport that is cheaper, makes less noise, does not have gas expenses, can ride through pedestrianized areas, as an incentive which the local government provides to cyclists, and engages them physically when they travel?

Designing the SP scenarios with real information such as speeds, travel times and slopes can lead to more realistic experiments and more valuable data. These SP experiments are a necessary continuation of the present research to measure peoples' views and perceptions of active transport. If the technical details reveal that for certain routes travel times and speeds are comparable, the price of an electric bicycle is lower than the mean price of a motorbike, the lack of electric bicycles fleet must be sought in the perceptions or the trends of the local population. However, since electric bikes is a relatively new alternative transport mode, population awareness should be raised regarding their clear advantages over motorcycles.

3.4 The sample

3.4.1 Households and individuals

The collected sample consists of 604 households and 1288 individuals. The data collection process took place from August 2013 to April 2014 in monthly intervals and consisted of four questionnaires. The first questionnaire included questions about the household structure and vehicle ownership. The second questionnaire contained questions about the individual household members and some attitudinal questions. The third questionnaire was an activity diary – accompanied with a GPS device to log the respondent's travel schedule. The fourth questionnaire was an SP experiment – containing experiments of future vehicle choice. The final questionnaire was accompanied by a series of different psychometric questions to collect the respondents' attitudes and perceptions. All questionnaires are attached in the appendices section of the thesis.

Table 5 Household and individual sample and population

Variable	Sample	Population
Mean household size 1	13,7	26,4
Mean household size 2	28,8	29,4
Mean household size 3+	57,4	44,2
Gender (females)	50,3	49,9
Mean age	42,67	44,8
Education level: None	3	10,2
Education level: Elementary	3,7	28,1
Education level: Highschool	13,8	14
Education level: Lyceum	35,2	26,3
Education level: IEK (After secondary)	8,6	4,2
Education level: University and higher	35,7	17,1
Mean income (€)	14.697	13,607
Unemployed	25,9	26,7
Parking spots at home	1,1	0,9
Own 0 cars	16,8	27,6
Own 1 car	32,6	44
Own 2+ cars	50,6	28,2
Own a motorcycle	37	32
Have a smartphone	36,7	*
Fuel cost per month (€)	80,7	*
Driven kilometers per month	290	*
Mean residence age (years)	30,92	*
Mean residence size (square meters)	95,24	*
		*data not available for this scale

Table 5 presents multiple socio-demographic variables and the comparison between the collected sample and the population. All demographic data comes from the 2011 census; except for the mean income which is 2016 data. The main differences spotted between the sample and the population are households with one member, which are underrepresented in the sample and the low education level individuals that are also underrepresented. Also, the car ownership is overrated in the sample. Some of this may be explained by the low response rate of the low education individuals and the difficulty to reach one-person households during the hours that the surveys were conducted. It must be noted that the collected sample consists of the 2,76% of the island's population.

3.4.2 Vehicle fleet

Table 6presents the statistics of the vehicle fleet of the collected sample. Key findings include the almost universal use of gasoline vehicles; with the non-existent presence of alternative fuels, except for a few diesel vehicles. Also, bicycle ownership is starting to increase. Notably, 2012 is the mean purchase year for bicycles in the sample (note that surveys took place in 2013 and 2014).

Table 6 Vehicle fleet

Cars	
Mean engine size (cc)	1430
Fuel type: Gasoline	99,1
Car size: Small city car	34,8
Mean purchase year	2005
Mean purchase price	15000
Motorcycles	
Engine size	239
Fuel type: Gasoline	100
Motorcycle size: Small (Scooter or <125cc)	64%
Mean purchase year	2004
Mean purchase price	2000
Number of bicycles in the sample	69
Mean purchase year of bicycles	2012

3.4.3 Daily activities and travel

Table 7 presents information on the daily travel and activities of the sample. Chapter 4 discusses this information in depth. It must be noted that both the average trip distance and travel time are low compared to a more urban area and the percentage of people traveling alone is high.

Table 7 Activities and Travel

Mean wake-up time	8:05
Mean first departure from home	9:54
Mean first arrival at home	16:01
Mean daily trips	2,04
Mean trip distance (km)	2.2
Mean trip travel time (minutes)	12,6
Percentage of people traveling alone	66,1
First daily activity: Work	40,6
First daily activity: Education	37,5

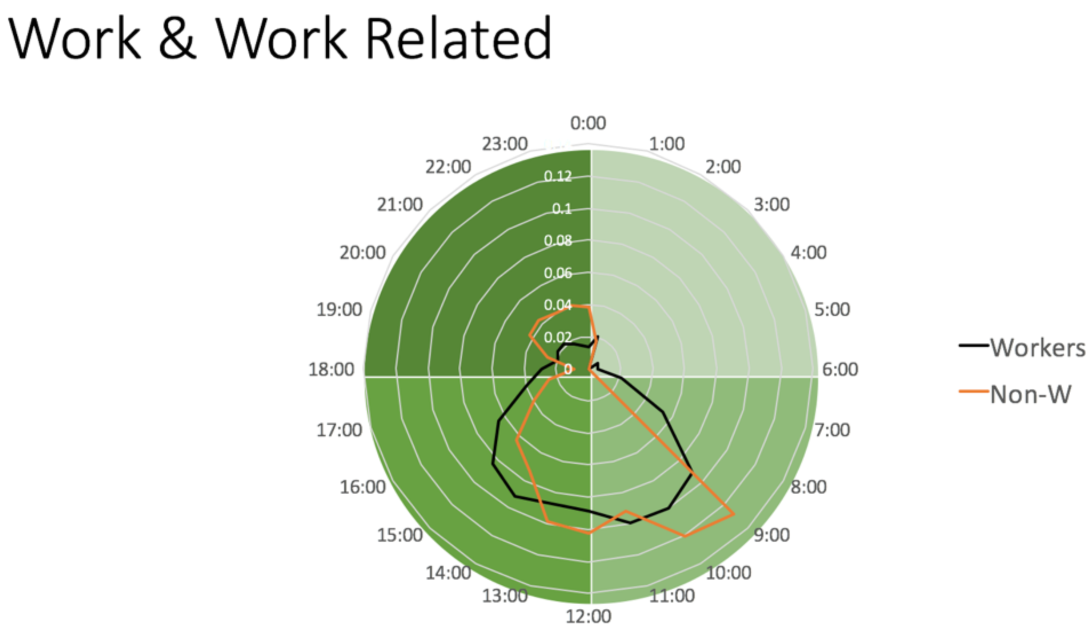


Figure 15 Work and Work related activities timeline

Figures 13-16 present a 24-hour view of certain activities conducted by the people in the sample. Figure 15 presents the timeline of work and work-related activities. It is a mostly flat graph concentrated around 8:00 to 16:00.

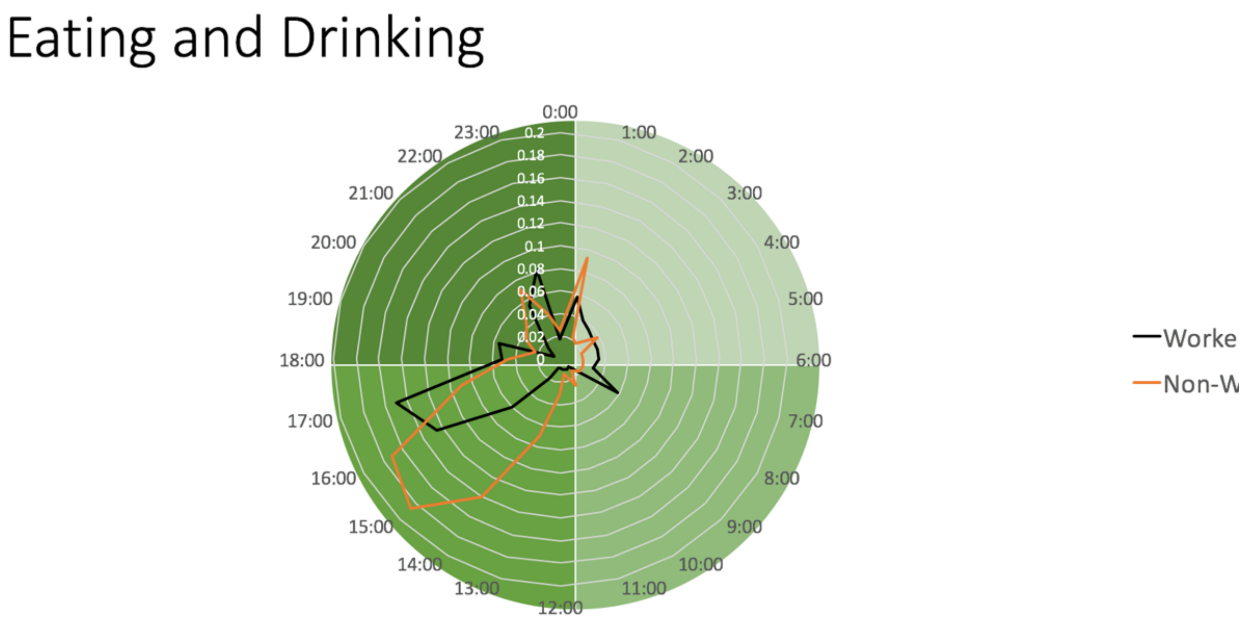


Figure 16 Eating and Drinking timeline

Figure 16 presents the eating and drinking patterns of individuals. Notice the later concentration of this activity in the day among workers.

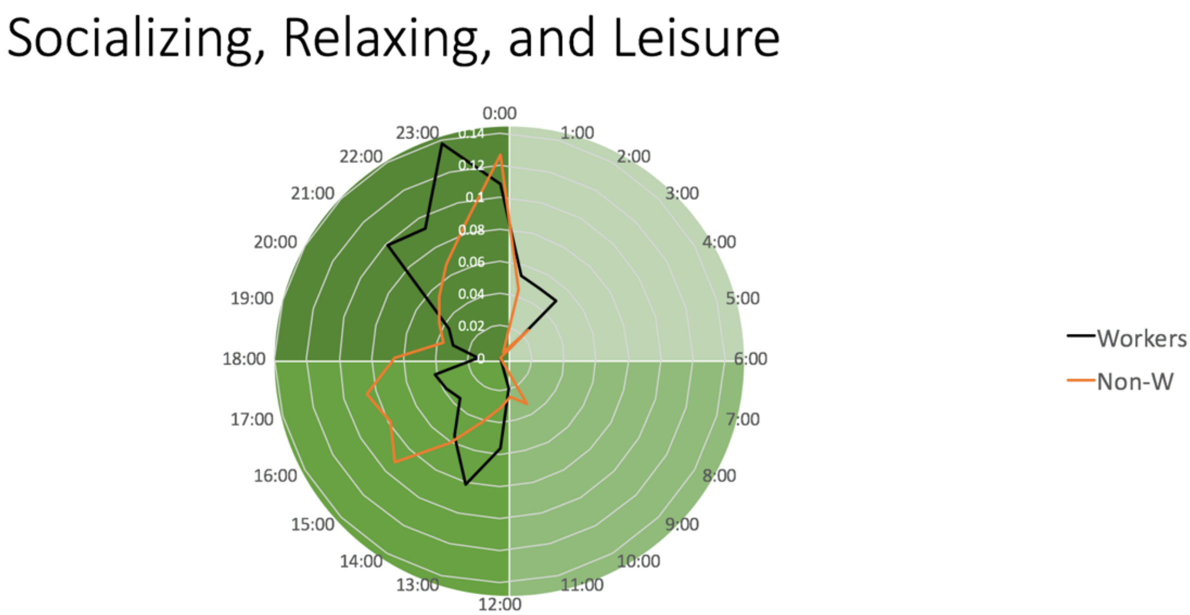


Figure 17 Socializing timeline

Figure 17 presents the socializing, leisure and relaxing hours. There is high activity even during work hours, hence the intermediate stops and trips that will be discussed in Chapter 4. This is attributed to the lifestyle of the study area, where a portion of workers have small breaks for socializing and leisure during work hours.

Figure 18 Caring timeline

Figure 18 presents caring and helping other people hours. This, among others, presents a successful data collection effort, as the activity diary was able to capture in-house activities of individuals. Workers care for other people even in late hours.

3.5 Methodology used in Chapter 4 – Daily rhythms

This thesis compares urban and island daily rhythms by examining departure and arrival times, mode choice, the correlation between times and activities and tour structure. The absence of activity diaries for the urban case prevents us from creating comparable activity sequence plots and time-of-day charts for the two study areas, but the exercise has still been useful in understanding a lot more about the behavior and activity sequences of people in the island area. First, the average morning departure times and work activity durations are compared. Then, tour structure is analyzed. Tours are identified and grouped into primary and secondary tours, with primary tours containing work, education, shopping, leisure and other activities as the main trip purpose. Intermediate stops are also noted. Thus, the tour structure can be one of the following types: primary tour (with no intermediate stop or secondary tour), primary tour and secondary tour (with no intermediate stops), primary tour with an intermediate stop but no secondary tour, and finally primary tour with both an intermediate stop and a secondary tour. The next step is the analysis of the tour structure, depending on the temporal positions of the intermediate stop(s). Four groups are identified: HMH (home – main activity – home), HiMH (Home – intermediate stop – main activity – home), HMiH (home – main activity – intermediate stop – home) and HiMiH (home – intermediate stop – main activity – intermediate stop – home). The final step of this analysis is a comparison of the modal split in the two areas, into general and activity-specific. This is followed by an examination of the bivariate correlation between the morning departure time and the duration of the various activities and the statistical significance of this correlation. The departure time is measured as time elapsed from midnight (in minutes) so that the two variables are comparable. Correlation tests include work, leisure, education and shopping activities, measured across the appropriate sample clusters.

Stochastic Frontier Model

Stochastic frontiers were developed for models of production. A production function is an ideal amount a unit can produce for a given set of inputs. In empirical settings observed outputs are not ideal (maximum) for reasons that are due to unknown random factors and measurement error (v) that are specific to each observed unit and due to productive inefficiency, that also varies with each observed unit (u). Applying this model to the departure from home can reveal the factors affecting the "ideal" departure time. Similarly, for the last arrival at home in a day. To examine the relationship between output variables (arrival at home) and input variables (characteristics of the person and her household) a regression model is created with the dependent variable being the indicator of output and the independent variables being the array of variables we desire to test for their significance in influencing arrival time. The model we use here takes the following form:

Index i represents each tract (data row, respondents), i=1,…,2447. Table 11 shows the estimates of the vector **θeta**. Variable v is the usual random error term capturing measurement error and variable u is a positive valued offset between observed arrival and the ideal arrival time at home. The random error term v is assumed to be normally distributed with zero mean and constant variance across observations. The random positive valued term u is specified as a function of other unobserved factors that do not allow the person to come home at the desired time. A similar formulation and specification were used by Pendyala (Pendyala et al., 2002) in which the equivalent of a cost stochastic frontier (adding the u in equation 6) was used for departure and a production stochastic frontier (subtracting the u as in equation 6) for the arrival. The skewness of least squares residuals can be used to detect if the data conform to this setting. In this analysis, we found that the only cost type of frontier can be estimated, possibly indicating that the desired departures and arrivals are later than observed. We also show simple linear regression models for the same data.

Latent Class Choice Model

A latent class choice model is developed to examine tour structure further. The initial assumption for this model is that the latent trait *Lifestyle* divides the sample into two distinct classes, each class having their utility function for tour structure.

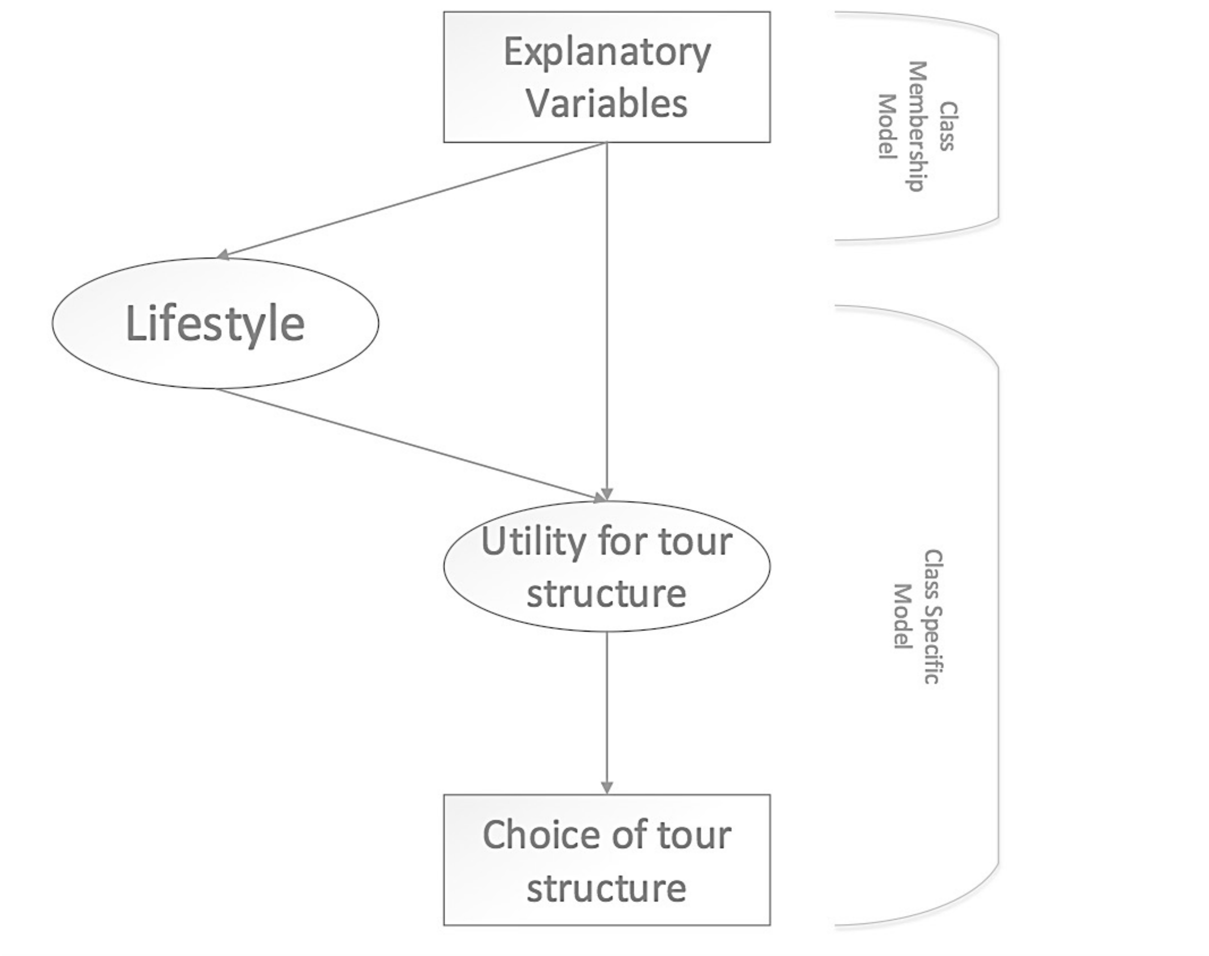


Figure 19 LCCM modelling framework

Each of the two class specific utility functions can be written as:

$$U_{in} = V_{in}(X_{in}, Z_n, \beta) + \varepsilon_{in} \qquad (1)$$

where X_{in} is a vector of attributes of alternative i, Z_n a vector of person's n characteristics and β parameters to be estimated, all three constructing the systematic part of the utility V_{in}. ε_{in} is the random component. The probability of an individual choosing an alternative, depending on the class she belongs could be written as:

$$P_n(i|s) = \frac{e^{V_{in}(X_{in}, Z_n, \beta)}}{\sum_{j \in Cs} e^{V_{in}(X_{in}, Z_n, \beta)}} \qquad (2)$$

Where Cs is the set of alternatives belonging to class s.

We assume that membership to a class depends on the characteristics of the individual (or household). A class-membership function can describe this relation:

$$P_n(s) = \frac{e^{f(Z_n, \gamma^S)}}{\sum_{r \in S} e^{f(Z_n, \gamma^S)}} \qquad (3)$$

Where $f(Z_n, \gamma^s) + \sigma_{ns}$ is the latent continuous variable of the *Lifestyle* trait, S being the set of classes, Z_n a vector of person's n characteristics and σ_{ns} an error component.

3.6 Methodology used in Chapter 5 – Active transport

3.6.1 A hybrid, macro-mesoscopic model of transport simulation

The 4-step model is an econometric model that simulates person travel. It is developed by Michael McNally (Mcnally, 2007) and it is dominant in travel demand analysis for decades. The application and usage of the model are nearly universal and has received widespread positive acclaim as well as some respectful criticism. The main function of the model is that it simulates person travel in a specific study area by applying four sub-models or steps.

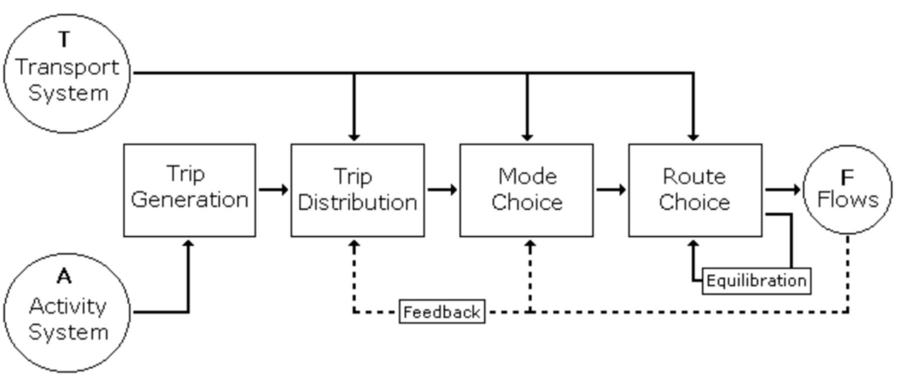


Figure 20 4-step model (source: (McNally, 2007)

Figure 20 presents the four steps followed in the model. In the following sections, we will briefly review each step. The application and extension of the 4-step model are done in Chapter 5.

In this thesis, a hybrid simulation model is used. In the hybrid model, the basic structure of the 4-step model is used, while extending individuals steps with innovative components. This extension provides additional richness to the model and at the same time utilizes available open data for the components and combines other simulation methodology elements such as the population generation traditionally used in activity-based models. The steps of the hybrid model are described in the sections below and in Figure 21.

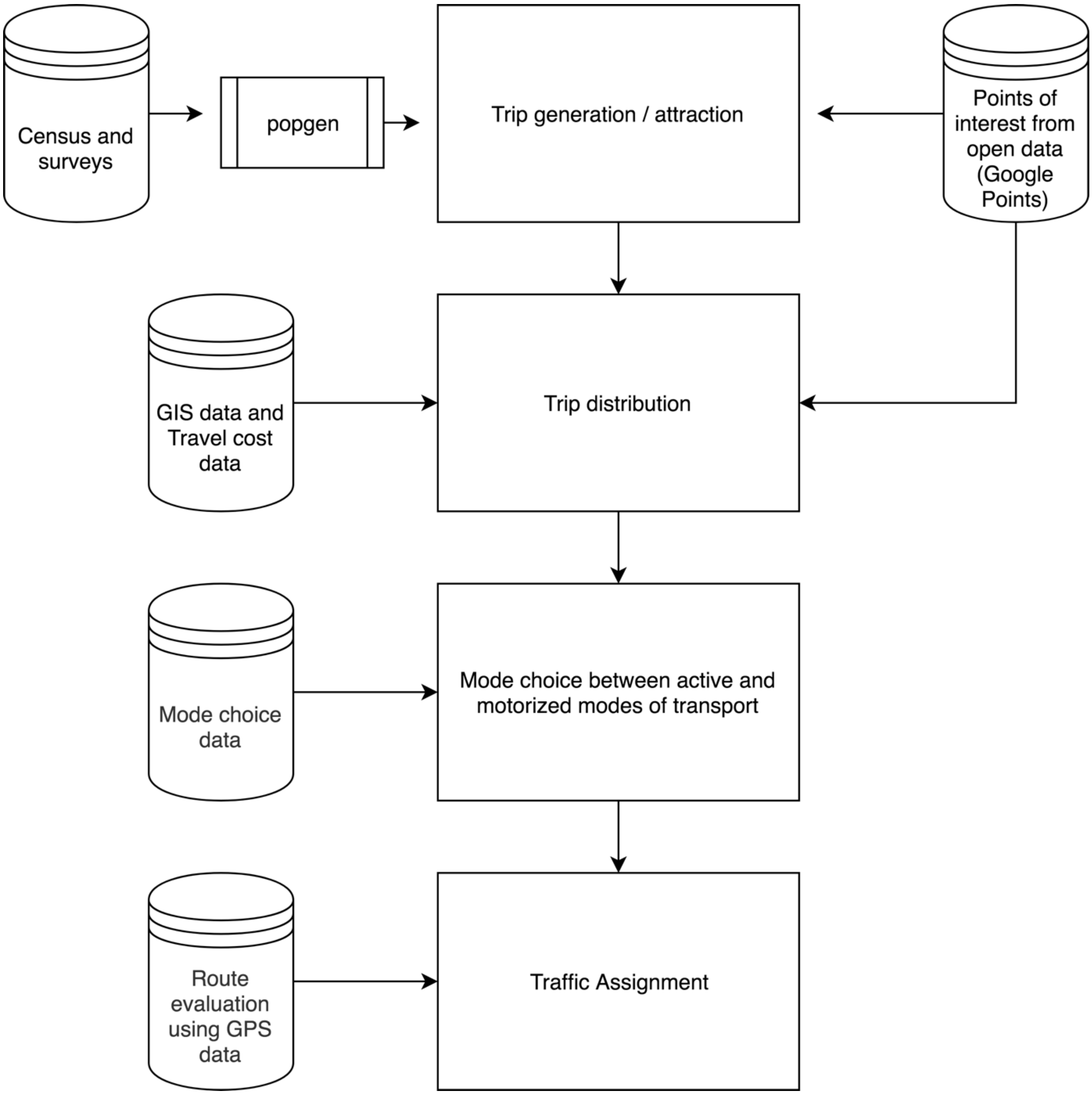


Figure 21 Hybrid simulation model

3.6.2 Trip generation

Trip generation is the first step of the model. The goal of trip generation is to "define the magnitude of total daily travel in the modal system" (McNally, 2007). During the model process, separate models for generating trip productions and trip attractions are developed.

$P_i^p = f_P^p(T)$ (T transport system characteristics)

$A_j^p = f_A^p(T)$ (T transport system characteristics)

Where P_i^p are the total trip productions for generated for trip purpose *p* in the zone (or other analysis unit) *i* and A_j^p are the total trip attractions generated for trip purpose *p* in zone *j*. The models are basically a multiple regression model containing factors that influence the production or the attraction of trips such as: zone population, workers in zone, the age distribution, car ownership, number of points of interest, land use and other characteristics. There are at least three different types of trip purposes: Home-Based Work (HBW), Home-Based Other (HBO) and non-Home-Based (NHB). HBW contain trips which ends are in the home and the work place of the person. HBO are trips that origin or end at home and the other end is an activity different than work. NHB are trips that do not include the home of the individual in any of their ends. It must be noted that the above refer to internal trips in the zonal area.
In the present thesis, trip generation and attraction are modeled in the level of zones by recreating the total population of each zones, as well as, the households they live in. Using combined data from the 2011 national census and the data collected in the framework of the thesis, the marginal distributions of households and individuals are calculated. Attraction-wise, the zones are allocated characteristics that are pooled from available open data, such as google places in the zone (workplaces, leisure, commercial shops and establishments, points of touristic attraction, special places). External trips are modelled differently; in this thesis, there are modeled by inserting special zones (airport and ports) that are scaled to the measure of the internal zones and are strongly affected by seasonality. External zones are mostly used to quantify the effect of tourist presence in the study area.

3.6.3 Trip distribution

Trip distribution sub-model transforms the production-attraction matrices produced by step one to origin-destination matrices which are imperative to the model process and useful for researchers and practitioners. It is essentially a destination choice model (McNally, 2007). Trip distribution calculates these matrices as a function of the transport system characteristics, zone attributes and network attributes (travel time and travel cost; the generalized cost of travel). A sample process is described below:

$T_{ij} = a_i b_j P_i A_j f(t_{ij})$

where:

$a_i = [\Sigma_j b_j A_j \; f(t_{ij})]^{-1}$ and

$b_j = [\Sigma_i a_i P_i \; f(t_{ij})]^{-1}$

and $f(t_{ij})$ is a measure of the network level of service.

This process is called a gravity model. The evolution and content of gravity models as a measure to quantify and model the movement of human populations from 1940, is based on the straightforward idea that: "the interaction between two populations is expected to be proportional to their size and reversely proportional to their distance." It has been studied extensively. Sen and Smith (Sen and Smith, 1995) have conducted an extensive analysis of the gravity model application and theory.

3.6.4 Mode choice

The third step, mode choice, transforms the origin-destination matrices of step two into mode-specific matrices. This process is done by using discrete choice modeling. The modeling is done using random utility models (Ben-Akiva et al., 1997) and it reflects the mode choice of individuals in the sample. The methodology is described in Chapter 3.7, where hybrid choice models are discussed. The models produced disaggregate results that must be generalized and applied to the specific zones of the aggregate 4-step model.

3.6.5 Route choice (traffic assignment)

The final step of the model is concerned with the traffic assignment in the network. It applied all above steps and reflects the actually predicted traffic flows. The equilibrium of demand and supply is achieved. The most basic algorithm used for route choice is a pathfinder algorithm called all-or-nothing.

3.7 Methodology used in Chapter 6 - Future fleet purchase

This section presents the hybrid choice model methodology that is applied in Chapter 6. The hybrid choice model acts as an extension to random utility model and is used to incorporate the effect of latent traits in the decision-making process. Combining socio-demographic data with psychometric analytics reinforces the modeling abilities to predict human behavior. Extensive and in-detail presentation of the model is discussed in the work of Ben-Akiva (Ben-Akiva, et.al., 2002). This section presents the modeling equations.

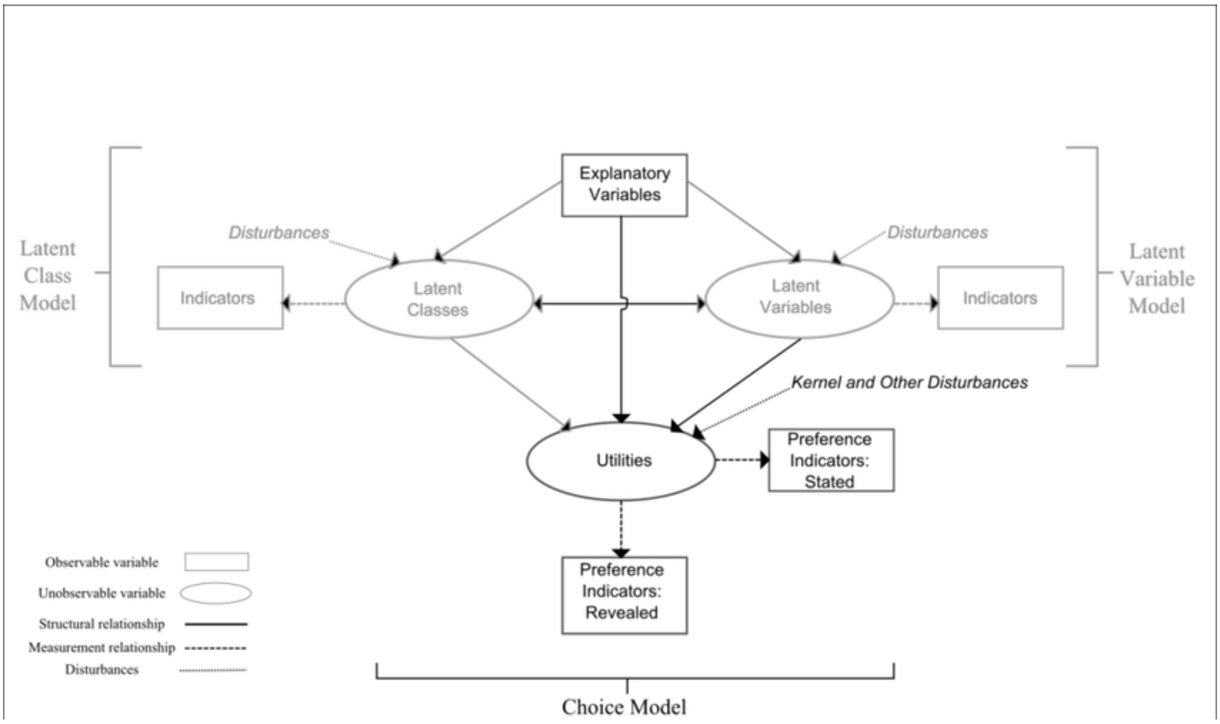


Figure 22 Hybrid choice model framework source: (Ben-Akiva, et.al., 2002)

3.7.1 Equations

In this section, the hybrid choice model equations are being presented. For the case study, we used a model with only one latent variable, *Exuberance*.

Structural Model

$Exuberance_n = Z_n\gamma + \omega_n$ *ω ~ N (0, Σω)*

$U_n = X_n\beta + Exuberance_n\delta + \varepsilon_n$ *ε~ N (0, Σε)*

Where:

$Exuberance_n$: Latent Variable

Z_n, X_n: Explanatory Variables

ω_n, ε_n : Vectors of random disturbance terms

$\beta, \gamma. \delta$: Unknown parameters

$U_n$is the utility of the alternative, β is the vector of the observed variables and γ is a diagonal matrix of unknown parameters associated with the latent variable

$Exuberance_n$, $U_n$is a vector of random disturbance terms associated with the utility terms. The choice model is assumed to be based on utility maximization:

$y_i = 1$, if $U_i = \max\{U_i\}$ *i = all the 720 cars*
$y_i = 0$, otherwise

y_i : the choice indicator

Measurement Model

$I_{Exuberance_n} = \alpha + \lambda Exuberance_n + \upsilon_n$ *υ ~ N (0, Συ)*

Where $I_{Exuberance_n}$ is a vector of attitudes and perceptions, *α* a vector of unknown parameters that indicate the association between the responses to the scale, λ are vectors of unknown parameters that relate the random variable to the indicators, $\upsilon_n$is a vector of random error terms.

Likelihood function

$$f\left(y_n, I_{Exuberance_n} \middle| Z_n, X_n; \alpha, \beta, \gamma, \delta, \lambda\right) = \int_{Exuberance_n} P(y_n | Exuberance_n; \beta, \delta, \Sigma_\varepsilon) f\left(I_{Exuberance\ n} \middle| Exuberance_n; \lambda, \Sigma_\upsilon\right) f(Exuberance_n | X_n; \gamma, \Sigma_\omega) dExuberance_n$$

Chapter 4: Everyday life tier - Rhythms

4.1 Introduction

Lifestyle choices are very relevant to travel behavior. Lifestyle as a term can mean different things. A synthesis of household structure, the number of children, the number of people in a household who work, living in an urban center or commuting considerable distances every day are all lifestyle components that fit the definition when looking at a household(Krizek and Waddell, 2002). When concentrating on an individual's lifestyle, choices such as work type and work hours, career, orienting time allocation towards work or other activities, and others can be involved. Lifestyle, of course, can be used as a term to describe other aspects of an individual's life that have a straightforward effect on her travel behavior. Aspects or personal traits, stemming from personal beliefs and perceptions, can create a combination of lifestyle and personality. For example, a person who has a sedentary lifestyle and devalues physical exercise can be described as having a whole different lifestyle from a "sporty" type of person who seems to lose no chance, even in a tight daily schedule, to work out. The relationship between these lifestyle types and clusters, and travel behavior has been the subject of many papers (Litinas et al., 2009; Sallis et al., 2004; Summala, 2007)). This is also related to the quality of life.

Place of residence influences a wide array of quality-of-life factors, ranging from health (Eberhardt and Pamuk, 2004) to environmental quality and other important factors. Lifestyle choices can affect the place of residence, but this is a two-way relationship. A person with a certain lifestyle will choose a location that fits her/his needs and desires, but living in a certain location can also shift and reform a person's needs, desires, and everyday behavior, changing their lifestyle.

Differences between places of residence influences travel behavior (Bagley and Mokhtarian, 2002). This can be quantified and explained using the trip chain structure. Kamargianni et al. Kamargianni et al., (2012) explore teenagers' travel patterns in morning school tours, identifying 17 different types and comparing the frequencies of different tour structures between an urban, a rural and an insular area. Students from the urban area tend to have a simpler structure to their tours, while students from the two other areas were more likely to have an intermediate stop before or after school. Of course, average travel time is relevant as well.

Activities and time of day are the subjects of various approaches and studies (Auld and Mohammadian, 2012; Goulias, 1999; Goulias et al., 2011; Schönfelder et al., 2002). A methodology that is often used in the literature, representing an actor's daily choices that can, largely, dictate the rest of the daily pattern of travel and activity, is the study of morning departure and evening arrival times. Some stochastic models representing these times treat the departure times as discrete (MNL nested logit models or mixed logit models). Others, emphasizing the continuous nature of time as a variable, treat departure times as continuous (continuous-time models, ordered GEV and their variants). A review of model techniques and methodologies on this subject is presented in Sasic & Habib (2013) who use a heteroscedastic generalized logit model to investigate commuting in urban and suburban areas of Toronto. Pendyala et al. (2002). and Pendyala (2003), calculating the spatiotemporal constraints of daily human activity, formulate temporal vertices of the Hagerstrand space-time prism. They attempt to model the origin point and terminal point of this prism, often difficult to observe in survey data, using stochastic frontier models. The method aims to achieve the following: (a) formulate these models to estimate origin and terminal points of the time vertex; (b) compare the results of the model between different geographic areas; (c) compare the results of the model on different days, to identify day-to-day variations. The two last goals were attempted in the thesis providing results of "remarkable similarity" between the geographic areas of San Francisco and Miami and between different days, indicating a minimal day-to-day variation. The shared results of stochastic frontier models include the following: a more than 60-minute-earlier origin vertex for workers compared to non-workers that drop to around 50 minutes for part-time workers, while people who work from home have an origin vertex 86 minutes later than people who commute to work. Car availability and driver's license produce vertices that are later in the morning, and older individuals have an earlier origin vertex. We are performing a similar comparison here.

Latent Class modeling (LCM) has been used extensively in the literature as a method to examine the individual behavior including non-directly observed variables further. It is a part of structural equation modeling and is mainly used to examine and identify subgroups of the population which are called “classes.” This thesis uses a Latent Class Choice model, a model which is not very extensively used in transportation literature. Exceptions include Greene and Hensher, (2003), Swait, (2002.), Bhat, (1997) and Hurtubia, et.al. (2014).
Summarizing, individuals’ daily activities structure and temporal organization have been studied extensively. Trip chains and tour structure, time-of-day analysis, and departure time models have been employed to examine variables influencing spatiotemporal variations. Our thesis shows that different lifestyles among places influence the daily schedules of individuals, contributing to the literature regarding new methods and perceptions of time allocation at different levels, both spatial and temporal. We find this to be of value because both methodologies used, stochastic frontier models concentrating on the temporal differences and latent class choice model on spatial differences, providing useful insight on the effects that lifestyle has on the observed variance. This includes identifying differences in the complexity of tours and mode share in Chios and Athens and similarities in other aspects of behavior.

4.2 Data and models

4.2.1 Study area

Chios Island is in the Aegean Sea, seven miles off the coast of Asia Minor. It is the fifth-largest of the Greek islands and has a population of 51,398. It is described extensively in Chapter 3.

Athens is the capital and the largest city of Greece. The city of Athens proper has a population of 664,046, and the metropolitan area of greater Athens has 4,013,368 residents (2011). The population density in the urban area is 7,462 people/ km2.

4.2.2 Sampling – Chios (Island area)

This research uses data from the ongoing travel survey taking place on Chios island as part of the "GreTIA – Green transport in island areas" scientific project (more discussed in Chapter 3). The sample was divided into three subsets – working people, non-working people, and students – to capture the variance in daily activity patterns between those population segments. Descriptive statistics for the three groups of respondents are reported in Table 8.

Table 8 Descriptive statistics

	Chios				***Athens***			
	Workers	Non-Workers	Students	All	Workers	Non-Workers	Stu-dents	All
N	273	307	40	620	1109	646	193	1948
Average age	41.5	43.4	20.4	36	40.8	49.2	16.2	44.2
Gender (woman)	48.9	53.1	36	50.9	46.3	56.1	51.8	51.3
% with college degree	56.3	40.6	18.2	42.7	45.4	19.4	6.7	34.2
% of daily time spent in shopping activities	3.2	5.4	4	4.3	-	-	-	10.5
% of daily time spent in recreational activities	8.1	6.2	16	7.5	-	-	-	6.5
% of daily time spent in home care activities	4.8	26.2	3.5	16.2	-	-	-	-
Mean waking-up time	7:45	8:28	10:10	8:09	-	-	-	-
Mean time of departure from home	9:23	11:04	11:40	10:16	8:46	10:29	9:49	9:32
Mean daily work duration	5:59	0:16	0:50	5:54				7:05

Average personal income is not representative of Greece's national economy because the study area is one of the highest-ranked areas in the country regarding bank savings accounts and is regarded as a mid-to-high-income region. Non-workers are occupied with home care, as this task takes up 26.2% of their daily time, while the percentage falls to under 5% for both workers and students. Shopping activity shows no significant variance between the three subgroups but recreation is highly popular amongst students, taking up to twice the amount of time in their daily schedules as it does in workers'. Waking-up time, even for workers, is much later than the regular waking-up times in urban centers. With a mean commuting distance of below three kilometers, which corresponds to a less-than-ten-minute commute in regular traffic conditions, workers do not seem to feel the pressure to rise early during the week. Even more interesting is the mean departure time, almost an hour and a half after most jobs in public and private sectors begin in Greece. Non-workers' first trip from home begins at around 11:00. Students have a more relaxed schedule, exiting their homes for the first time just before noon. Average work duration is six hours per day (part-time workers and freelance professionals bringing the average down from eight hours), and small amounts of working activity are found in non-workers' schedules (mainly helping the working person of the household or taking small shifts in the family business). Part-time work in the students' subgroup accounts for a mean of 50 minutes per day.

4.2.3 Sampling – Athens (urban area)

This thesis uses a random sample of 1948 individuals from a travel survey conducted in Athens in 2012. Due to differences in the diaries used in Athens and Chios part of the information available for Chios is not available in the Athens database. However, using the data that are harmonized between the two areas, general remarks include: The majority of the sample in Athens are workers, either full time or part time, with a mean age of 40.8 and 45.4% having a college degree. These statistics are comparable to the Chios case. Moreover, when it comes to non-workers, the sample in Athens is older (a mean age of 56.1 as opposed to 43.4 in Chios) and mostly female. The non-worker cluster also has a significantly lower percentage of people holding a college degree. The student cluster is also significantly different, as the Athens database contains a large number of high school students, while the database in Chios comprises mainly undergraduate students.

Setting these differences aside, a comparison between morning departure times and work activity duration leads us to the first conclusions on the variance in rhythms between the two places. Average departure time in Athens is almost 45 minutes earlier than that in Chios. Even workers in Chios initiate their first trip of the day more than half an hour later than their colleagues in Athens. We will test these differences in a later section of the thesis accounting for education and employment type differences between the two samples. One could comment that the distances are greater, and travel lasts longer in the urban area so this is a well-expected result, but looking at the daily average duration of work activity, things become more clear. People in Chios work over an hour less. The samples have proportional percentages of public and private-sector, and full-time and part-time, workers. Considering that work duration is shorter in Chios, this means that people in Chios either go to their jobs later or leave their job sites earlier in the afternoon. It could also mean less frequent over time or a more relaxed approach taken by those who are not bound by a strict timetable. This is the first indicator of location-dependent lifestyle affecting daily rhythms.

4.3 Analysis and findings

Table 9 shows that secondary tours, in Athens and Chios, tend to have fewer intermediate stops than primary tours, with Athens having no stops. Overall, Athenians do not make intermediate stops and the few people who conduct intermediate stops prefer to do so before their main activity (for most of them, the stop involves escorting kids to school). On the contrary, Islanders prefer the opposite pattern, making their stops after conducting their main activity, and there is a small percentage (3.4%) who conduct intermediate stops both before and after their main activity.

Table 9 Tour structure with intermediate stops

Main tours	**Chios**	**Athens**
Home-Main-Home	69.9%	98%
Home-Intermediate-Main-Home	10.3%	0.8%
Home-Main-Intermediate-Home	16.4%	0.2%
Home-Intermediate-Main-Intermediate-Home	3.4%	0%
Secondary tours		
Home-Main-Home	88.2%	100%
Home-Intermediate-Main-Home	3.9%	0%
Home-Main-Intermediate-Home	5.9%	0%
Home-Intermediate-Main-Intermediate-Home	2.0%	0%

The above observation allows a classification to be made of the daily rhythms in the two areas. In the urban area, people affected by long travel times and distances conduct a primary tour during the day and avoid making any intermediate stops during it. Commuting fills a big part of their everyday schedule, and they seem to avoid prolonging it, at least by making intermediate stops. They conduct their secondary activities during the day by making a secondary tour, where again they avoid stopping at intermediate locations. Islanders, though, seem to prefer to complete their entire daily travel in a single tour, which contains all the stops at which they conduct their main and secondary activities.

Table 10 provides a more focused comparison of the travel behavior and mode choices in the two locations. The first major difference is the almost non-existent use of public transport in the island area. Used only by students and elders, the public bus system of Chios takes up roughly 2% of the modal split. In Athens, over a quarter of the sample uses public transport for their daily travel. This is as expected due to the extensive public transport system of Athens that has a major subway connecting large portions of the urban environment and a dense system of bus routes. Also, car use is significantly higher in Athens, by ten percentage points over that in Chios. The gap between car and public transport use in Chios is filled by a large proportion of walking and motorcycle use. People on the island seem keener to walk, as distances are smaller and the center of the city is safer for pedestrians. Also, motorcycle use is very popular in Chios because they perform well in the narrow roads of the city center.

The proportions using cars to make trips to work very close in the two cases, at almost half of the sample. Walking to work is four times more popular in the island case, with only 4.9% of the sample walking to work in Athens. The car use percentages are also very similar for trips made for leisure purposes in the two areas. Walking trips also increase when looking at leisure as the trip purpose, at 25.7% for Athens and 40% for Chios. The above results reveal that even if, in the island case, walking has a larger mode share and, in both cases, there is a sizable percentage of walking as the mode choice for leisure activities, half of the sample uses a car to go to work on both the island and urban cases.

Table 10 Modal split

Modal split	Chios	Athens
Walking	22.2	10.7
Car	28.2	38.0
Motorcycle	12.2	4.0
Bicycle	2.3	0.9
Public transport	1.8	30.8
Taxi	0.3	2.4
Car to work	49.3	59.0
Walk to work	17.9	4.9
Car to leisure activity	30.9	26.7
Walk to leisure activity	40.4	25.7

The next section reports the correlation between morning departure time and various activities duration. As mentioned in the methodology morning departure time is measured in elapsed time from midnight. A larger number in elapsed time means that the individual begins her first trip later in the day. In that manner, positive correlation between the two variables means that if the activity durations are longer the morning departure time is later in the morning, and negative correlation means the opposite. One would expect, for example, a negative correlation between work duration and elapsed time

Results reveal an insignificant correlation between the morning departure time and the duration of work in the island area. In contrast, in the urban area, a strong correlation exists; longer work hours are related to an earlier morning departure. This is yet another indicator of the different rhythms between the two study areas. Morning departure hours are not influenced much by the hours someone works in the island area while in the urban case, work hours dictate the temporal location of the morning departure.

Table 11 Stochastic Frontier (v-u) model for arrival time at home

	Departure				Arrival			
	Ordinary Least Squares		Frontier (v+u)		Ordinary Least Squares		Frontier (v+u)	
	Co-efficient	Co-eff/S.E.	Coefficient	Co-eff/S.E.	Co-efficient	Coeff/S.E.	Co-efficient	Co-eff/S.E.
Intercept	556.90	34.19	369.15	31.06	1014.29	49.04	781.96	39.39
1 if Chios resident; 0 otherwise	6.45	0.56	17.22	2.00	17.01	1.16	6.29	0.48
1 if Female; 0 otherwise	13.33	1.19	24.55	2.92	-6.90	-0.48	0.46	0.04
1 if age 18 or less; 0 otherwise	-38.01	-1.32	-36.64	-1.64	-45.82	-1.25	-38.74	-1.16
1 if Age 65 and above; 0 otherwise	12.83	0.61	24.94	1.67	-33.57	-1.26	-33.46	-1.47
1 if College and above education; 0 otherwise	-7.24	-0.60	9.28	1.04	-8.28	-0.54	-11.45	-0.82
1 if elementary highest education; 0 otherwise	-38.90	-2.35	-18.75	-1.57	-55.36	-2.64	-42.13	-2.26
1 if a business owner; 0 otherwise	-10.77	-0.33	-57.82	-1.87	-73.53	-1.76	-71.94	-1.87
1 if home duties; 0 otherwise	44.61	2.16	41.78	2.75	-87.65	-3.34	-92.26	-3.97
1 if unemployed; 0 otherwise	119.94	3.45	50.20	2.08	-67.88	-1.54	-89.93	-2.27
1 if freelance worker; 0 otherwise	20.90	1.20	28.31	2.13	-12.05	-0.54	-27.50	-1.36
1 if retiree; 0 otherwise	20.19	0.99	18.12	1.18	-119.17	-4.60	-103.33	-4.57
1 if student; 0 otherwise	134.50	5.92	89.53	5.28	86.66	3.01	97.26	3.67

1 in no driver's license	25.70	1.21	35.96	2.19	-50.52	-1.87	-56.31	-2.37
1 if no cars in household; 0 otherwise	-8.95	-0.56	-12.65	-1.02	28.90	1.43	26.50	1.47
1 if walked to office today; 0 otherwise	-8.57	-0.55	-4.40	-0.38	-83.14	-4.21	-57.21	-3.22
1 if drove car today; 0 otherwise	-6.17	-0.47	-16.18	-1.66	-17.11	-1.02	-15.02	-1.00
1 if took bus today; 0 otherwise	-34.38	-2.01	-31.52	-2.46	-48.86	-2.25	-29.02	-1.49
1 if went to work today; 0 otherwise	-80.30	-5.56	-38.02	-3.59	52.76	2.88	80.78	4.75
1 if went to school today; 0 otherwise	-71.85	-2.98	-13.63	-0.73	8.05	0.26	7.55	0.27
1 if first activity was shopping, social, or entertainment today; 0 otherwise	97.16	6.62	84.19	7.27	34.71	1.86	29.87	1.81
			Compound Error Variance			Compound Error Variance		
Lamda			4.26	14.35			2.61	13.69
Sigma			224.06	1126.69			288.47	1167.69

The same result appears when comparing education activity duration with morning departure times in the student cluster of the two samples. In Athens, more education hours mean earlier morning departure times, but in Chios, there is a positive correlation between the two variables, though not significant. This, apart from the variations between the two areas, has a sampling explanation, as mentioned in other parts of the thesis, that sample in Chios contains university students, while in Athens high school students are also interviewed.

The leisure activity durations comparison reveals an intriguing fact: People in the island area appear to have a correlation between the long duration of leisure activity and the late departure from home in the morning. This could reflect non-working or student clusters of the sample, but it is also a sign that people in Chios can organize their activity patterns in a more relaxed manner. The fact that there is not a strong

correlation between leisure activity duration and morning departure times in the urban area strengthens this finding.
When we compare the duration of shopping activity with the morning departure time of the non-working group we find that the urban case sample shows a negative correlation between the two, indicating that long shopping hours need an early home departure. In Chios, there is also a negative correlation but not that strong and significant.
The analysis continues with a stochastic frontier (v+u) model for arrival time at home. Results are presented in Table 11.
The reference group is a combination of the excluded groups military and rentier. Simple linear regression shows we have no difference in departure and arrival times between the Athens and Chios samples. However, if one accepts the stochastic frontier model as a valid representation of the desired departure time, we see that Chios residents would prefer to leave 17 later than their Athenian counterparts when we consider education, employment type, age and gender differences. Employment has significant influence in all four models of Table 11 with persons in home duties, retirees, and unemployed leaving home later and arriving home earlier than other groups, while, business owners leave earlier than everybody else. Students leave and arrive late by a considerable amount of time, and they appear to have a shift of their schedule by more than an hour per day, but younger students are leaving earlier (see the indicator of fewer than 18 years old) and arriving earlier at home. Freelancers also tend to departure half an hour later than the reference group. Education levels provide mixed results. Interestingly, people that went to work departed earlier and came back later indicating they spend longer periods out of the home in a day. Bus users also seem to depart earlier. This may be due to the long commute times.
Overall the results indicate that there are very few statistically significant differences between departure and arrival times between Athens and Chios. This result is unexpected; one could expect people from the urban location to return home at a later hour. However, the analysis also revealed that the socio-economic characteristics are more influential in the arrival and departure times than the location. For this reason, we estimated a latent class choice model, to further examine the sample, attempting to look further into tour structure. A factor analysis revealed that the ideal number of classes (depending on the BIC and AIC) is two. The results are presented in Table 12.
Chios residents mostly populate Class 1, and Class 2 is mostly populated by Athens residents providing further evidence of significant and substantial differences in trip

chain behavior between the two places. This means that people that actually reside in Chios are predicted to have an Athenian lifestyle and vice versa. In addition, car ownership is a significant predictor of class membership at higher than 95% significance. Motorcycle ownership and living in an apartment are also significant at less that 95% and more than 90%. An initial examination of the tour structures from the two classes reveals an important fact: People in the mostly urban area tend to avoid conducting intermediate stops on their primary tours during the day. This could be attributed to under-reporting, but with a large sample, this becomes less likely. In the island case, people conduct an intermediate stop on their way to their main daily activity or on the way home from it. An explanation for these two observations could be down to the average traveling distance and travel times, which are larger in the urban case, and may push people living in the urban area to organize their activity patterns in such a way. Stopping at an intermediate destination could be difficult for a series of reasons, such as finding a parking spot, dealing with tight schedules and long travel times, or avoiding peak traffic hours; reasons not faced in the island area. It seems that people on the islands prefer to conduct their main and secondary activities within a single trip, before returning home. This is unexpected, as smaller distances and a more appealing urban structure and built environment could motivate Islanders to make more tours and spread their activities throughout the day.

Table 12 Latent Class Choice model results

Class Membership Model				
VARIABLE [Definition]			Coef.	t-stat
CLASS_CAR [Number of cars in the household]			-0.598	-2.47
CLASS_AREA [Dummy - Individual lives in urban area]			-6.75	-4.77
CLASS_MOTO [Number of motorcycles in the household]			1.61	1.74
CLASS_FLAT [Individual lives in a flat]			1.56	1.83
Class Specific Model				
	Class 1 [Island]		Class 2 [Urban]	
VARIABLE [Definition]	Coef.	t-stat	Coef.	t-stat
ASC_PR [Primary tour with no stops or secondary tour]	-0.0647	-0.13	6.03	6.66
ASC_PRS [Primary tour and secondary tour]	-0.550	-1.08	5.15	5.81
ASC_PRI [Primary tour with intermediate stop]	1.17	4.87	0.184	0.40

ASC_PRIS [Primary tour with stop and secondary tour]	fixed			
B_WORK [Individual is a full-time worker]	-0.298	-2.76	-0.298	-2.76
B_TIME [Time elapsed from midnight to first departure]	-0.0012	-4.08	-0.0012	-4.08
B_FEMALE [Individual is a female]	0.489	1.86	0.489	1.86
B_CAR1 [Individual drives to main activity]	0.730	1.92	-	-
B_HH1 [Number of persons in household]	-0.495	-2.28	-	-
B_CAR2 [Individual drives to main activity]	-	-	1.59	2.73
B_HH2 [Number of persons in household]	-	-	0.186	0.96
Rho bar	0.541			

4.4 Conclusion

This chapter examines the relation between location-dependent lifestyle encountered in different places and the organization of society's daily rhythms. While a multitude of studies have associated daily activity, and travel patterns with various factors such as ICT usage, socio-economic variables, psychological traits and another part of the literature has compared samples from different places, this thesis extends the literature by comparing two locations that have a different lifestyle, deriving from and affecting the set and setting of the place.

Results from the analysis revealed significant differences in the way the daily life is organized between the urban and island area of this study. These results can be grouped into three axes: a) tour organization differs between the two areas. In the urban area people prefer to conduct a secondary tour through the day for their secondary activities, while in the island case people prefer to make an intermediate stop on their way to or from their primary activity; b) walking takes up a much larger share in the modal split in the island area. In both cases leisure activities are strongly associated with walking, but the proportion for the Islanders is greater; and c) strong correlation exists between the duration of work, education and shopping activities and early morning departure times in the urban area, while no significant correlation exists in the island area. On the contrary, leisure activity duration is correlated with late morning departure times in the island area but not in the urban case. The stochastic frontier analysis reveals that there is no significant difference between the home arrival times of individuals in the two areas, but, there are differences in the desired departure from home in the morning. In fact, socio-demographic data such as occupation or education are more significant than the location. Latent class clustering analysis provides an insight into the tour structure of the respondents. Respondents that tend to prefer tours with an intermediate stop instead of a simple secondary tour are more likely to belong to the island cluster.

Our findings show distinct travel behavior in each one of the two places. The physical environment is the main factor, the effect of which is revealed in the walking share. The less dense island environment, with smaller distances and safer to walk roads and neighborhoods, favors walking as a mode. However, bicycle as a mode is not affected by the above, and it is not substantial in both areas. Lifestyle differences seem to play a major role in all other results. The more flexible timetable of the islanders, aided by a mixture of smaller travel times, relaxed work schedule, and proximity of various activity locations leads to the organization of daily patterns in a more independent manner. In fact, only leisure duration seems to affect morning departure times in the island, while work, shopping, and education activities duration affect the absolute early onset of an individual's schedule in the urban area. Concluding, different set and setting and a more favoring urban environment may not result in the adoption of an active transport lifestyle or trend but can lead to a more relaxed and independent management of the daily time schedules and activity patterns.

Our analysis challenges transferability of activity-based models, and we conclude if one needs to transfer models we also need to account for differences in the population and place-based factors that underly this variability. This thesis points out one way through latent classes to account for this variability. Policymakers are facing a greater chance of succeeding in their goals when adjusting their decision tools to fit the lifestyle of the area and when consulting the local community.

Also, a more in-depth analysis could be conducted if activity diary data becomes available from Athens. Activity patterns and time-of-day graphs could aid in the better understanding of the individual's decisions. An innovative mode choice SP experiment is already available for the island area. Combined with a smartphone app-based mode choice experiment in the urban area will shed light on the reasons for differences in travel behavior. Future studies will incorporate suitable clustering and modeling, examining in more depth the relationship between morning departure and evening home arrival times controlling for a variety of traits in the sample, in both areas and clusters of similar social and demographic characteristics. They will, also, include indicators of land use, infrastructure, the perception of place and built environment characteristics to examine further differences observed between the two areas.

Chapter 5: Short-term tier – Green policy infrastructure and soft measures

5.1 Introduction

Sustainable mobility is defined as "Satisfying the needs of the current generation without compromising the ability to satisfy the needs of future generations" (Brundland Report, 1987). Thereforeit is the organization of transportation systems in a manner to minimize environmental impact. Transportation is an economic activity that accounts for a big percentage of emissions global wise, while emissions are at the origin of the global warming phenomenon. This is the reason for the regulations enforced by many countries and multinational organizations (United Nations General Assembly, 2015).

However, the concept of sustainability goes largely beyond the mere consideration of emissions, being the "direct" environmental impact from motorized transport activity. Obviously, sustainability relates to the reduction of the extensive use of fossil fuel energy sources in transportation, also regarding future scarcity of these energy resources; the impact that future scarcity would have to other economic-productive activities, as well as various market pricing distortion to be derived, would further complicate and dramatically affect economic life, geopolitics, and welfare.

Also, the concept of sustainability affects other aspects of welfare, more related to the quality of life. The objective of "decoupling traffic and economic activity" also became a crucial dimension of sustainability: how to satisfy transport demand (for passengers and freight) while minimizing the resources used (transport means, capacity offered, energy). In wider terms, the objective is to stimulate economic activities further, but rationalize/minimize the resources used for satisfying the derived transportation activity thus breaking current "direct analogies" between production volumes and traffic volumes.

At the policy level, objectives related to "decoupling" imply the re-engineering and reorganization process of the transport system. Regarding passenger transport, policy measures to increase the share of public transport –thus reducing the use of private cars- go to that direction. Regarding freight, policies encouraging modal shift from door-to-door road to intermodal transport expect similar effects. In both examples, the use of transport means of bigger capacity, combined with the increase of occupancy rate of those means, are based on the concept.
Technically, the policies refer to a wider "logistics" approach. The problem is to redesign transport chains to concentrate/consolidate passengers and freight at appropriate locations in such a manner, to achieve modal shift and maximize occupancy rates; as a result, to minimize the whole vehicle-kilometers produced while satisfying the actual demand regarding passengers-kilometers and tones-kilometers respectively.
To achieve a successful redesign process, satisfying technical capacity requirements is a necessary but not sufficient condition; the satisfaction of users' quality requirements regarding transport time, safety, reliability are critical factors to success. From the rationalization process, several positive "network" effects would occur: more fluidity in physical circulation, less congestion, time savings for passengers and freight, increased safety, thus allowing a real reduction of "external cost."
Green transport is a concept strongly related to sustainable mobility and going beyond the technical and operational parameters presented above. Green transport integrates further technological and social innovation in the redesigning process. Along with intermodality/co-modality issues, patterns of private car's use and logistics, it focuses on alternative fuel technologies (e.g. natural gas, electric vehicles) or even non-motorized/active transport means (bicycles and walking). To successfully promote green transport, it is necessary to study in depth daily needs and travel patterns; innovative plans often have to combine green transport systems with the reconsideration of the land-use organization and the promotion of alternative patterns of land-use operations.
Green transport issues exceed the field of technical rationalization of transport networks and deals with wider perceptions of welfare. Driving forces for planning and promoting green transport systems are new values, behavior and lifestyle issues.
This chapter presents the concept, definition and design process of the sustainable or green transport scenarios that are assessed in the platform. It also is concerned with the methodology that supports the evaluation of these scenarios, a transport simulation model. The model is described in detail.

Based on these themes mentioned before, this thesis combines relevant solutions and policy measures to develop green transport policy scenarios to be tested and assessed in the study area. The definition of policy scenarios was based on several "building blocks"; these are possible interventions, solutions, and measures categorized by "nature" (e.g. infrastructural interventions, the introduction of new means in the study area, reorganization of existing network, change of utilization mode). The appropriate choose of components within these building blocks allow the definition of integrated alternative scenarios/plans.

5.2 Definition of Alternative Scenarios

5.2.1 Feedback from research activities and adjustment of initial assumptions

The thesis has stated its dynamic system approach from the first chapters. Initial hypotheses, concepts, and hypotheses are reconsidered and adjusted during the thesis process. The adjustments may derive from the literature review, the research findings, the socio-economic context of the country and the wider geographic area and the feedback the thesis has from the local communities, stakeholders and decision makers through the public consultations.

The consideration of the above factors led us to rethink about several possible measures. The most important of the reconsiderations are presented below. The introduction of electric cars as a policy measure was not included in the list of proposed measures. While the hybrid choice model developed in Chapter 6 revealed that eco-friendly individuals are more probable to purchase a hybrid vehicle in the future, the financial situation of the country and the drop in personal income along with the mixed feelings, as well as the low scores that this measure scored in the public consultation concluded in the disqualification of the measure. The good scores of electric bicycles and bicycle sharing systems both in the public consultation and the mode choice model was another indicator that the alternative plans should be more concentrated on active vs. motorized transport.

The public consultations also revealed issues about the quality of urban life and the levels of sound pollution especially on the port and the center of the city. This is the second group of measures, the traffic congestion solution, and urban environment.
Some measures did not excel at the public consultations and modes that are not the best choices among the alternatives (from the mode choice model) such as sharing systems and parking locations. Sharing systems, especially bicycle, are considered as a part of some measures for two reasons: a) the popularity of this type of mobility is expected to rise in the next years, as public access to sharing mobility apps becomes greater and as attitudes and perceptions shift towards sharing systems and b) the local community has no official sharing system (car or bicycle) but has self-organized in a carpool system (parents rotate taking children and classmates to class, people living in villages share rides with each other, students hitchhike) so the local population has some familiarization with the process of sharing a ride but this lacks preference when it is done in a formal manner, as the model results indicate.
Also, parking spots were a controversial topic on the public consultations. From the supply and demand side, a popular scientific opinion is that new parking spots equal more traffic. However, a significant part of the local community ranks new parking spots as a high priority measure while 40,7% of the total sample ranks the creation of new parking spots as a priority measure. Trying to combine the solution to the congestion problem while respecting the need for parking spots led us to the measure about parking spots described in the next section.
Congestion taxes were also re-considered. Apart from the low scores in public consultations three reasons affected the non-inclusion of the measure in the proposed: a) the foggy classification between urban and rural trips in the study area; congestion taxes focus almost directly to urban trips; b) the practically non-existent percentage of people using public transport, a portion of the network users that traditionally would support a measure like congestion taxes and c) the relevant inequality of the measure: taxing engine size and not vehicle use and affecting horizontally all income categories.
The output of various research and investigation in the framework of GreTIA considering the conclusions allowed at a first stage better identifying the most suitable measures to propose, mainly at the level of infrastructure. The proposed measures are presented in the next section. Combined with the other levels (building blocks), they will allow subsequently defining integrated scenarios.

5.2.2 Methodological framework for the definition of scenarios

Referring to a system approach to the development of alternative green transport scenarios (plans), the definition of some building blocks for scenario building is a necessary methodological step. Such building blocks are:

- Infrastructure level: Low cost and small and medium scale infrastructure developments (parking spots, terminals/park and ride areas, the creation of bicycle lanes.).

These interventions (or measures) mainly refer to low or medium cost infrastructure works, since the necessary space is already available for public use (e.g. existing roads) and needs surface technical adaptations given a change of mode of utilization.

- Transport means: Introduction of new transport means (e.g. bicycles)
- The level of operations: Measures regarding traffic regulation (e.g. pedestrianization, measures of traffic restriction).

Furthermore, the determination of alternative plans was a process running parallel to the thesis from the first chapters. Final decisions differ from some indicative initial plans since the thesis elaboration allowed to review some preliminary working hypotheses, identify new parameters through various field surveys, better assess driving forces and investigate pilot tests.

5.2.3 Definition of building blocks

This section discusses the definition of the different building blocks, the basic measures that on their own or combined, lead to the creation of the various policy packages.

Parking spots

Where we are moving parking spots and not creating new, in this way we avoid the extra load created by more parking spots, we free space on the streets, and we internalize the external costs by making residents pay for parking (this also pushes people with marginal elasticity to shift to another mode)

As described in the previous section there is a need to re-organize parking spots for the study area in a way that both respects the need of the local community for parking spots and does not deteriorate the traffic congestion condition in the town. The solution proposed for the synthesis of these two issues is the relocation of parking spots from the side of busy roads to certain parking locations. This serves a multitude of purposes.

First, the relocation of parking spots means no difference in the number of spots. Even if the number of parking spots created is slightly more than the parking spots removed, the effect that this will have on the traffic congestion will be minimal combined with other measures that will take place in the scenarios that parking spots reallocation will be included.

Secondly, the relocation of parking spots leaves the part of the busy roads that was used for parking (in many cases illegally) free. This free space can be utilized for the creation of better and wider pavements (22% of the sample says that they completely agree -7 out of 7- with the statement that the pavements to their work are very narrow, while almost 80% agree with the statement). They can also be used for the creation of bicycle lanes, as per some scenarios described below.

Finally, this measure is a way of externalizing the internal cost of traffic congestion by charging the (at the most cases previously free) parking spots in the dedicated parking areas. Of course, this must be done on social groups that cannot use active transport from the parking locations to their destination (elderly, disabled). Also, this brings up the discussion about a complimentary measure to parking locations which is the use of park and ride systems (autonomous buses, golf cars, bike sharing systems). It also pushes people that are able and willing to commute using active modes to do it finally.

Estimated Cost: 2.000.000 € for parking of 500 places on the ground - 350.000 € for a 40 bicycle-8 station bike sharing system – 12.000.000 € for a five bus-3station autonomous bus system.

Creation of bicycle lanes

The creation of bike lanes is most probably the first thing that comes to mind when someone is talking about green transport policy measures. However, literature and practice (Caulfield, 2014; Motoaki and Daziano, 2015; Tilahun et al., 2007) show that bike lanes are not a one-size-fits-all and neither a panacea measure. The creation of bike lanes is a measure that costs a lot – especially if a local authority has decided to plan and implement a bike lane system carefully.

In the case of the study area, creation of bike lanes was greeted with positive scores and thoughts both on public consultations and survey data. Almost 50% of the sample stated that building bike lanes is ranked first of second priority measure for them. It should be noted that there no bike lanes present on the island.
The perception of the author is that a bike lane system should be interconnected. There is no real point in creating scattered strips of bike lanes in the locations on the network that it is easier or less costly. For this reason, it was decided that three different, integrated bike lanes will be proposed. Each one can function on its own, but the creation of 2 or all of them would create an even larger interconnected network of bike lanes. The beginning point of all bike lanes is the city center (Chios central square). The first bike lane runs through the city to the north suburbs and neighboring town Vrontados from the coastal route (Figure 23). The second runs from the south point of the port (Chandris hotel) through the coastal route to the airport and ends in the tourist region of Karfas (Figure 23). Bike lane 3 runs from the port of Chios town to the suburb of Kampos, south of the city center (Figure 23).
Bike lane 1 connects the two most populous towns of the island, Chios, and Vrontados. There were two route alternatives for this bike lane; each one has positive and negative characteristics. Bicycle GPS traces reveal that speeds are higher and mean slope is lower on the coastal route. It is also a route by the sea, and it passes next to the students' dormitories. A negative characteristic of this route is that on windy days it can be hard to ride a bicycle. The width of the roads on this route is at most points enough for the creation of a simple bike lane, though more width would be needed in some parts of the route is a more advanced bike lane was chosen.
Bike lane 2 connects city center with the popular tourist destination Karfas. It also passes by the island's airport. Bicycle GPS traces reveal the highest speeds and lowest slope from all proposed bike lanes. In all parts of the route, the width is sufficient for the creation of a simple or an advanced bike lane. There are some large parts of this route that the width is enough for both a bike lane and a wide pavement. However, there is a part of high, abrupt slope near the route's end. Also, car and motorcycle speeds on this route are high (GPS recorded many traces with speeds over 100km/h) and the presence of trucks is frequent.
Bike lane 3 connects city center with the also popular tourist destination and picturesque suburb of Kampos. This is the proposed bike lane on the narrowest roads. A relevant study in the study area (Kapros and Proios, 2010) has already proposed measures for the creation of one-way roads in the area. This measure would be very

helpful in the implementation of the bike lane in the area. Also, a part of the proposed bike lane runs through the narrow, picturesque streets of Kampos, where motorized traffic is minimal.

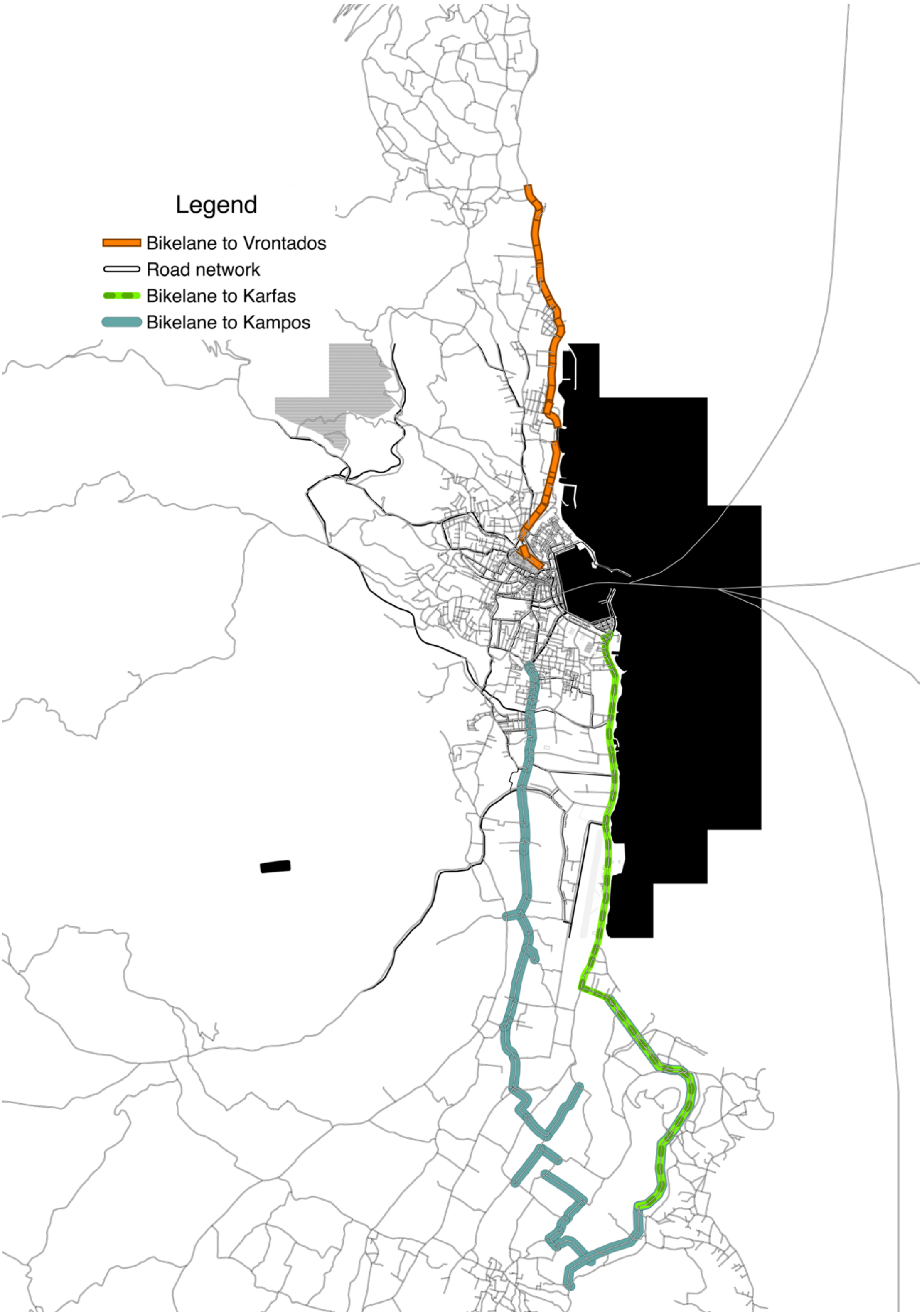


Figure 23 ALL BIKE LANES

Table 13 Bike lane evaluation

Bike Lane	Total length(km)	Mean recorded speed of bicycles (km/h)(GPS)	Mean recorded speed of cars (km/h)(GPS)	Average slope	Street width	Presence of lights
To Vrontados (1)	3.8	15,1 (20.4 electric)	47,8	1,4%	>70% wide enough	70% of the route
To Karfas (2)	4,7	14,4(22,3 electric)	52,4	0,7%	>95% wide enough	80% of the route
To Kampos (3)	4,3	13,9 (19,5 electric)	44,2	0.9%	~50% wide enough	90% of the route

Table 14 Cost estimates for bike lanes

Simple	18.000 €
Advanced	50.000 €
State-of-the-art	130.000 €
**Explanations*	
Simple	Painted lane at the side of the main road
Advanced	Separate lane with boundary
State-of-the-art	Separate lane with boundary + bicycle lockers, stations, and first aid kits

Pedestrianization of streets

The pedestrianization of streets is a measure widely known to improve certain aspects of urban life and to create a safer environment for pedestrians and users of active transport modes. A series of European cities are enforcing such measures in their downtown area. Only in 2014, 6 European cities started implementing such measures (Citylab, 2015). In the case of the study area, the measures proposed are split into two spatial categories, proximal to each other. The first includes the pedestrianization of the road next to the island's harbor. The second is the pedestrianization of all streets comprising the towns historical center and more precisely streets contained in the polygon Aplotarias – Psixari – Venizelou – part of Polytechneiou – Ralli (shown in Figure 24).

These measures must be accompanied by at least two new parking spots proximal to the city center for the convenience of the users of the transport network. It must be noted that recently (2013) the main shopping alley of Chios town, aplotarias str. was pedestrianized. This measure was accepted as successful by a wide majority of the citizens.

Problems with the proposed measures include a) difficulty in social acceptance, at least at the proposal and initial stages of the implementation; and b) effect on the traffic around the pedestrianized areas. More specifically, the first proposed pedestrianization (harbor road) is a measure that has been discussed for decades in Chios and is half implemented (one-way pedestrianization during summer months, for some hours of the day) for some period. The major issue, other than traffic diversion, will be managing the extra traffic from ships during the arrival time of the vessels approaching Chios harbor. There are a lot of possible solutions to this issue, namely some of those include: a) the diversion of the traffic through a part of the pedestrianized roads for a small period; b)the creation of a coastal road on the north of the harbor and c) the change of location of Chios harbor.

The second pedestrianization is expected to be harder to be accepted by the public. State-of-the-art and practice (Korinthos, Syros relevant cases, international such as Norfolk, Genève) show that the long-term effects of the pedestrianization of the city center are positive and include improvement of the urban quality of life, reduction of accidents and noise pollution, boost in tourism and rise in active transport usage. Problems with the pedestrianization include, again, the diversion of traffic to other links, the discomfort of residents (although a big part of land use in the area is commercial and public buildings) and access to particular groups (disabled, elderly, services) in the area.

Figure 24 all pedestrian roads

Table 15 Estimated cost of pedestrianization

Simple	1.500 €
Advanced	25.000 €
State-of-the-art	40.000 €
**Explanations*	
Simple	Simple marking for pedes-trian road
Advanced	Rebuilding of road and tiles
State-of-the-art	Total reconstruction with decoration

5.2.4 Building blocks

As mentioned before this section describes the combination of components which results in the creation of the building blocks.

Infrastructure
- Bike Lanes
- Parking Spots
- Shared system stations

Transport Means
- Bicycles
- E-Bicycles
- Shared bicycles
- Regular buses
- Golf Cars
- Driverless Buses

Operational
- Pedestrianizations
- Park and Ride systems

Figure 25 Building blocks

5.2.5 Scenario development

The developed scenarios are split into two layers. The first layer contains scenarios that are composed of maximum two components from the components and the second layer contains scenarios that are composed by more than two. The construction of policy bundles, scenarios built by more than one measure/action/component has been a thesis stated objective and a widely-used state-of-the-practice policy. The detailed Scenario development and classification in the two layers is presented below

Table 16 Scenario development

	Infrastructure			Modes				Operational	
Scenario/Components	Bike lanes	Parking spots	Shared systems	Bicycles (e-bikes)	Shared bicycles	Golf Cars	Driverless buses	Pedestrianization	Park and ride
Scenario 1 (BAU)	✘	✘	✘	✘	✘	✘	✘	✘	✘
Scenario 2.1 (Bike lane to Vrontados)	✔	✘	✘	✔	✘	✘	✘	✘	✘

Scenario 2.2 (Bike lane to Karfas)	✔	✘	✘	✔	✘	✘	✘	✘	✘
Scenario 2.3 (Bike lane to Kampos)	✔	✘	✘	✔	✘	✘	✘	✘	✘
Scenario 2.4 (All bike lanes)	✔	✘	✘	✔	✘	✘	✘	✘	✘
Scenario 3.1 (Pedestrianiza-tion of port road)	✘	✔	✘	✘	✘	✘	✘	✔	✘
Scenario 3.2 (Pedestrianiza-tion of city cen-ter)	✘	✔	✘	✘	✘	✘	✘	✔	✘
Scenario 3.3 (Both pedestrianizati ons)	✘	✔	✘	✘	✘	✔	✘	✔	✔
Scenario 4.1 (Parking spots & Golf cars park and ride)	✘	✔	✘	✘	✘	✔	✘	✘	✔
Scenario 4.2 (Parking sports & Driverless buses park and ride)	✘	✔	✘	✘	✘		✔	✘	✔
Scenario 4.3 (Parking sports & shared bikes park and ride)	✘	✔	✔	✘	✔	✘	✘	✘	✔
Scenario 4.4 (Parking sports & regular buses park and ride)	✘	✔	✘	✘	✘	✘	✘	✘	✔

Layer 1 – Up to two components

Scenario 2.1, 2.2, 2.3 and 2.4

Scenario 3.1 and 3.2

Scenario 4.4

Layer 2 – Two+ components

Scenario 3.3

Scenario 4.1, 4.2 and 4.3

Rise in Active

Scenarios under that category are expected to have a direct impact on creating a larger share for active modes, especially the use of bicycles. The scenarios listed here are based on the measures described in section 2.1.2.2. Each bike lane creation is examined on a scenario by itself and with the addition of a bike sharing system. A combination of bike lanes scenario is also evaluated. These scenarios are assessed by allocating a different impedance on the links containing bike lanes on the simulation software. The impedance modifies the t0 for these links and affects the mode choice proportional to the beta of the presence of bike lanes estimated in the mode choice model.

Table 17 Scenarios of group 2

Scenario 2.1	*Creation of bike lanes from Chora to Karfa*
Scenario 2.2	Creation of bike lanes from Chora to Kampos
Scenario 2.3	Creation of bike lanes from Chora to Vrontados
Scenario 2.4	Creation of bike lanes from Vrontados to Karfa/Kampos
Scenario 2.1.1	Creation of bike lanes from Chora to Karfa and bike sharing system
Scenario 2.2.1	Creation of bike lanes from Chora to Kampos and bike sharing system
Scenario 2.3.1	Creation of bike lanes from Chora to Vrontados and bike sharing system
Scenario 2.4.1	Creation of bike lanes from Vrontados to Karfa/Kampos

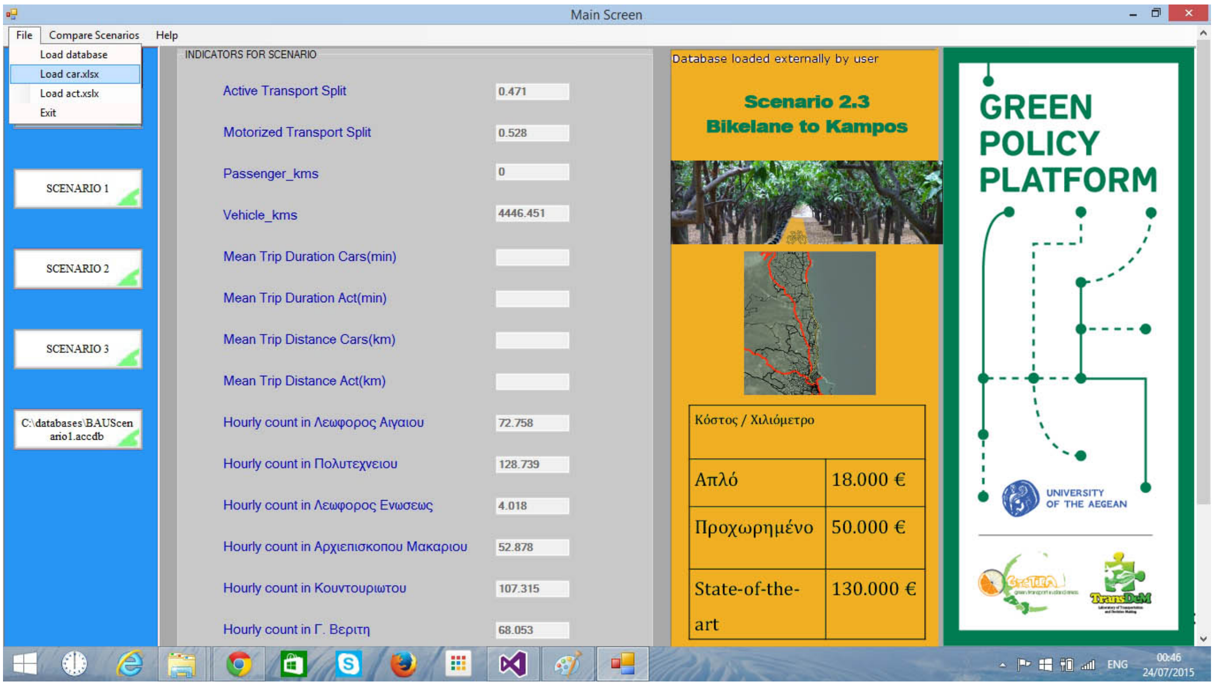
Traffic Congestion Solution & Urban Environment

Scenarios under that category are expected to have a direct impact on less use of motorized modes, the creation of a safe, noise and pollution free urban environment for locals and tourists. The two basic scenarios 1.1 and 1.2 contain the measures discussed in 2.1.2.2: The pedestrianization of coastal route and the pedestrianization of city center. All the remaining scenarios are combinations of the basic scenarios with parking spots, park, and ride and sharing system measures. Note that in this scenario group, apart from the KPI performance, the re-direction of the traffic that the network simulation provides is imperative. The proposed pedestrianization areas handle a big part of the city and transit traffic. The eight different scenarios are described below:

Table 18 Scenarios of group 3

Scenario 3.1	*Pedestrianization of coastal route*
Scenario 3.2	Pedestrianization of city center
Scenario 3.1.1	Pedestrianization of coastal route with parking spots
Scenario 3.1.2	Pedestrianization of coastal route with parking spots and golf car rides
Scenario 3.1.3	Pedestrianization of coastal route with parking spots and bike sharing system
Scenario 3.1.4	Pedestrianization of coastal route with parking spots and both golf car rides and bike sharing system
Scenario 3.2.1	Pedestrianization of city center with parking spots
Scenario 3.2.2	Pedestrianization of city center with parking spots and golf car rides
Scenario 3.2.3	Pedestrianization of city center with parking spots and bike sharing system
Scenario 3.2.4	Pedestrianization of city center with parking spots and both golf car rides and bike sharing system

5.1.8 Example of a scenario screen



Εικόνα 1 Early Scenario Screen

5.3 Allocating analysis to Traffic Analysis Zones

The task of allocating the socioeconomic forecasts to Traffic Analysis Zones (TAZ) will be described in this section of this section. It should to extend the effect and power of data from the census, the process of original allocation of socio-economic data (before the forecasts) included the creation of a synthetic population using the software POPGEN (Goulias, et.al., 2011). In this way, the combination of census and survey data led to the population of all TAZ with synthetic agents. This is done with respect to survey and census marginal distributions.

5.3.1 Zoning system

The study area was described analytically in Chapter 3. The simulation model is concentrated on Chios town and will provide secondary information on the rest of the island. For this reason, the zones are denser in Chios town (marked 8 in the Figure below). The overall administrative areas of the island are the following:

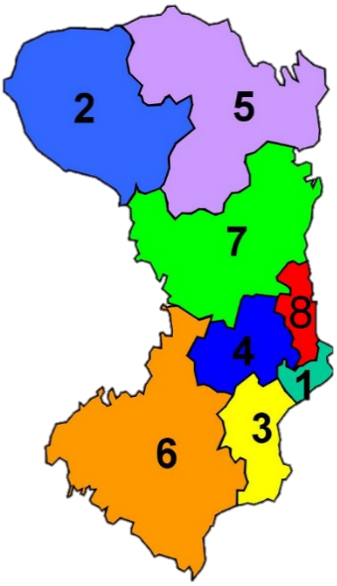


Figure 26 Chios Administrative regions

Region 8 on the map, Chios town, contains the 41 zones that will be used in the simulation modules. External zones include North Chios (2, 5 and 7 on the map), Central Chios (1 and 4 on the map) and South Chios (3 and 6 on the map). There is an alternative zonal system available, with external zones being the port and the airport of the island to be used in tourist scenarios.

Concerning the 41 zones of Chios town, the initial plan was to create one zone per residential block within the town limits. This was the way the questionnaires were run and all the data available on that level. A figure is depicting the original residential block zones and population.

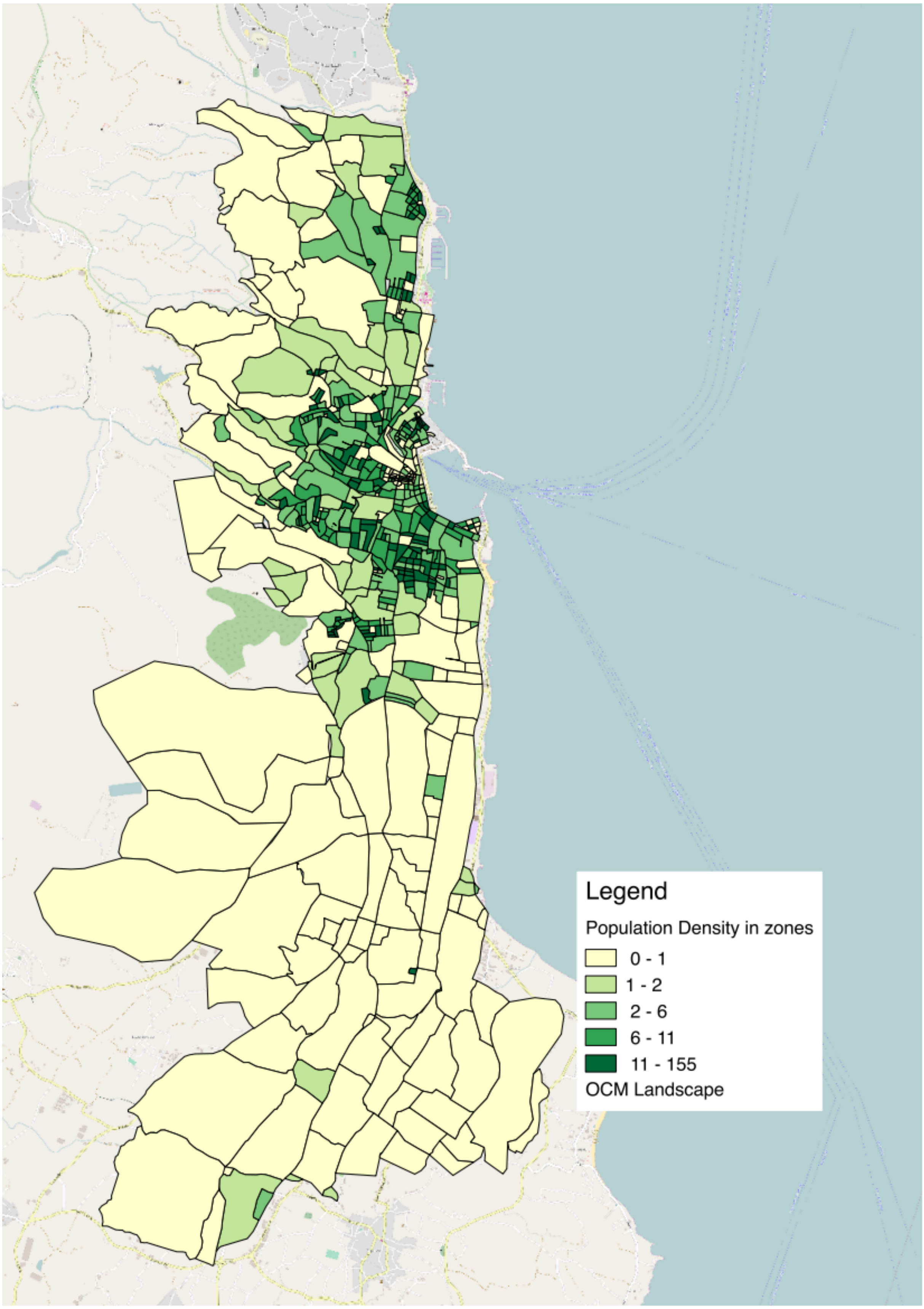


Figure 27 Original Small Zones

The original residential block zones were aggregated in 41 mega-zones, mainly because most of the 551 original zones were too small for any results to be comparable. Also, while managing to collect a representative sample from almost all the zones, some small zones ended up having 1 or 2 persons as their sample, which would make the process of synthetic population creation unreliable.

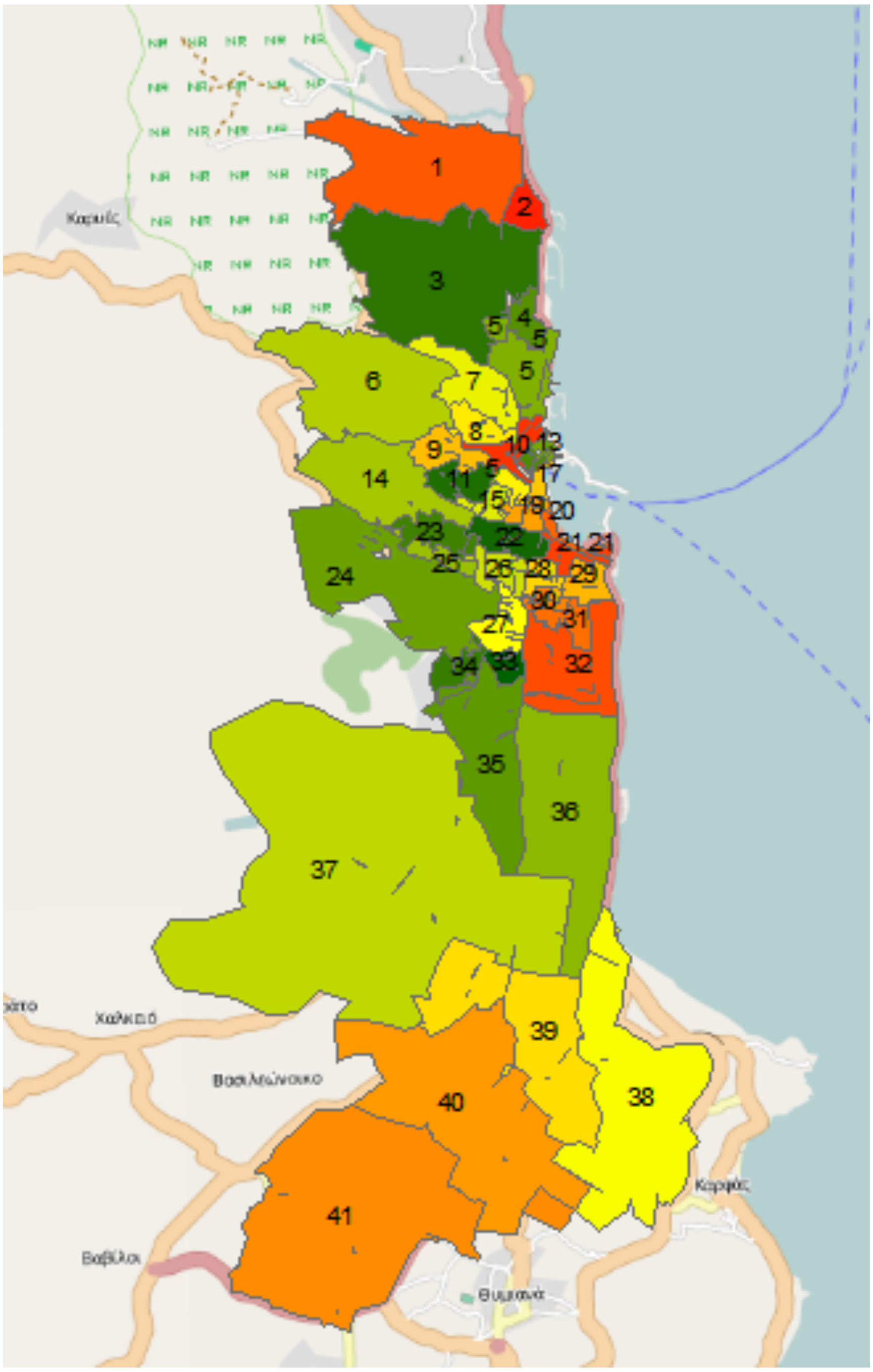


Figure 28 MegaZones

Finally, a figure showing the process of defining zones in the study area. During the process 3 consequent steps were made: a) the creation of scattered zones, containing whole neighborhoods or places of interest in the study area; b) the creation of central, small zones to account for high population density in the central areas of the town and c) the aggregation of peripheral zones to account for low population density and little number of facilities (job places, schools, shops etc.)

5.3.2 Allocation of forecasts into the zones

The allocation of forecasts into the zones could be treated as a simple application of the different growth rates in the population of each zone. However, a more sophisticated approach used in this part of the thesis includes the allocation of different rates of growth in every zone depending on the forecasts for each area of Chios town. The decision includes empirical evidence and consultancy from local planners, policymakers, and civil engineers.

Zones 1-7 and 34 to 41 (zones on the suburbs of Chios town) are allocated a small growth of population. Zones located in the center of Chios town are allocated a larger deficit that the average. The overall negative growth remains at the constant rate of -0,18.

5.4 The hybrid simulation model

5.4.1 Network Coding

Coding the island's network was a major part of the preliminary work of the simulation model. The completed network includes 18484 links and 7021 nodes, and it is constantly updated. Figure 26 depicts the links in the network, color coded for their type. After the successful creation of the links in the network and their geocoding to depict as closely as possible the real links, the link classification took place. The links were divided into 3 link types. Primary network, which contains the wider links of the network, usually main roads that connect villages and run through Chios town, Secondary network, which contains the less wide, residential roads and finally Dirt road network, which contains rural, small but mapped roads, most of them accessible by a regular vehicle.

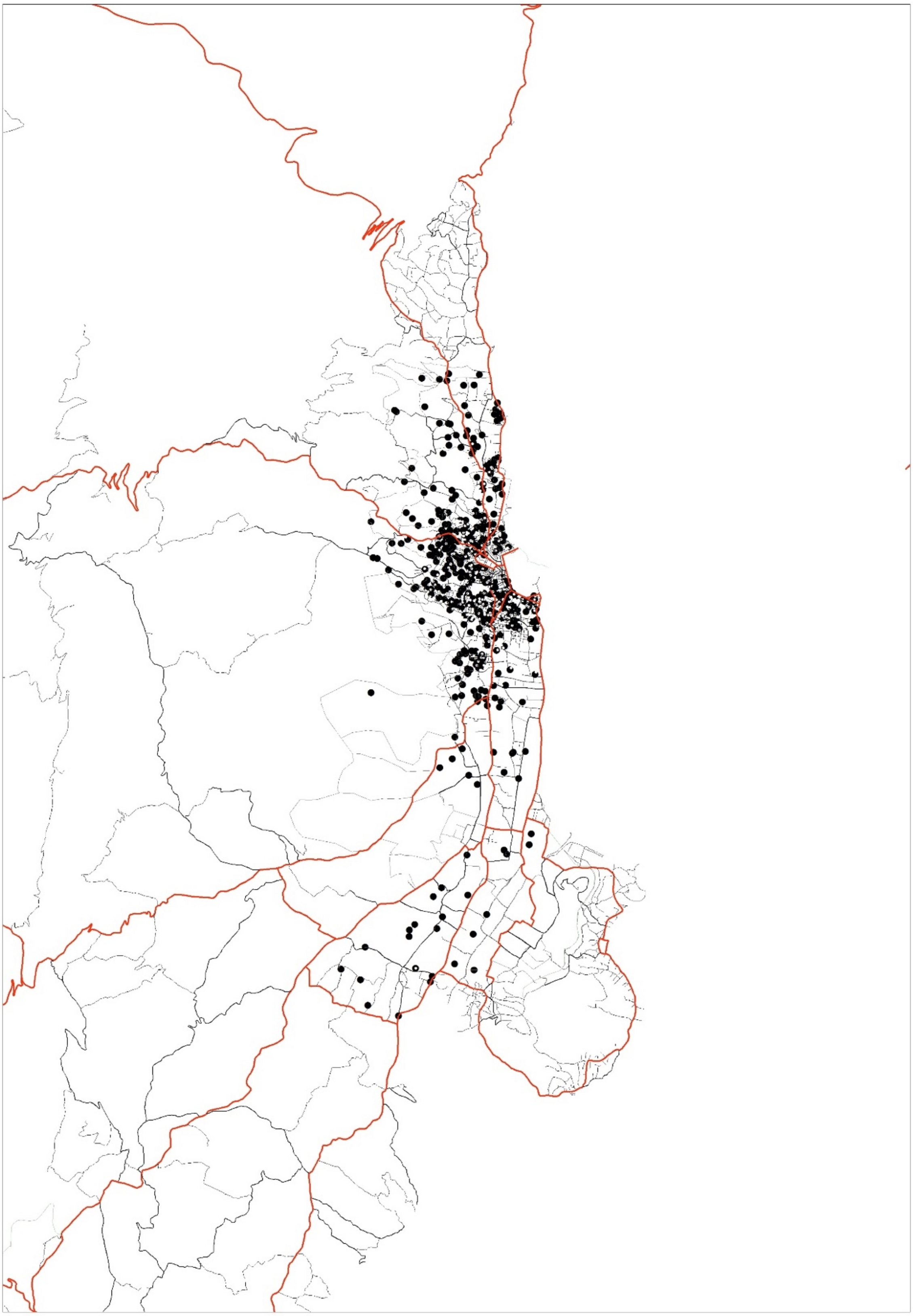


Figure 29 Part of Chios NETWORK (Red: Primary, Black: Secondary, Grey: Dirt Roads) with Surveyed Household locations

The process of network coding and editing continued with the specification of link types properties as shown in the figure below. Some of the properties are set by the geography of the network (length or distance from nodes). Other values were inserted for every link: Classification in a link type, v0 PrT, number of lanes, Capacity, name of the link, transport systems available (depends on the modes the user chooses to exist). Note that the transport systems availability are inserted two times for every link to specify cases of one-way links or one-way bike lanes. The other properties shown in Figure 30, are completed by the software after a simulation iteration takes place.

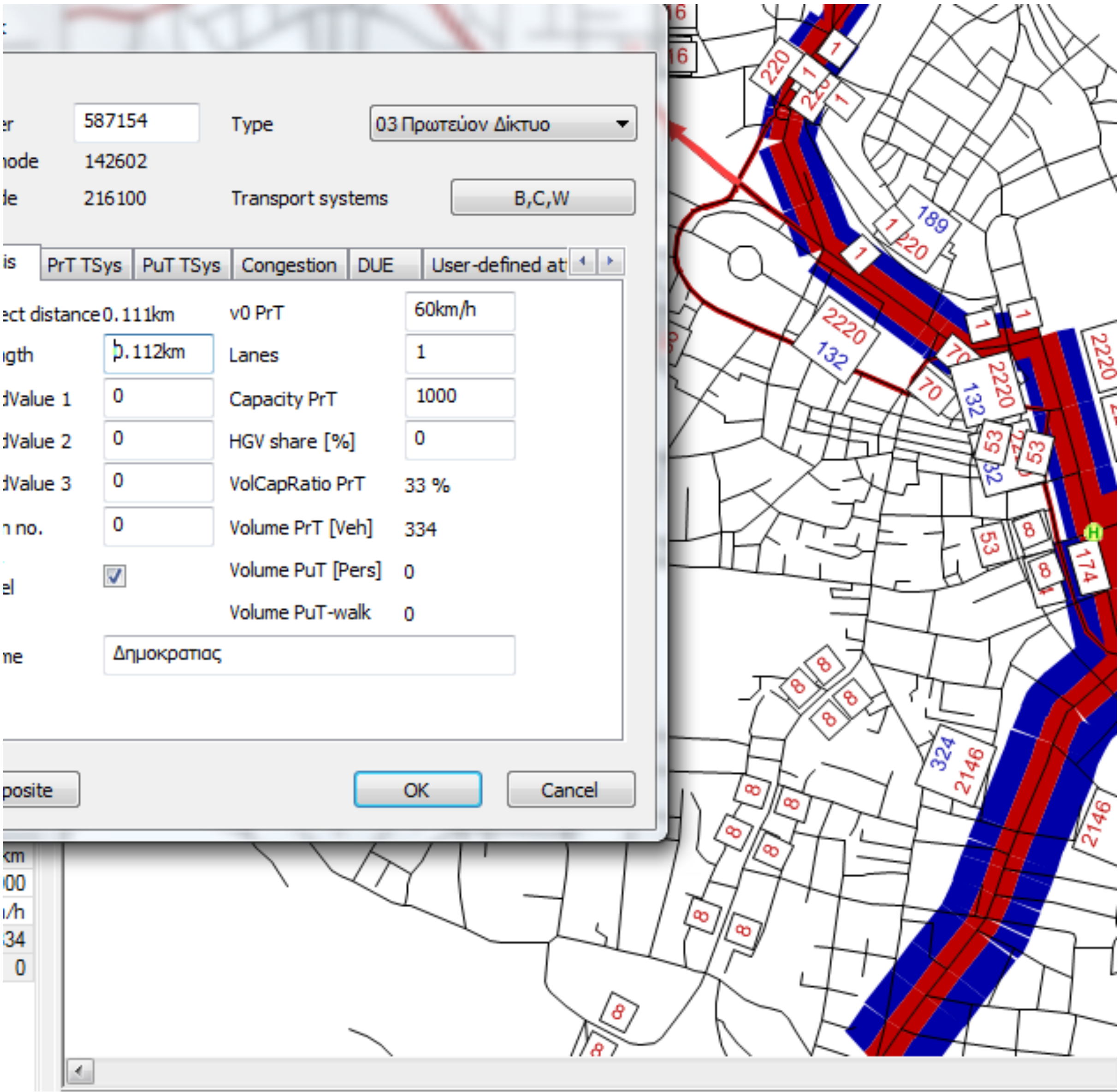


Figure 30 Link Type Properties

The activity diary survey showed clearly that there is a small portion of the population using public transport systems (buses) on the island. This fact and the decision to concentrate the simulation efforts on Chios town led to the deduction of buses as a transport system of the simulation. However, the researchers have available the whole bus network of the island, both urban and KTEL buses, lines, stations, timetables, and fares. The PuT (Public Transport) module of the simulation is fully working and available for future policy analysis and the local authorities of the island. Below is a screenshot of the network and the timetable:

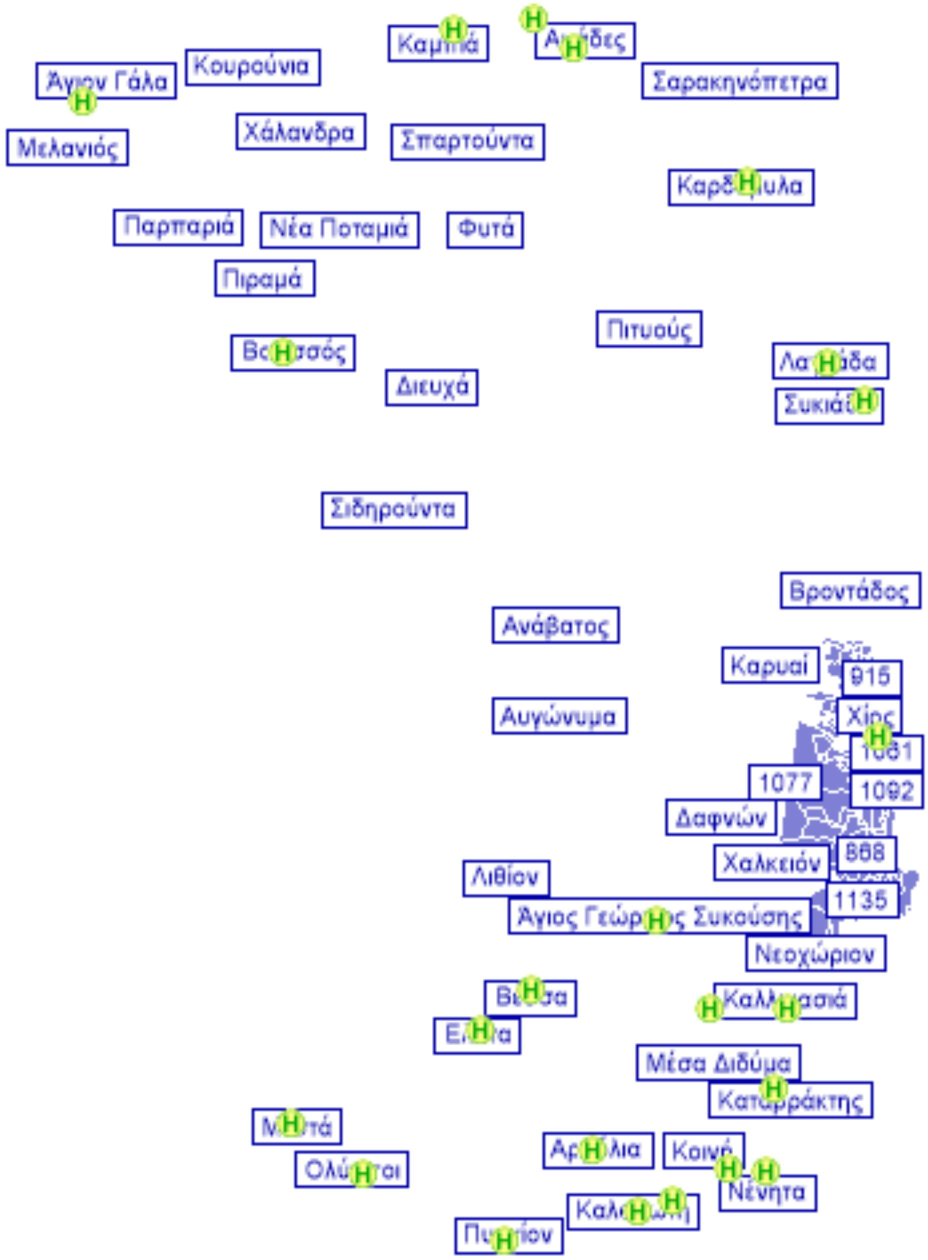


Figure 31 Bus Stops and Village Zones

5.4.2 Design and implementation of the simulation model

Introduction

The simulation was designed and run in PTV Visum software. It was decided to concentrate on a 4-step aggregate static model. The model will create the basic scenario which will be used to predict future flows and to test future policy scenarios. Inputs of the model include data from Greek Statistics Agency (1991, 2001 censuses and 2011 predictions), input from the satellite surveys of the thesis and input from the synthetically created population, both households, and individuals.

Trip generation

The first step of the modeling process is the calculation of productions and attractions for every zone in the network. This step's input is from the census of 2011 and the synthetically created population of the year 2011.

Trip Production

The trip rates methodology was used to calculate zone trip production. According to this methodology, individuals were separated into categories of specific socioeconomic characteristics and, for each category, trip rates were estimated based on the data available regarding the current situation in the study area. The rates represent the mobility of each category of individuals. The categorization and the rates are shown below.

Categories:

1. Gender: Female or Male
2. Age Category: Up to 18, 18 to 65, Over 65
3. Worker or non-worker

Rates:

Table 19 Trip rates

Trip rates	Worker			Non-Worker		
Age	<22	23-65	65+	<22	23-65	65+
Woman	3 (8 cases)	2.21	-	2.61	1.88	0.55
Man	4.44	2.35	1 (2 cases)	2.73	2.26	1.53

The next step was the creation of a specifically designed synthetic population, with different marginal for every zone. The challenge here was to identify joint marginal distributions, as the census does not include most of them. For example, the census would provide the number of men, workers and in the age category 1 for a certain zone but not the number of men, who work and are under 18 years old for this zone. This could be tackled with two different methods: Either by entering individual trips as a special variable in the synthetic population and using the sum for each zone or by gaining the joint marginal through the process of the synthetic population for each zone. The latter was chosen because, for the former, we would need an estimate of zone trips.
Using the joint marginal distributions from the synthetic population and the equation below, the trips for every zone were calculated:

$$Ti = \sum_{j} a_{ji}^{k} t_{j}^{k} k_{i}$$

a_{ji}^{k}: number of individuals in zone i with zonal characteristics k, which corresponds to trip rate category j.
t_{j}^{k}: trip rate for household category j in zones with characteristics k.
k_i : weight identified as total (census) / synthetic population. Used to correct the differences between the synthetic population totals and the true totals.
A total number of trips estimated for the study area for the base year 2017 is **45.499**. Trips for every zone are listed below:

Table 20 Generated Trips For Each Zone

Zone	**Trips**	**Zone**	**Trips**
1	1352	20	762
2	1193	21	1164
3	2557	22	1390
4	1056	23	1877
5	609	24	861

6	1274	25	945
7	1196	26	2653
8	1052	27	907
9	2170	28	1514
10	1346	29	1251
11	1992	30	1083
12	423	31	1364
13	850	32	777
14	1572	33	928
15	1470	34	593
16	6	35	1347
17	115	36	918
18	142	37	891
19	601	38	687

Trip distribution

For the trip distribution step, a dummy generalized cost function was used to aid the gravity model function. The particularities of the study area, such as the small travel distances between the zones or the absence of tolls and other on the way fees and expenses make the generalized cost function simple and straightforward:

$GC^{PrT} = D_i^j FuelKM + VoT\ TT_i^j$

The gravity model is formulated as follows:

$$Tij = \frac{Tripsi\ POIj\ ae^{(-\lambda GC)}}{\sum_k POIk\ ae^{(-\lambda GC)}}$$

Tripsi: Number of trips originating in zone i

Shopsj: Percentage of Points of Interest[1] *as buildings in zone j (weight of attraction)*

α,λ: parameters of the distribution model

Mode choice

The mode choice step used for this simulation is a binary choice logit model between Active and Motorized transport. The concept of the whole thesis leads us to create a mode choice survey containing innovative, active and green modes for the respondents to choose from. The modal split from the activity diaries is as follows:

[1] Google places were used as an estimator. It includes shops, places of interest, restaurants, workplaces, bars/cafes, public buildings, museums, etc.

Table 21 Modal Split

Mode	Percentage
Walking	35,9
Regular Bicycle	3,9
Other non-motorized	0,3
Private Car	38,1
Van/Mini-Van	0,9
Carpool	0,2
Motorcycle 50 and 125cc	7,1
Motorcycle >125 and <250 cc	8,8
Motorcycle >255 and <750 cc	1,9
Motorcycle >750 cc	0,5
Taxi	0,4
Boat	0,1
Other private	0,3
Urban Bus	1,2
KTEL	0,1
School Bus	0,3

As seen in Table above the three more popular modes are Car, Motorcycle, and Walking. The very low percentage of the Public Transport is a particularity of the study area (almost 1%). The Figure below depicts the four modes that are used in the mode choice module of this simulation. The bicycle was added because of the future scenarios testing bike lanes.

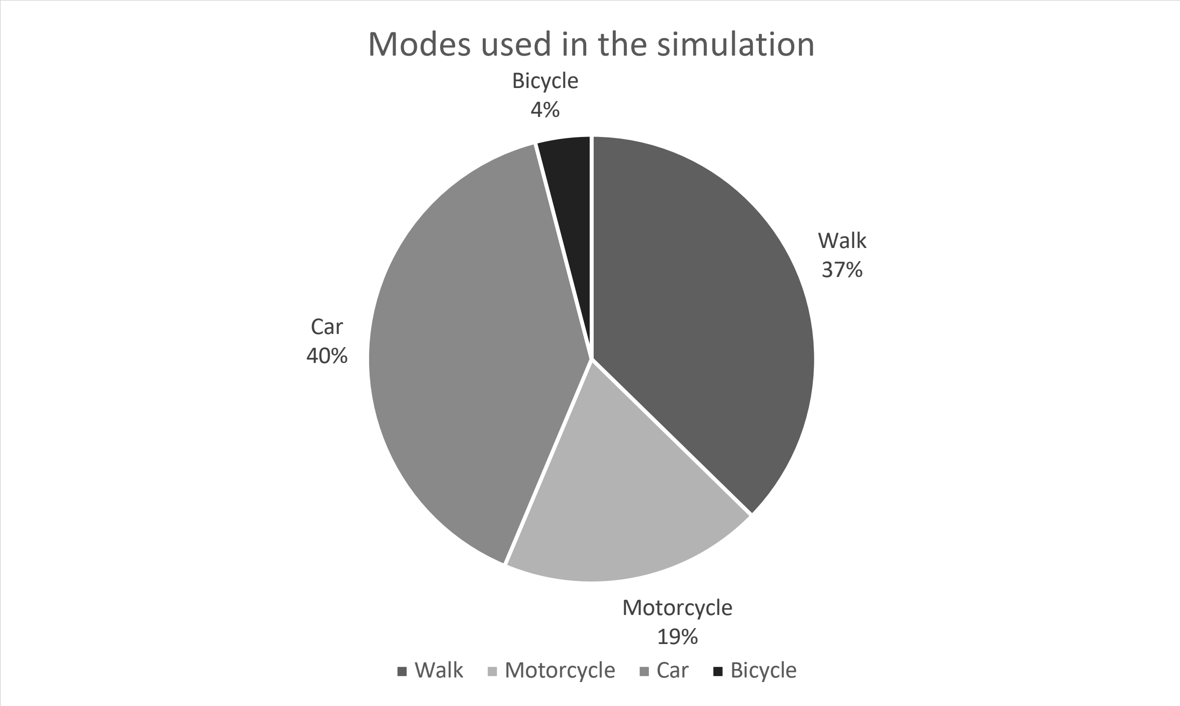


Figure 32 Modal split

The results from the mode choice model are shown in Table 22:

Table 22 Mode choice model results

Model:	Multinomial Logit
Number of estimated parameters:	4
Number of observations:	846
Number of individuals:	846
Null log-likelihood:	-586.403
Cte log-likelihood:	-586.317
Init log-likelihood:	-591.608
Final log-likelihood:	-186.297
Likelihood ratio test:	800.211
Rho-square:	0.682
Adjusted rho-square:	0.675
Final gradient norm:	+6.320e-003
Diagnostic:	Maximum number of iterations reached
Iterations:	1000
Run time:	00:06
Variance-covariance:	from analytical hessian
Sample file:	gretia_activity.dat

Name	Value	Std err	t-test	p-value	
ASC_Act	0.00	fixed			
ASC_Mot	-6.51	0.455	-14.30	0.00	
B_ActTT	-5.10	1.09	-2.90	0.00	
B_MotTT	-21.4	11.1	-1.93	0.04	

Id	Name	Availability	Specification
1	A1_Act	ActAv	ASC_Act * one + B_ActTT * ActiveTTSCALED
2	A2_Motoriz	MotAv	ASC_Mot * one + B_MotTT * MotTTSCALED

Travel time for active transport and motorized transport are allocated an alternative specific beta. On the case of active transport, it is lower, but this is not a straightforward indicator that the users of the network prefer active transport as the travel times for active transport be much higher than those of motorized.
The betas of the travel time coefficients are inserted into the 4-step model in VISUM. The mode choice part of the simulation software calculates modal preference taking into account the t0 for each different mode, the travel time betas, tCur (current iteration speed) and impedance for different links. The algorithm for the mode choice part of the simulation is described below:

1. Creation of skim matrices for all modes based on t0 of OD matrices
    a. t0 differs for every mode and every link type
    b. Motorized differs for main network, secondary network and tertiary network (dirt roads)
    c. Active differs in 3 levels depending on road width
2. Calculation of mode choice depending on the betas of travel time and the skim matrices
3. Check for restrictions on network imposed by different scenarios (one-way streets, pedestrianization)
4. Check for presence of bike lanes – If bike lanes are present in the scenario the impedance for this links for active modes changes
5. Repeat process for chosen interactions

Calibration
Simulation model results were calibrated using data from GreTIA traffic counts conducted during July and August 2012 in 10 points in Chios town and 7 points outside

of Chios town and by traffic counts conducted using pneumatic road tubes during January 2014.

Street	BAU Scenario VISUM	Traffic counts with researchers Summer 2012	Difference %	Traffic counts with tubes Winter 2014
Handakos	320	327	2,14%	
Iroon	223	201	-10,95%	
End of Aplotaria	140	160	12,50%	
Kountouriotou	479	520	7,88%	
Nautikos Omilos	56	66	15,15%	
Veriti	84	94	10,64%	
Airport	581		21,49%	740
Coastal Vrontados	243		-14,08%	213
Veriti 2	469		-7,82%	435
Chios - Chalkios	233		-18,88%	196
Frangomachalas	69		13,75%	80
Vrontados Interior	453		-7,09%	423
Aipos	44		-4,76%	42

The calibration reveals that most of the count points differ between 5 and 15% which is an acceptable difference because of the seasonality, the difference in aggregation (counts with tubes are aggregated result of a 24 hour, 10 day counts in a single day PCU, counts with researchers are 3 day, half an hour interval counts) and the static 4-step model.

5.5 Policy assesment

5.5.1 Simulation results

In this section, a part of the results derived from the plan evaluation will be presented and discussed

Table 23 Simulation scenario results

KPI/Scenario	BAU	2.1	2.2	2.3	2.4	3.1	3.2	3.3	4
ACTIVE TRANSPORT SPLIT	0.44	0.54	0.56	0.54	0.57	0.53	0.53	0.57	0.38
MOTORIZED TRANSPORT SPLIT	0.56	0.46	0.44	0.46	0.43	0.47	0.47	0.43	0.48
PUBLIC TRANSPORT SPLIT	0	0	0	0	0	0	0	0	0.14
PASSENGER KILOMETERS	349696.8	341761.6	353505.6	34336	354471.4	338817.6	339197.76	359757.12	342770
VEHICLE KILOMETERS	285700	288650	300600	290000	302450	285200	285520	306960	342770
– MEAN TRIP DURATION	6min 17 sec	6min 48 sec	6min 54 sec	6min 49 sec	7min 2 sec	6min 7 sec	6min 27 sec	7min 45 sec	12 min
– MEAN TRIP DISTANCE	3,67km	6,93 km	6.93	6.93	6.93	3.65 km	3.95 km	7.93	4.29 km
SHIFT TO ACTIVE		10% UP	12% UP	10% UP	13% UP	9% UP	9% UP	13% UP	6% DOWN

SHIFT TO MOTORIZED		10% DOWN	12% DOWN	10% DOWN	13% DOWN	9% DOWN	9% DOWN	13% DOWN	6% UP
ACCIDENTS	0.82	0.68	0.67	0.68	0.66	0.68	0.68	0.67	0.73

The initial comparison of BAU, 2.4, 3.3 and 4.1 scenarios reveals some interesting findings. It can be noticed that 2.4 and 3.3 are the extreme versions of Scenarios 2 and 3, meaning that all the bike lanes are implemented in 2.4, and the whole area of Chios city center is pedestrianized in 3.3. After noticing this fact, the difference in the various indicators presented in Table 23.

A first remark is the shift to active and motorized in the various scenarios. In the BAU scenario, motorized transport accounts for more than 50% of the modal split in the area. In both 2 and 3 Scenarios, active transport overtakes motorized as dominant mode. In the case of bike lanes with 55% and an impressive 11% rise from BAU scenario and the case of a pedestrian road with 51%. Scenario 4 drops the share of active transport, but it allocates a 14% share to public transport, which is non-existent in the BAU scenario.

Considering that overall trips do not change, at least in scenarios that have the base year population; it does change in the scenarios that run on forecasts, the travel times and distances are interesting to discuss. Scenario 3 is the only scenario that marginally reduces travel time and distance. This may be attributed to the shift of short distance trips in the central zones from motorized to active, thus avoiding congestion and parking finding delays. Scenario 4 longer travel times are attributed to the mode change in park and ride stations. Scenario 3 has the longer travel times. There can be two explanations for this: a) the overall shift to active transport which has longer travel times and b) the re-routing of motorized trips to longer routes to avoid the dedicated bike lanes in some of the busy links of the network. The differences between Scenarios 2 and 3 can also be attributed to the fact that Scenario 3 intervenes in the city center, while Scenario 2 extends its intervention to the city suburbs.

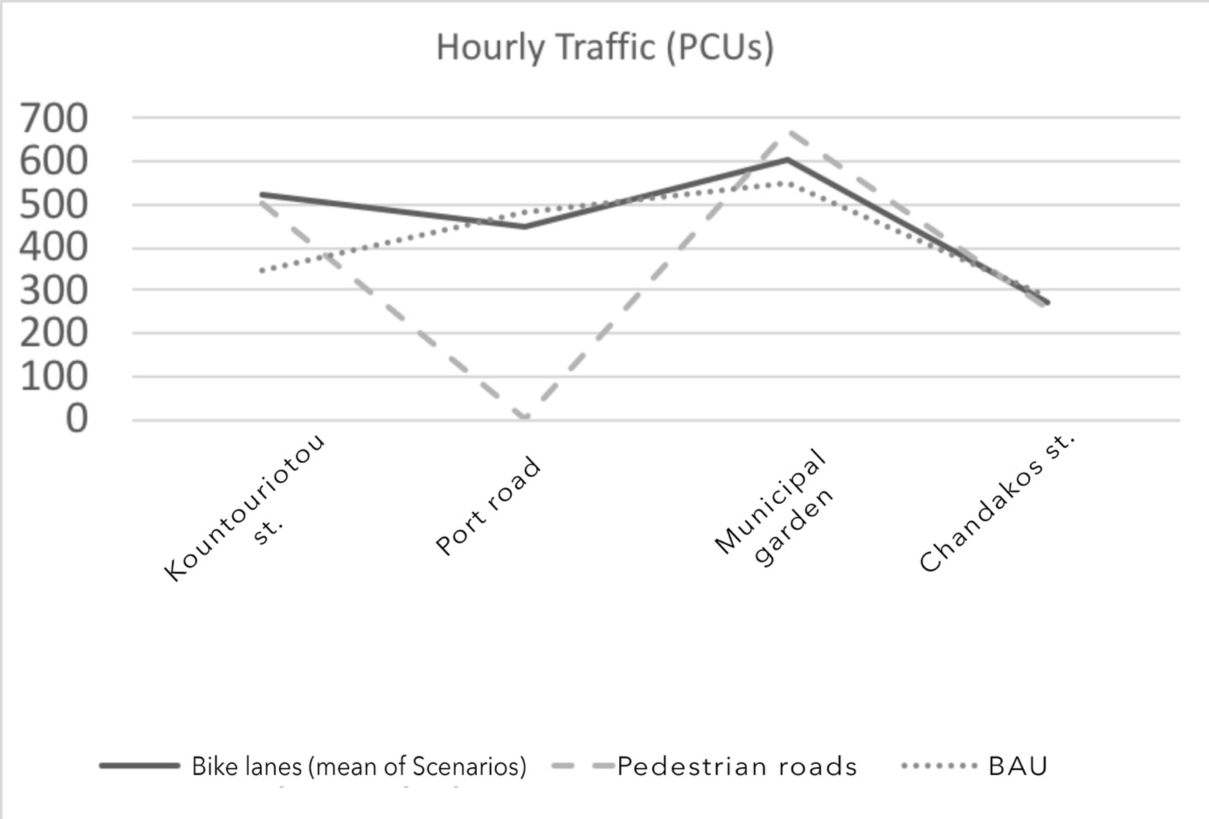


Figure 33 Traffic in various links/scenarios

The network simulation can provide hourly counts for every link in the network in every different scenario. This is an important aspect of the simulation model and the platform of the thesis, as it provides information to the decision makers such as the diversion of the traffic when a link closed to motorized modes or is allocated a bike lane and the extent of traffic congestion in high demand periods or forecasts. Figure 33 presents the different hourly traffic forecasts for Scenarios BAU,2.4 and 3.3 in four different links in the study area. The differences are in the ±200 PCUs in almost all four links and 3 scenarios, except for the case of the coastal/port road in Scenario 3, which of course is pedestrianized and has no motorized traffic. Scenario 3.3 also leads to a ~200 PCUs in the municipal garden road, a straight result of the pedestrianization of the routes in the city center. It must be noted that this does not lead to traffic congestion in the static model. Kountouriotou Street is affected by both 2.4 and 3.3 and has a higher hourly traffic than the basic scenario. Handakos street, on the other hand, seems to be mostly unaffected by the different scenarios.

5.5.2 Forecasts and Sensitivity Analysis

As an initial work of this chapter population, car ownership, and GDP forecasts were made for two future horizons. These forecasts seem to have a minimal effect on aggregate and disaggregate travel numbers such as a number of trips. For example, in the case of population growth, the average change of trips in some of the networks zones is ±1 trips. It was decided to use a sensitivity analysis, to analyze the effect a ±20% population change would have to the overall trip number of the network.

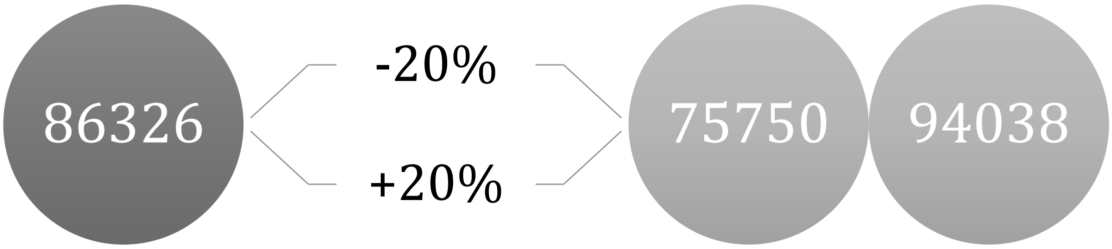


Figure 34 Overall trip change

As depicted in Figure 34 a 20% drop in the total population results in almost 11.000 fewer trips and a 20% rise in 9000 more.

Table 24 Synthetic population results

Zone	Synthetic population for 2015	-20%	+20%
Chios-1	657	541	773
Chios2	547	451	643
Chios-3	1269	1046	1492
Chios-4	687	566	808
Chios-5	317	261	373
Chios-6	635	523	747
Chios-7	805	663	947
Chios-8	660	544	776
Chios-9	1156	953	1359
Chios-10	692	570	814
Chios-11	1036	854	1218

Chios-12	230	190	270
Chios-13	405	334	476
Chios-14	752	620	884
Chios-15	751	619	883
Chios-16	30	25	35
Chios-17	49	40	58
Chios-18	17	14	20
Chios-19	324	267	381
Chios-20	378	312	444
Chios-21	545	449	641
Chios-22	892	735	1049
Chios-23	792	653	931
Chios-24	393	324	462
Chios-25	497	410	584
Chios-26	1168	963	1373
Chios-27	478	394	562
Chios-28	719	593	845
Chios-29	765	630	900
Chios-30	539	444	634
Chios-31	757	624	890
Chios-32	417	344	490
Chios-33	429	354	504

Chios-34	300	247	353
Chios-35	703	579	827
Chios-36	465	383	547
Chios-37	387	319	455
Chios-38	336	277	395
Chios-39	242	199	285
Chios-40	422	348	496
Chios-41	568	468	668
Total for Chios town	27211	23129	31293

This is anticipated as the trip generation module is based on population size. The rise in trips in the high population forecasts may lead to congestion in some links. For example, in Scenario 3.3/High Population links Tsouri and Kountouriotou depicted in Figure 35 are predicted to be congested, Kountouriotou has a 1400/hour and Tsouri 1000/hour traffic, which may be lower than the capacity but taking into account that this is a static model, the probability of the roads being congested during peak hours is high. Actual traffic counts in the area, which depict the temporal variance, can confirm this.

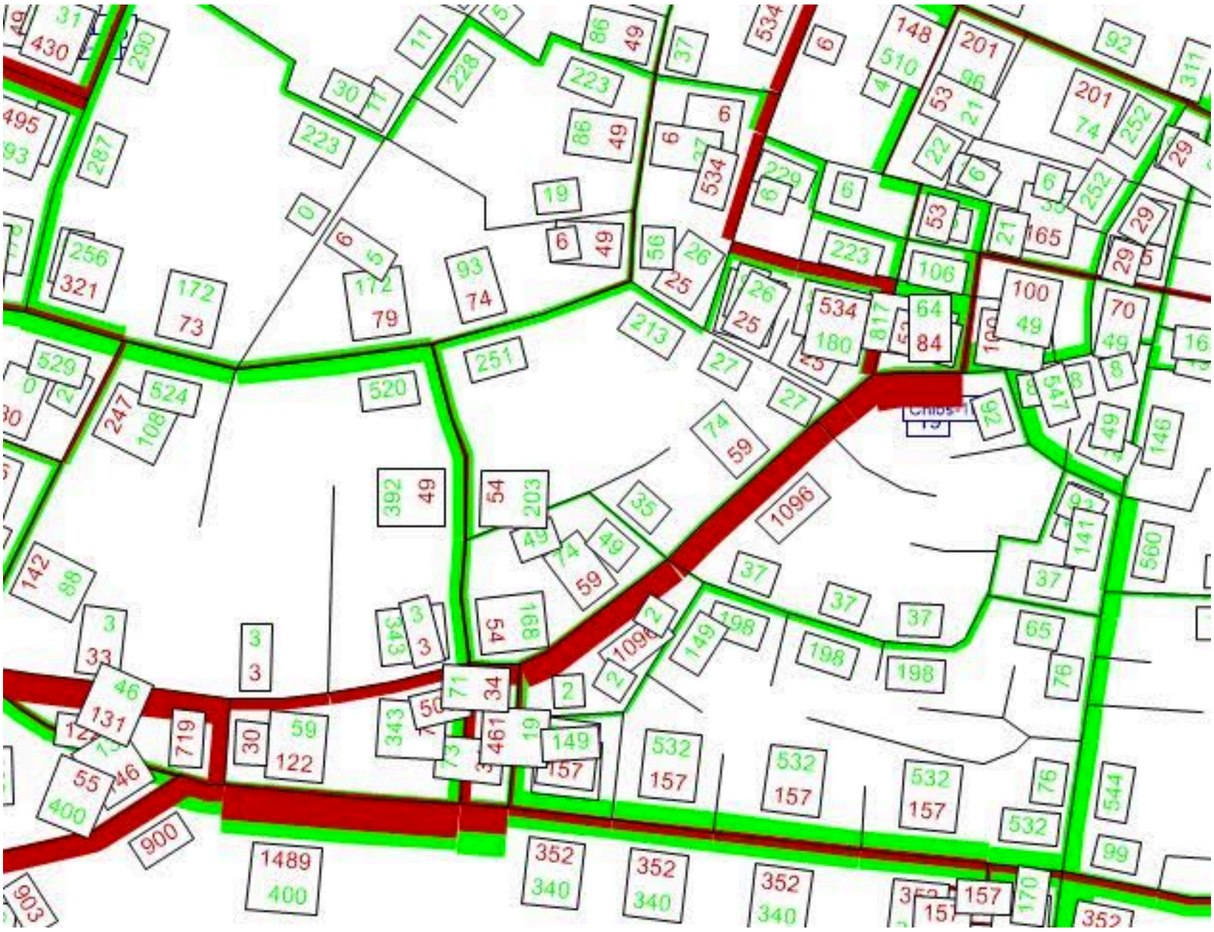


Figure 35 Snapshot of the simulation model results

Another type of forecast that is conducted has to do with the average daily expenses for fuel. This forecast is dependent on the presence of alternative fuel vehicles (AFVs) on the network. Using data from Chapter 6, more specifically from the hybrid choice model about an alternative vehicle purchase, Figure 36 depicts the average expenses for fuel in a daily basis on BAU and Green scenario (of the hybrid choice model, not of the simulation). This is further discussed in Chapter 6.

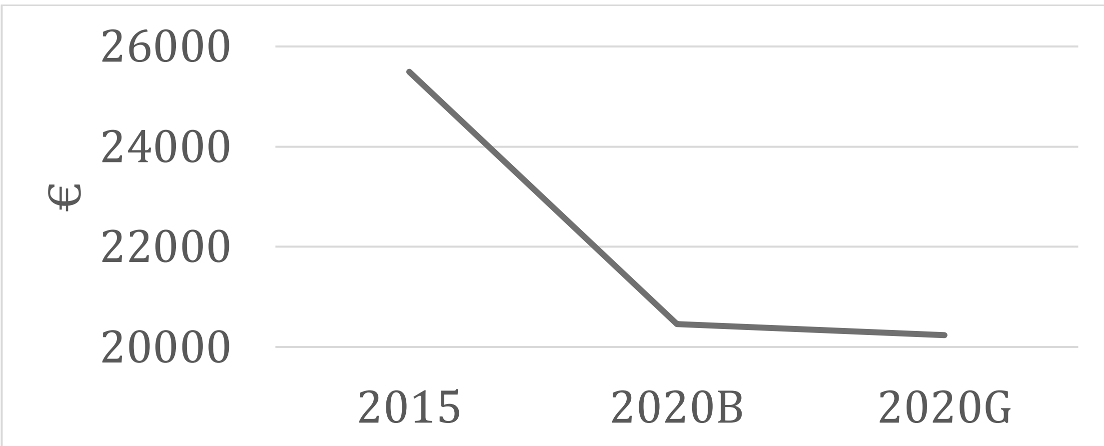


Figure 36 Future Fleet effects on fuel cost

The graph reveals two facts: The presence of AFVs in the network lowers the average daily fuel consumption about 5000 euros. Also, the difference between the two scenarios (described in Chapter 6) is smaller compared to the difference with the present situation.

5.6 Conclusions

This chapter attempts an exploratory analysis into the effect that green policy measures have on the overall network performance and the well-being of residents and tourists in the study area. Particular attention is given to sustainable transport solutions, such as the creation of bicycle lanes and the pedestrianization of certain links.

Chapter 5 initially provided an insight into how green transport is defined, what does it include and what solutions does it provide. This insight is useful because it defines the terms and sets the base for further discussion and evaluation of the effect various sustainable transport solutions have on the network. This analysis is done independently from the modeling analysis on other chapters but is aimed to be comparative to the future fleet purchase analysis to measure the effect that these different philosophies have on the overall well-being of the citizens.

The analysis initially provides information about the study area and the zoning system that is chosen for this analysis. The particularities of the study area, available secondary data, and primary data are presented. The final choice about zones was to regard the rural places of the island as three external zones (North, Central, and South Chios) and to focus on 41 internal zones in the center of Chios, where the adverse effects of transportation are more evident. The 41 internal zones are derived from over 500 mini-zones, resident blocks that are the more detailed level of secondary data available. The data for each zone is a synthesis based on secondary data from the census, primary data from over 1000 household and person interviews, GPS collected data, population and other data projections and the synthetic generation of households and persons to match the actual situation.

The analysis continues with the presentation of the 4-step model methodology that is used to assess the various, selected green policy measures. The creation of the transport network from scratch, the classification of different links, the integration of the zoning system and the introduction of the various means of transportation into the model are all part of the model formulation. The 4-step model is modified in two main ways from the traditional 4-step model. First, the trip generation model is formulated using synthetic population data to use the most recent data available and to guarantee the best model fit. Additionally, the trip distribution model uses Points of Interest as weighting factors, directly derived from Google places ensuring that each zone is allocated a specific weight factor that is derived through actual crowdsourcing, through the citizens' active actual preferences.

Results from the scenario assessment provide useful insight into the performance of the proposed measures. It is evident that in both the scenario groups of active transport, bike lanes and pedestrianization, the share of active transport in the modal split is significantly higher. This is an expected result. Also, other KPIs such as accidents or passenger kilometers (in some scenarios) return positive results. It is also evident that in some cases (especially in the bike lane scenarios) the passenger kilometers, the mean trip duration and distance rise compared to the base scenario. This is due to the various changes that a rise in active modes impose to the transport system. Impedance and skim matrices vary, different routing options are present (especially in the pedestrianization scenarios), and in every case bicycle and walking are slower modes than car and motorcycle. When assessing the various policy measures, one must weight benefits and sacrifices. In any case, promoting a more sustainable, safe and cleaner urban environment needs at least strong commitment by the public authorities and patience for longer travel times from the citizens

Chapter 6: Long-term tier - Fleet choice

6.1 Introduction

Alternative fuel vehicles (AFVs) and connected and automated vehicles (CAVs) are widely regarded as a more sustainable alternative to fossil fuel vehicles and as a response to the widespread externalities of transport especially CO2 emissions. However, the market penetration is not yet at a significant level. Apart from this, AFVs have gained controversial reviews, with public opinion often regarding them as unreliable, unnecessary or immature. Also, CAVs have a public opinion of an immature technology that is on the fringes of science fiction. Thus it is important to understand the relationship between the perceptions of individuals for vehicles and their willingness to purchase a vehicle.

Some studies, such as (Campbell et al., 2012; Jin et al., 2015; Larson et al., 2014), approach the subject of car purchase by measuring the effect of attitudes and perceptions. Other studies investigate the relationship between the willingness to buy an AFV and certain personality traits. Nordlund et.al. (Nordlund et al., 2016) in a recent article argue that different groups of car owners (conventional vehicles, AFVs, EVs) have different norms and set of values, with owners of AFVs being more open to change, less conservative and more aware of the external costs of transportation. This thesis addresses this topic by presenting an integrated modeling framework to explore future car purchase, especially AFV and CAV, based on certain personality traits. It describes a menu-based, modular approach to a car purchase, where the respondent can choose different levels of various attributes to construct their ideal vehicle. This method is distinct from the traditional stated preference experiments, in which ready products appear to the respondent. In this case, the respondent has the full choice set to choose from, with each attribute level having a price that sums up to the final vehicle price.

More specifically this thesis estimates a hybrid choice model to measure the effect that the pro-environmental attitudes the symbolic towards a car and the tech-friendly attitudes have on the future car purchase choice of the individuals. Results from the case study of the thesis reveal that using just a symbolic latent variable; we call it Exuberance, can lead to different results depending on the study area and lifestyle, and that using two or more latent variables can provide a further and more detailed investigation of future car purchase.

6.2 Methodology

This section describes the proposed methodological framework to study future car purchase. It initially presents the questionnaire design and implementation and then the modeling framework and related equations.

6.2.1 Survey Design

The "Future Car Purchase" survey was developed as part of the data collection effort conducted for the "Green Transport in Islands" in the Greek islands of Lesvos and Chios (2013-2015). The survey was carried out in parallel with other survey instruments that collected data regarding socio-economic characteristics, activity diaries, GPS traces, Stated Preferences experiments about mode choice and tourist destination choice, spending patterns and attitudinal data (see for more details(Tsouros et al., 2015a)).

The web survey presented the respondent with a menu-based approach. A "build-your-own" section was presented to each respondent in which he/she could choose between levels of different attributes such as engine size, car type, car edition and fuel type, actively constructing his/her ideal vehicle. Then, a price for the selection would appear on the screen, and the respondent had the opportunity to either accept the constructed vehicle and submit his/her choice or re-construct the vehicle from the beginning or by changing the levels of some attributes. Every different attribute level had a specific price for its selection which is visible to the respondent at all times.

This process is repeated two times for each respondent, one for each different future macroeconomic scenario. The two scenarios ask the respondent to imagine that the described circumstances will be the reality in 5 years from now. The initial scenario is the Business as Usual (BAU) scenario which predicts a continuing economic stagnation in Greece, with a similar situation in wages, GDP and unemployment, lower gas prices and similar emission taxes. The green scenario predicts a small growth in macroeconomic indicators, less unemployment, higher gas prices and higher taxes on emissions.
The menu-based approach can also be described as a modular approach, where the respondent can pick different modules to create the ideal vehicle. Table 25 presents the attributes and levels: engine and car size, fuel type and degree of automation.

Table 25 Alternative attribute variables (with variable name)

Engine Size (CC)	Car type	Fuel type	Car version	Degree of Automation
1000-1199 – CC1	Small city car – CS1	Regular gas – FT1	Basic version – CE1	No Automation – AT1
1200-1599 – CC2	Medium city car – CS2	Diesel – FT2	Comfort version – CE2	Function-Specific Automation – AT2
1600-1999 – CC3	Sedan – Family car – CS3	Hybrid – FT3	"Hi-Tech" version – CE3	Combined Function Automation – AT3
2000 – CC4	SUV – CS4	Electric – FT4	Sports version – CE4	Limited Self-Driving Automation – AT4
	Sports car – CS5	Natural gas – FT5	Full extra – CE5	Full Self-Driving Automation – AT5
	Pick-up truck – CS6		Luxury – CE6	

.

This survey design creates a large, exhaustive choice set: a full choice set. Every constructed alternative varies from another by at least one attribute level. The number of alternatives in the full choice set is 3600 (4x6x5x6x5). We coded the different alternatives starting from Alternative 1 in the following way:

Alternative1: ENGINESIZE1 (Engine Size) – CARSIZE1 (Car Type) – FUELTYPE1 (Fuel Type) – CAREDITION1 (Car Version) – AT1 (Degree of Automation)
Alternative2: ENGINESIZE1 (Engine Size) – CARSIZE1 (Car Type) – FUELTYPE1 (Fuel Type) – CAREDITION1 (Car Version) – AT2 (Degree of Automation)

…

Alternative3600: ENGINESIZE4 – CARSIZE6 – FUELTYPE5 – CAREDITION6 – AT5

Starting from Alternative1, AT starts from 1 and runs through 5 then CAREDITION runs from 1 to 6, then FT is set to 2, and again CAREDITION runs from one to 6, until FT is set to 5. Then CARSIZE is set to 2, and the whole process is repeated until ENGINESIZE is set to 4.

This is also the way the utilities are formed, for example:

$$V_4 = \beta_{CC1} * CC1 + \beta_{CS1} * CS1 + \beta_{FT1} * FT1 + \beta_{CE1} * CE1 + \beta_{AT4} * AT4 + \beta_{PRICE4} * PRICE4$$

This methodology creates 3600 different alternatives.

The case-study presented in this thesis includes only the following 4 attributes and has 720 different options. From the total of 720 utilities, only the 100 chosen by the respondents are used. The attributes used in the case study are engine size, car size, fuel type and car edition

6.2.2 Effect of latent traits

To understand the relationship of symbolic attitudes towards vehicle types we have to use a combination of latent variables. Table 26 presents the possible user types that the two latent variables can produce. The use of one latent variable may result in very different purchase choices. For example, a person who has exuberant attitudes towards vehicles could be a potential buyer of an AFV if they also have a pro-environmental stance, but could also be a regular, gasoline car buyer if they do not.

This hypothesis is going to be tested using the following modeling framework. The case study tests this by creating a latent variable called *Exuberance* which is similar to the definitions of symbolic view of vehicles that is found in the literature. The relationship of this latent variable with different cars, based on fuel type and car size differences will be able to verify the need for more than one latent variables to classify potential buyers of AFVs and CAVs. It must be noted that for CAVs a third variable measuring the "Tech-Savviness" of the individual may be used. Data from social media and the extensiveness of use, possession of gadgets, age, and occupation, can be utilized as input for the structural model of the "tech-adaptation" latent variable.

Table 26 Latent traits and user profiles

Latent Trait	Tech-Saviness: Yes			Tech-Saviness: No	
	Eco-friendliness			**Eco-friendliness**	
Exuberance		Yes	No	Yes	No
	Yes	Ecological conscious with symbolic view of vehicles and tech savvy – Prone to purchase both an AFV and a CAV	Indifferent about environment with symbolic view of vehicles – Prone to buy a large, gasoline fueled car or a CAV	Ecological conscious with symbolic view of vehicles – Inclining towards AFV	Indifferent about environment with symbolic view of vehicles – Prone to purchase a high, gasoline fueled car but no CAV
	No	Ecological conscious without symbolic view of vehicles – Bicycle user/ Non-motorist – May have a small chance to	Indifferent about environment with practical view of vehicles – Decides future vehicle purchase in a "rational" way, taking into account more practical attributes such as performance or price –	Ecological conscious without symbolic view of vehicles – Bicycle user/ Non-motorist	Indifferent about environment with practical view of vehicles – Decides future vehicle purchase in a "rational" way, taking into account

		purchase CAV	Because of tech savviness may be prone to buy a CAV		more practical attributes such as performance or price

6.2.3 Framework

Figure 37 presents the overall modeling framework. The three latent variables are structured from socio-demographic data such as gender, age, occupation, education, income, and possession of gadgets (such as a smartphone). They then are measured through indicators. Indicators are Likert scale attitudinal questions, *I1* to *I5* are used to measure *Exuberance* while *I6* to *I10* to measure *Eco-Friendliness* and *I11* to *I15* to *Tech-Savviness*. The various alternative attribute variables, the modules of constructing the ideal vehicle are inserted directly into the utility function of the alternatives, as well as, the latent variables. The goal of this framework is to measure the effect that each level of each attribute has on the car purchase choice and also to see how the latent variables affect the selection of specific vehicles. This framework will test our initial hypothesis that each combination of these three latent variables will influence the future purchase choice in a different way.

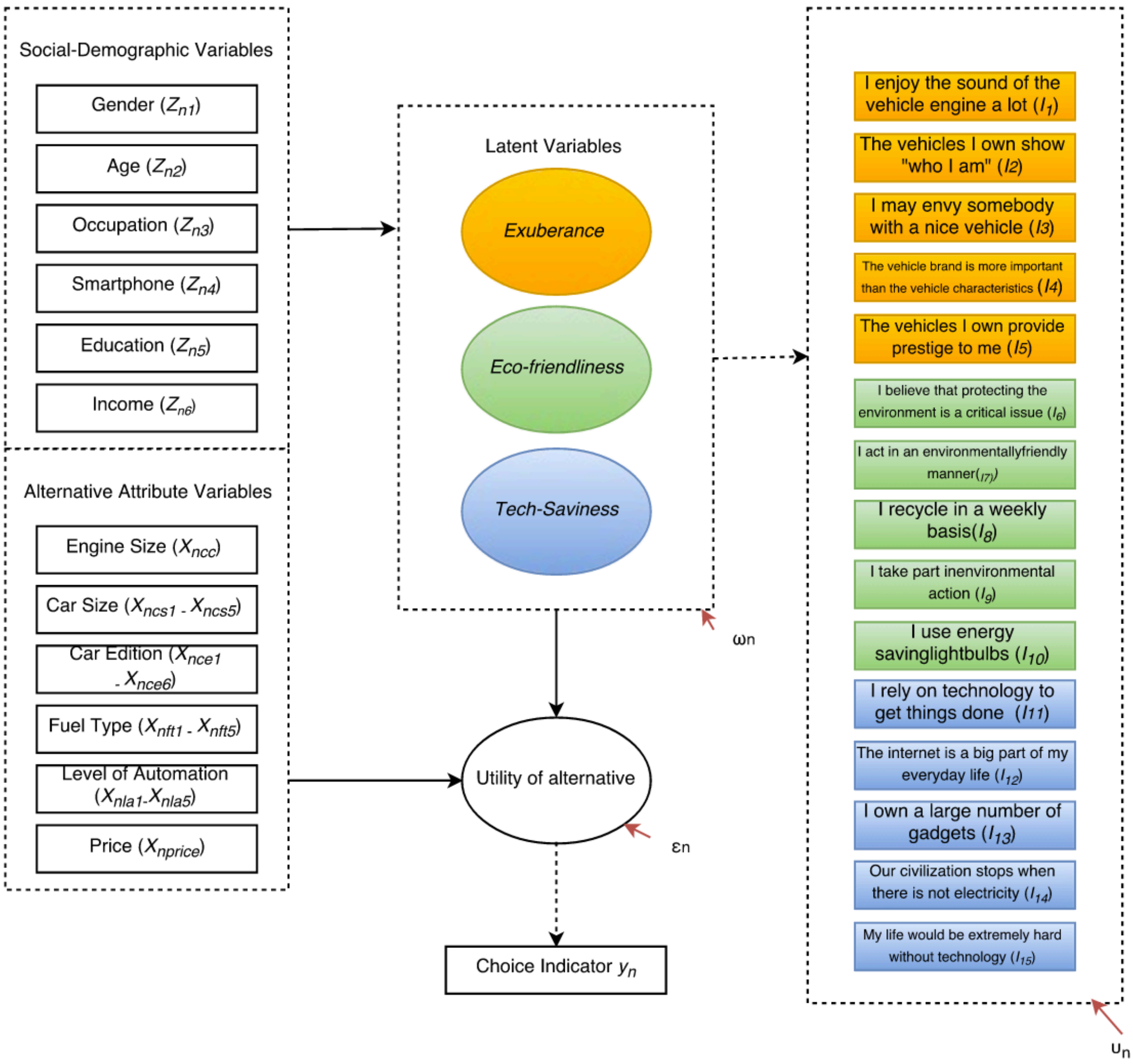


Figure 37 Modelling Framework

6.4 Descriptive statistics

6.4.1 Study Area

The island of Chios is described extensively in Chapter 3.

The island of Lesvos is also located in the Aegean Sea, north to Chios. It is the third-largest Greek island with a population of almost 86,000 one-third of which are located in the main town of Mytilene. There were 25,632 private owned vehicles on the island as per 2015. The effect of seasonality is high on both islands as the population tends to double during summer months, creating a very different transport demand situation. The presence of AFVs and CAVs is almost non-existent in both islands.

Table 27 Socio-Demographics

Socio-demographic characteristics n=515		
Characteristic	Category	Percentage
Age	18-30	42.9
	31-59	40.4
	60+	16.8
Gender	Female	51.3
	Male	48.7
Car License	Yes	79.0
	No	21.0
Motorcycle License	Yes	53.0
	No	47.0
Occupation	Employer	3.5
	Freelancer	12.9
	Employee	26.9
	Household/Housewife	8.8
	Unemployed	2.9
	Pensioner	11.1
	Student	20.5
	Not Stated	13.5
Education	No Education	3.7
	Elementary	5.6
	High School	13.7
	Lyceum	36.6
	IEK (~Community college)	9.9
	AEI (University)	24.5
	Master	4.3

Table 28 Indicator descriptive statistics

Indicators of Exuberance	**Mean**	**SD**
I_1 The vehicles I own show "who I am."	2,51	1,147
I_2 I may envy somebody with a nice vehicle	2,94	1,366
I_3 The vehicle brand is more important than the vehicle characteristics	2,83	1,231
I_4 The vehicles I own provide prestige to me	2,65	1,241

I_5 I enjoy the sound of the vehicle engine a lot	3,85	1,958
Indicators of Eco-Friendliness	**Mean**	**SD**
I_1 :I believe that protecting the environment is a critical issue	5.52	.963
I_2: I act in an environmentally friendly manner	4.66	1.073
I_3: I recycle in a weekly basis	4.21	1.511
I_4: I use my shopping bag, not those of the supermarkets	3.88	1.523
I_5: I use resources (energy, water, electricity) in a sustainable manner (wisely)	4.78	1.354
I_6: I walk or cycle to minimize my ecological footprint	3.79	1.804
I_7: I take part in environmental action (reforestation, cleaning of shores etc.)	3.66	1.587
I_8 : I use energy saving lightbulbs	5.07	1.414
I_9 : I use class A home appliances	5.03	1.377
Indicators of Tech-Saviness	**Mean**	**SD**
I_1 :I rely on technology to get things done	4.00	1.72
I_2: Internet is a big part of my everyday life	3.91	1.83
I_3: I own a large part of gadgets	3.85	2.03
I_4: Our civilization stops when there is no electricity	3.86	2.04
I_5: My life would be extremely hard without technology	4.02	2.02

6.5 Model results: LV Exuberance and LV Tech-Saviness

This section presents the results of the model and in particular, the results of the structural and measurement model of the *Exuberance* and *Tech-Saviness* latent variables and the choice model. The model that is presented in this section is a two-variable, HCM.

Table 29 Structural model results

Variable name: Exuberance	**b**	**t-stat**
mean	3.83	43.61
Age (>65)	0.038	2.86
Female	-0.005	-0.23
Has Smartphone	0.02	1.85
Graduate Degree	0.099	1.98
Has motorcycle license	0.137	2.47
sigma	-0.252	-2.82
Variable name: Tech-Saviness	**b**	**t-stat**
mean	7.72	18.02
Education level: University and higher	0.82	7.46
Age (as continuous variable)	-0.28	-5.725
Number of cars in the household	0.40	1.552
Occupation: Private Employee	0.254	1.92
Occupation: Freelancer	0.410	2.72
sigma	-0.340	-3.01

Table 29 presents the results of the structural model of the latent variables. As can be viewed from these results, older age, higher education motorcycle license holders are more likely to have symbolic attitudes towards vehicles. Also, owning a smartphone has a positive sign and gender is not statistically significant, contrary to literature findings that mostly find men having strong symbolic links to vehicles and woman tending towards more practical ones. Working as a freelancer or private employee, being younger, and having higher education are the variables that are statistically significant in the structural equation model of the Tech-Saviness LV. Number of cars does not seem to be a statistically significant variable.

Table 30 Measurement model results

Exuberance			Tech-Saviness		
Variable name	**B**	**t-stat**	**Variable name**	**B**	**t-stat**
a1			aa1		
a2	-13.4	-3.68	aa2	-22.2	-4.42
a3	-12.4	-2.37	aa3	-10.9	-5.20
a4	-5.17	-2.27	aa4	-9.01	-4.20
a5	-13.8	-1.78	aa5	-2.82	-4.12
I enjoy the sound of the vehicle engine a lot			I rely on technology to get things done		
The vehicles I own show "who I am."	4.12	2.82	Internet is a big part of my everyday life	1.94	8.42
I may envy somebody with a nice vehicle	3.98	2.82	I own a large part of gadgets	0.72	10.92
The vehicle brand is more important than the vehicle characteristics	2.08	2.75	Our civilization stops when there is no electricity	4.90	7.40
The vehicles I own provide prestige to me	4.26	2.81	My life would be extremely hard without technology	3.12	2.80
s11	1.94	32.03	ss1	0.33	40.02
s12	-0.916	-13.70	ss2	-0.54	-28.90
s13	-1.11	-27.15	ss3	0.74	-18.78
s14	-0.603	-31.23	ss4	0.87	-24.20
s15	-0.467	-19.38	ss5	-0.58	-12.12

Table 30 presents the results of the measurement model.

Table 31 Choice model results

Variable Name	B	t-stat
β_{CC1}	5.71	2.07
β_{CC2}	6.96	2.20
β_{CS2}	5.58	7.20
$\beta_{CSOTHER}$	4.12	8.81
β_{FTGAS}	8.24	5.54
$\beta_{FTHYBRID}$	6.77	6.44
β_{CE2}	6.35	6.34
$\beta_{CEOTHER}$	1.84	8.26
β_{price}	-2.05	-9.23
$\gamma\,\boldsymbol{Exuberance1}$ *(specific to alternatives with hybrid fuel)*	-0.281	-3.68
$\gamma\,\boldsymbol{Exuberance2}$ *(specific to alternatives with engine size larger than 1600CC)*	0.175	2.89
γTechSaviness (specific to alternatives with Automation levels 4 or 5)	4.12	8.20
rho-square-bar	0.584	
Draws	10,000	

Table 31 presents the results of the choice model. The second level of engine size attribute (sizes from 1200 to 1599 CC) seems to be the preferable among respondents, followed by the small-sized engines and leaving the larger sizes last. The second tier of car size is preferred (a medium sized city car), all the larger sizes than that come second in preference and small sized city car last. When considering fuel type, gasoline is the preferred one, followed by hybrid and leaving diesel, electric and natural gas as third options. Comfort version of car edition (a level up from the basic one) is the preferred car edition, followed by all other, more expensive editions which are preferred to basic edition.

The latent variable *Exuberance* negatively affects the choice to buy a hybrid fueled vehicle. This relationship means that respondents holding symbolic attitudes towards vehicles do not prefer hybrid fueled cars as a purchase choice. Also, the latent variable positively affects the choice to buy a product with more than 1600 CC engine size.

The latent variable *Tech-Saviness* positively affects the purchase of vehicles that have higher or highest automation levels, levels 4 or 5. This is a well-expected result as people that are more technology friendly and adapted are expected to have a more positive attitude towards automated vehicles and be more familiar with the idea of purchasing one.

6.6 Model results: LV Environmental Consciousness

We hypothesize that the latent variable has a significant effect on the choice of vehicle purchase and more specifically, that it strongly affects the choice of Hybrid and Electric vehicle and may also have an effect, in a subtle way, on the choice of Natural Gas or Diesel vehicle, capturing the effect of making a shift from traditional (over 95% of the study area) Gasoline vehicles. It is also expected to affect negatively, the purchase of Gasoline vehicles.

The overall utility of choice is a function of socio-demographic characteristics, alternative attributes, and the latent variable. The effect of the vehicle price is measured with alternative specific betas.

The equation for the choice model is presented below:

V1 = ASC_GAS * one + B_COSTG * GAS_COST_SCALED + B_GasCC1 * GasCC1 + B_StudentG * Student + B_FreelancerG * Freelancer + B_LastYearBuyG * LastYearBuy + ε_{gas}

V2 = ASC_DSL * one + B_COSTD * DSL_COST_SCALED + B_DieselCC4 * DieselCC4 + B_Cars * Cars + ε_{dsl}

V3 = ASC_HYBR * one + B_COSTH * HYBR_COST_SCALED + B_hybridCC4 * hybridCC4 + B_FreelancerH * Freelancer + B_StudentH * Student + B_IncHigh * IncomeHigh + G_ECOF_HYB * EcoF + ε_{hyb}

V4 = ASC_EL * one + B_COSTE * EL_COST_SCALED + B_Educ8 * Education8 + B_IncLow * IncomeLow + G_ECOF_EL * EcoF + ε_{el}

V5 = ASC_NG * one + B_COSTN * NG_COST_SCALED + B_NatGasCC2 * NatGasCC2 + B_NatGasEdition3 * NatGasEdition3 + ε_{ng}

EcoF = *θEcoF + θGender * Men + θAge * Ageunder30 + θPensioner * Pensioner + θEduc * Lyceum +θStudent * Student+ θEmployee * Employee+ωEcoF*

Table 32 contains the description of the variables used:

Table 32 Variable description

Variable name	**Variable description**
DSL_COST_SCALED	Cost of diesel alternative in the experiment divided by 1000
DieselCC4	Dummy variable taking the value 1 if Diesel engine in the experiment is over 2000 cc
Cars	Continuous variable indicating number of cars in the household
EL_COST_SCALED	Cost of electric alternative in the experiment divided by 1000
Education8	Dummy variable taking the value 1 if the respondent holds a Master's degree
IncomeLow	Dummy variable taking the value 1 if the respondent has a lower than 10000 yearly income
GAS_COST_SCALED	Cost of gas alternative in the experiment divided by 1000
GasCC1	Dummy variable taking the value 1 if Gas engine in the experiment is between 1000 and 1199 cc
Student	Dummy variable taking the value 1 if the respondent is a student
Freelancer	Dummy variable taking the value 1 if the respondent is a freelancer
HYBR_COST_SCALED	Cost of hybrid alternative in the experiment divided by 1000
HybridCC4	Dummy variable taking the value 1 if Hybrid engine in the experiment is over 2000 cc
IncomeHigh	Dummy variable taking the value 1 if the respondent has a lower than 10000 yearly income
LastYearBuy	Dummy variable taking the value 1 if the respondent has bought a car during the 2 previous years
NatGasCC2	Dummy variable taking the value 1 if Natural Gas engine in the experiment is between 1200 and 1599 cc
Variable name	**Variable description**

NatGasEdition3	Dummy variable taking the value 1 if Natural Gas edition in the experiment is “Hi-Tech” version
EcoF	Latent variable
Men	Dummy variable taking the value 1 if the respondent is a man
Ageunder30	Dummy variable taking the value 1 if the respondent is aged under 30
Pensioner	Dummy variable taking the value 1 if the respondent is a pensioner
Lyceum	Dummy variable taking the value 1 if the respondent is a lyceum (high school), graduate
Employee	Dummy variable taking the value 1 if the respondent is an employee

Vehicle choice model

The vehicle choice model was estimated in pythonbiogeme (Bierlaire, M. 2003) software. The model was estimated as a multinomial logit model (MNL), and then it was enriched with the presence of a latent variable, as discussed earlier. Separate results for the two models are presented in Table 33.

Table 33 Model estimation results

Results	**MNL Model**		**MNL with latent variable**	
	Coef.	**t-stat.**	**Coef.**	**t-stat.**
ASC_DSL	-1.58	-0.62	0.0394	0.05
ASC_EL	-1.30	-0.44	-1.30	-0.54
ASC_GAS	-3.10	-1.25	-0.580	-0.45
ASC_HYBR	1.36	0.55	-4.30	-1.98
ASC_NG	0.00	(fixed)	0.00	(fixed)
B_COSTD	-0.746	-4.84	-0.507	-4.08
B_COSTE	-0.786	-3.96	-0.427	-3.08
B_COSTG	-0.509	-4.01	-0.415	-3.344
B_COSTH	-0.688	-4.51	-0.226	-2.65
B_COSTN	-0.934	-4.26	-0.543	-3.29
B_Cars	1.05	2.26	0.755	1.94
B_DieselCC4	3.18	1.88	-0.251	-0.17

B_Educ8	3.27	2.52	2.87	2.55
B_FreelancerG	-2.28	-2.88	-1.09	-1.72
B_FreelancerH	-5.19	-3.99	-2.80	-2.67
B_GasCC1	1.40	2.16	0.815	1.42
B_IncHigh	-2.89	-2.60	-	-
B_IncLow	-4.75	-0.21	-	-
Results	**MNL Model**		**MNL with latent variable**	
	Coef.	**t-stat.**	**Coef.**	**t-stat.**
B_NatGasCC2	1.63	1.75	1.33	1.73
B_NatGasEdition3	2.47	2.35	0.869	0.96
B_StudentG	-2.69	-3.09	-1.35	-2.07
B_StudentH	-2.94	-3.07	-	-
B_hybridCC4	17.6	0.72	-	-
B_LastYearG	-	-	-2.49	-2.64
EcoF (specific to Hybrid)	-	-	0.585	2.21
Observations	206		206	
ρ squared	0.493		0.552	

Table 34 Structural and Measurement model

Structural Model		
	Coeffi-cient	t-stat
ϑ_{EcoF}	3.71	16.61
Men	-0.589	-3.12
Ageunder30	1.09	4.90
Employee	-0.952	-3.99
Lyceum (HighSchool)	0.963	3.04
Pensioner	-0.924	-2.83
Student	-1.39	-5.07
σ_{EcoF}	1.16	12.42
Measurement Model		
	Coeffi-cient	t-stat
α1	3.59	0.178
α2	1.98	0.214
α3	1.96	0.198

α7	0	-
α8	2.13	0.285
λ1	0.714	12.89
λ2	0.783	13.23
λ3	0.611	12.48
λ7	1	-
λ8	0.874	11.12
σ1	0.615	16.11
σ2	0.526	10.54
σ3	1.38	18.87
σ7	1.19	17.06
σ8	1.05	17.26

Results of the MNL model reveal that when the coefficient for natural gas is fixed, all other coefficients, but the ones for hybrid, are negative. Natural gas has the higher sensitivity to price, slightly larger than electric, diesel, and hybrid in that order. Gasoline has the lower sensitivity to price. This result was expected as the survey was designed to add extra cost for the adaptation of an alternative fuel vehicle, in order to simulate the actual condition in the market (even diesel cars or the cost of transforming a car to run on natural gas are more expensive than regular gasoline cars in Greece).

Large engine cars (over 2000cc) are preferred in the cases of hybrid and diesel fuel type, which agrees with the relevant literature. In the case of natural gas, medium sized cars are preferred while the presence of a small engine car in the task, positively affects the choice of a gasoline car. It must be noted that a small engine car with a gasoline engine is the less expensive alternative for a respondent. Natural gas "hi-tech" edition was found to affect the choice positively. This result can be explained by looking at the descriptive statistics of the sample: most the respondents that chose a "hi-tech" version of a car in the BYO task, were older than 50 years. The association of a less expensive and well-known alternative to gasoline may be the reason that seniors choose the hi-tech version of natural gas. However, a dummy variable of older ages, despite its positive coefficient, was not found to be statistically significant and thus, was not incorporated into the model.

Socio-demographically wise: Lower income negatively affects the choice of an electric vehicle, which is to the relevant literature. Individuals with higher income, are the ones considering purchasing an electric vehicle. Students avoid hybrid and gasoline choices (with similar negative coefficients), but, young individuals of higher income,

prefer a hybrid, also in agreement with the literature. Freelancers avoid gasoline alternatives, something expected from the literature review, but also avoid (and even with a higher negative coefficient) the hybrid choice. This was an unexpected result, which could be attributed to the higher percentages of freelancers, aged older than 40 in the sample. Finally, the presence of more cars in the household seems to affect the purchase of a diesel car positively. This may indicate a tendency of "car lovers" to select a different (but not so "green") alternative to gasoline, or large families to choose another less expensive but "safe" alternative to gasoline.
The model with the latent variable shows an improvement on the overall fit of the MNL. In this model, with the natural gas coefficient fixed again, the only positive coefficient is the diesel. The hybrid coefficient, probably through the influence of the latent variable, becomes negative. Most of the variables have the same effect as before. The latent variable *EcoF* positively affects the choice of a hybrid fueled vehicle and is statistically significant. This is the only alternative that *EcoF* variable has a statistically significant effect.
Table 34 presents the structural and measurement model results. Structural model variables are all statistically significant and have the expected sign. The negative influence of the variable Student, indicating either a university or a high school student was not expected, but the overall sample (not only the one used for this model) contains mixed student attitudes about environmental consciousness. People aged under 30 and that have at least obtained a high school degree are positive towards environmental friendly attitudes, by the literature. This model also reveals that women are more positively inclined to eco-friendliness than men. Pensioners and employees are not considered eco-conscious. Measurement model results are statistically significant and with the expected sign.
To verify that the model's identification, a sufficient number of draws have been used to reduce possible bias. 5000 draws were used in order to ascertain the stability of the parameter estimates.

6.7 Findings and discussion

This chapter proposed an integrated framework to model future car purchase of a conventional vehicle, an AFV or a CAV using three latent variables to account for behavioral heterogeneity, latent personality traits that affect the purchase decision. It did that by presenting a modular/menu based approach to the survey respondents. To our knowledge, this is the first study that attempts such an investigation using a full choice set, presenting the respondents with a menu style choice experiment where they can construct their ideal vehicle based on different levels of different attributes.

The chapter tested the methodology by designing and implementing a hybrid choice model in a case study of the Greek islands of Chios and Lesvos. The results of the applied methodology include classification of these levels. Medium sized city cars, with an engine size in the range from 1200 to 1600 CC, gas fueled and a level up from basic edition are the most popular vehicles according to the choice model. These are the levels that have the higher coefficients of the model. Of course, the price of the constructed vehicle has a negative effect on the choice. The effect of the latent variable, which reflects the symbolic attitudes towards cars, is negative on the choice to purchase a hybrid vehicle and positive on the choice to buy a car with a large engine.

The results about the effect of symbolic attitudes and perception on the willingness to purchase an alternative fuel vehicle are in accordance with some of the existing literature and disagree with another part. In a considerable number of the thesis, the high symbolic view of cars (as opposed to the practical view) is associated with the willingness to purchase an alternative fueled car. In this narrative, a person can see themselves as having a particular identity (green, environmentally friendly, tech/gadget person) that will regard the purchased vehicle as something innovative, different from the standard, even anti-conformist in some cases. However, it seems that in this thesis's case, the people who idolize the cars are not willing to purchase a hybrid vehicle. The latter could be explained by creating another narrative that says that people who perceive their car as a symbol (an indicator of power or prestige) and love non-practical aspects of the car (engine sound) are more prone to buying a "strong" gasoline car than a "soft" alternative fueled vehicle.

This confirms the hypothesis that more than one latent variable is needed to understand the different potential buyer's profiles consistently (see proposed profiles in Table 2).

Consequently, it could be said that assessing the effect of the symbolic on the choice may not be enough, as the symbolic as a general concept could be interpreted in different ways by individuals. It could even not have a consistent "behavior" across countries, lifestyles, and datasets. This could be avoided by using other indicators, jointly with the symbolic ones. For example, a latent variable modeling the ecological consciousness could add more useful meaning to analysis, eco-conscious and symbolic viewers could be associated with AFV more strongly. Results are useful for both policymakers – which can identify potential adopters of AFVs and CAVs based on attitudinal data (which can now be easily harvested through OSN) but also for industry.

Policy implications of the results include the realization that an integrated bundle of policies towards environmental awareness may tackle many issues at the same time. Individuals in the survey with strong attitudes towards the protection of the environment also tend to recycle frequently, to assist in forest fire protection or to clean up the beaches, to use sustainable home appliances and therefore, would rather prefer driving a hybrid. Also, information on new fuel types may be critical for their acceptance. With an almost, non-existing fleet of hybrid or electric vehicles on the island, very few people have had actual tangible experience with one of them. That is the reason, the elder part of the sample, choose natural gas as an alternative fuel, for being more "accessible" in their everyday lives.

Opportunities for future research include a more precise investigation of family interaction and the dynamics of joint household decisions. The family interaction could also shed more light on the effect of symbolic vs. practical attitudes and the effect they have on the final purchase decision. A more complete and in-depth definition of the Symbolic and the Practical could untangle the various interpretations of different researchers.

This chapter does not include any attribute related to vehicle autonomy, driving range or refueling stations. This happened for two reasons: First, the respondents are not so familiar with alternative fuel technologies, and we feared that adding more attributes (especially range and refuel that make most of the respondents in other parts of the world anxious) would turn the respondents towards gas or diesel. The second reason is that the mean travel distance in the main town of the island (main study area) is less than 5km, which makes vehicles with even a small driving range ideal and the need for refueling stations (other than home ones) secondary.

The survey includes two other bundles of vehicle choice, one for motorcycles and one for bicycles. The association of the latent variable may not be so strong with the purchase of a hybrid, because the environmentally conscious individual may choose to purchase a bicycle or walk, instead of buying a car. This is related to other latent or non-latent characteristics of the individual, such as fitness condition, distance to work or concept of the symbolic use of the vehicles and could be further discussed in another paper. An initial latent class analysis revealed a correlation between the environmental conscious individuals and the purchase of bicycles. A nested logit model structure, with the latent variable affecting different nodes, may be the right approach to tackle this issue in further research.

Chapter 7: The platform

7.1 Introduction

The final product of the policy tool, the platform is developed to be user-friendly and not to require specialized knowledge or specialization to be operated. The platform is designed to fulfill the user needs, whether the user is a person working in a public authority or a decision maker, or the user is a citizen who would like to gain more insight on the policy measures that affect his life. The front end of the platform is developed in JavaScript while the back-end is an SQL database containing all the necessary data that the platform needs to run.

As can seen in Figure 2, the platform GUI (Graphic User Interface) is divided into different result screens, control buttons, and text. The first screen is the KPI list. This screen shows the product of the KPI evaluation for each selected policy scenario. There is a list of 20 KPIs, whose value changes with every different scenario. Apart from the KPI number and name, a short description and units of measurement are shown on the screen.

The second screen is the Scenario Control screen. In this screen, the user can browse between the possible scenarios and sub-scenarios and pick one to reveal results and to explore options and controls further. There are a BAU (business as usual) scenario and two other main scenarios, bike lane construction scenarios (different routes as sub-scenarios and a super scenario with all available routes) and pedestrianization scenarios (various parts of the city center pedestrianized).

The third screen, horizontally browsing the GUI, is the added features control. This is the added features control. This screen controls all the available models that can be used as a single function or as a bundle of components. It controls future scenarios with different projections for population, GDP, macroeconomic scenarios, fuel price, and other projections. It also monitors the presence of tourists and their number (accounting for the seasonality). Finally, it controls the latent variable models that are working in the background: the eco-consciousness HCM, the Lifestyle latent class model, the Symbolic use HCM and the stochastic frontier model.

Right below the added features control, the actual controls of the models are presented. In this screen, the user can control the value of various socio-economic variables such as population, age distribution, education, car ownership, employment and employment categories distribution, income distribution and other. The values of some of these variables correspond to the betas of the structural model of the latent variable models, affecting the future car purchase or the daily rhythms. Other variables affect the simulation outcome or directly affect the output of the platform. For example, the number of highly educated individuals raises by 1.500 persons in a future scenario. This rise, reflected by the structural equation of the latent variable eco-consciousness affects the future purchase of hybrid vehicles, which in order affects the daily emissions and fuel cost.

On the left side of the controls, the map of interventions presents the interventions of the different scenarios. It can also host thematic, cognitive maps of the study area to quantify and geographically present the effect of each scenario or intervention.

Finally, the output screen is located on the bottom of the GUI. In the current version of the platform there are 4 different output screens: a)The rhythms output, depicting mean morning departure and afternoon arrival times, output governed by the stochastic frontier model and the rhythms latent class model; b) the trip chains, which are governed by the rhythms latent class model; c) the daily fuel cost, which is governed by the eco-consciousness and symbolic use HCMs, the population and the presence of tourists, as well as, the selected scenario of interventions and d) the daily emissions which are governed by the same factors as c.

7.2 Architecture

The architecture of the platform is depicted in Figure 38. The architecture follows a parallel approach, where individual components work side-by-side to provide data and results to the final product, the platform.

The first parallel component, "Lifestyle and Rhythms", is the everyday life temporal tier. In this component, mode choice and tour structure are examined and compared to an urban case scenario. Also, departure and arrival times are modelled and the effect of lifestyle is measured. The hypothesis that a distinct, latent lifestyle that affects residents of Chios and differentiates their travel behavior from people living in the Greek capital (an urban area) is verified by the usage of a latent class choice model. This component is discussed extensively in Chapter 4 of the thesis. The component provides time-sensitive analysis and results to the platform, for example daily departure from home times. Results from this tier, especially the tour structure and the effect of lifestyle on it are useful for identifying solutions for public transport, parking areas, commercial opening hours and de-congestion policy in the study area.

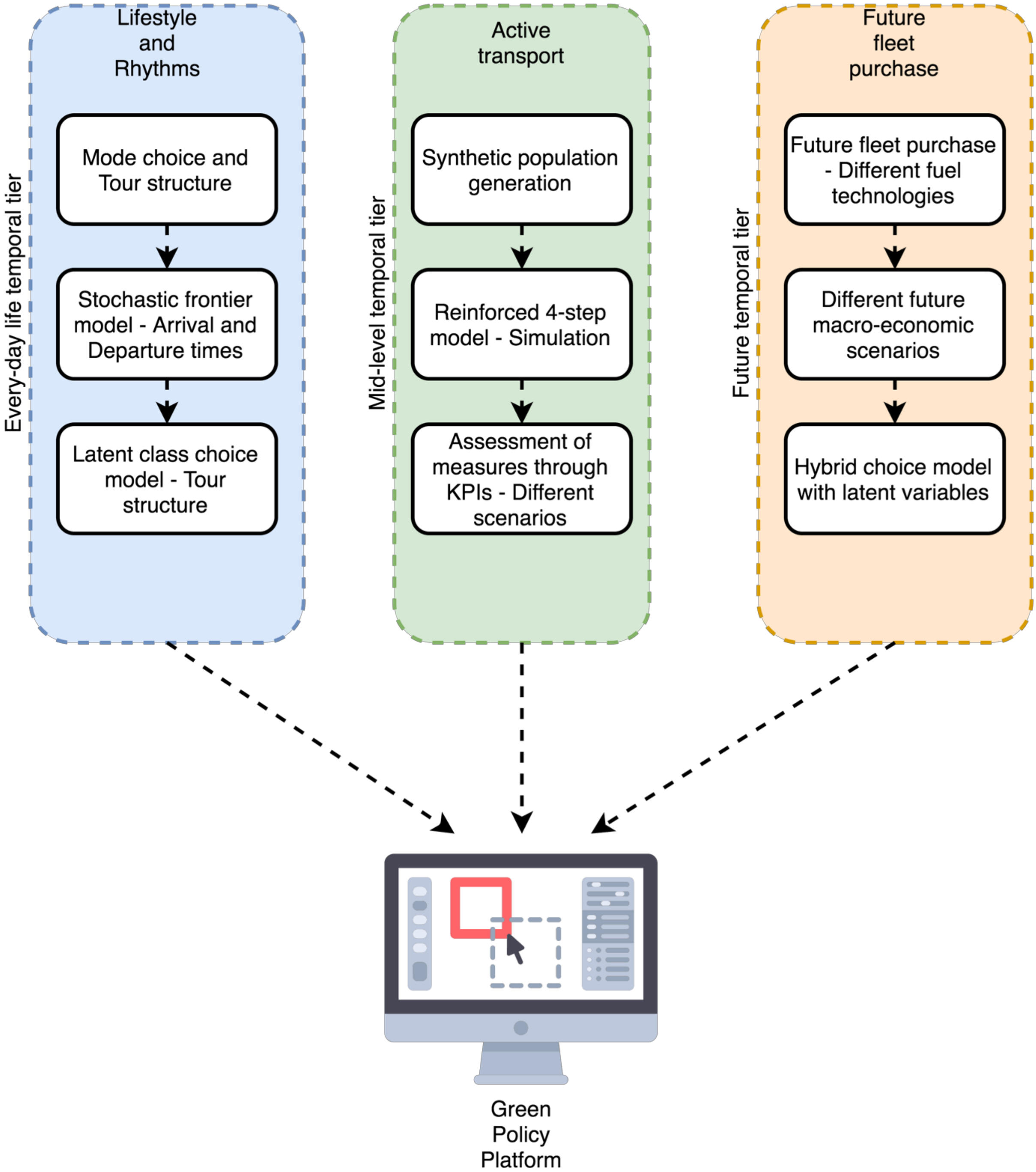


Figure 38 Platform architecture

The second parallel component is Active transport. The analysis is done on a mid-tier temporal level and is discussed in Chapter 5. The component includes the hybrid simulation model, with the evaluation of the sustainable transport policy measures and interventions. The assessment and the evaluation results are the main results provided to the platform. These results comprise the main platform output and the richest information that the platform can provide. The component provides most of the future scenarios results, the traffic maps and predictions, economic and financial evaluation and KPIs.
The final component is Future fleet purchase. This is a medium to long term temporal tier. The component is discussed in Chapter 6. The results of the hybrid choice model developed in this component provide the platform with results about the future fleet mixture of the study area. This component has integrated two different macro-economic scenarios. The results from this component can be compared with the results of the policy measures from component 2. This comparison is the root of the platform function, as different approaches to sustainable transport, measured by different analytical tools and econometric models are compared through the use of the dynamic tool, the platform.

7.3 Interaction of models' output and the platform

The output of the econometric models, in all the three different tiers feed the platform and its specific functions. The interaction of the platform and the models is done on the backend of the platform web service via a PostgreSQL database. Model output and specifically parameters are stored in the databased and then used by the platform to calculate various variables, including scenario assessment, KPIs, other indicators and general statistics (e.g. mean home departure time or daily cost fuel). From the platform architecture, it is apparent that all the models have results and output that feeds the platform. Some platform functionalities rely on a single model output and other rely on a combination of model outputs. Also, some model outputs are depicted on the platform without any further calculation or transformation, for example the vehicle/kms of a scenario. On the other hand, other model outputs are utilized to calculate different output variables, for example the effect of the percentage of freelancers in the study area. The presence of freelancers as a variable in the structural equations of the *Eco-Friendliness* latent variable model, and the *Exuberance* latent variable model, both affecting the future car purchase, indirectly affect the future fleet mixture. In this case, the user can interact with the platform, via the left-hand side menu, which is an input tab. The user can scroll between various percentages of freelances in the study area and see the effect that this has on various KPIs and platform results.

Output of the Daily Rhythms tier to the platform

The daily rhythms tier conducts three different types of analysis, two of which are models. The output of the models is inserted into the platform in two different ways. The first model, the stochastic frontier model, models departure and arrival times from home based on socio-demographic and location data. The output is transferred to the platform. The platform hosts a specific screen that depicts mean everyday departure from home time, arrival to home time and duration of various activities (work, education, leisure). The user can interact with the various socio-demographic controls, on the left-hand side of the platform and see the effect of socio-demographics on the daily rhythms and activity duration. Also, by interacting with the *Lifestyle* Latent Variable checkbox, the user can see the effect of the LV on these times.

The second model, the latent class choice model, models tour structure based on the effect of the LV *Lifestyle*. Tour structure is an important part of modelling and in the case of the platform, tour structure is depicted as the percentage of intermediate stops. The user can switch the effect of the LV on and off and see the effect it has on the percentage of intermediate stops conducted by the users of the network. This affects available parking space, possible commercial hours or other interesting information about the preferences of the network users.

Output of the Promotion of Active Transport tier

The Promotion of Active Transport tier is essentially an extended, hybrid simulation model, which results to a traffic assignment and provides various kinds of information and indicators including traffic flows in the network links, aggregate data such as passenger kilometers or daily trips.

The contribution of the Promotion of Active Transport tier to the platform is major and straightforward: it provides the different scenario evaluation via the KPIs which are the result of the simulation model. The main screen of the platform is occupied by the depiction of results of these KPIs. The user can interact with the platform by choosing different scenarios from the drop-down menu and also by comparing two scenarios. Two additional screens are available to the user, a map showing socio-demographic and travel related data in each scenario in the study area's zones and a second map providing the traffic flows of each scenario. At this point, the other socio-demographic and LV controls are not utilized, as the simulation model needs time to run and converge and including live changes in the socio-demographic information via the user's intervention would gravely affect the time needed to depict the changes and would slow down the platform's functionalities.

Output of the Future Vehicle tier to the platform

The Future Vehicle tier consists of a hybrid choice model of future car purchase. The model results allow for a model application and the exploration of the effect of certain variables (socio-demographic and latent variables) to the probabilities of certain vehicle purchase.

In this aspect, the Future Vehicle tier feeds the platform with the main data for the future scenarios. In this way the user can review predictions about the aggregate daily fuel cost and daily emissions depending on the fleet mixture of the future horizon. This is an essential part of the platform's functionalities, as the user can see the effect of the future fleet mixture and compare the results with the effect of the promotion of active transport measures in quantifiable indicators. Also, by turning on or off the effect of the LVs used in the Future Vehicle tier models, and by interacting with the socio-demographic controls of the left-hand side of the platform the user can review the effect of the latent variables in the previously mentioned indicators.

7.4 Implementation

Based on the mock-up described in the introduction it is evident that the platform has two distinct functions – the input controls and the output screen. The input controls are interactive – the user can interfere and identify the input, experiment with various levels of variables and select a specific scenario or future date. The output screen is divided into various smaller screens that contain useful information for the user. After reviewing similar applications and web interfaces, it was decided that the two functions of the platform tool should be strictly geometrically defined and they should be occupying different parts of the platform GUI.

As Figure 39 shows, the left part of the GUI contains the user control panel. In the control panel, the user can choose the date (for future scenario management), the specific scenario that they want to review, the socio-demographic data controls, the on-off buttons that control the presence of the latent variables in the output and the seasonality button (presence of tourists).

The remaining of the GUI is allocated to act as output screen – given the multitude of information that should be presented to the user. The output screen is divided into three main sub-screens: a) the list of KPIs; b) the map of interventions and c) the major output panel.

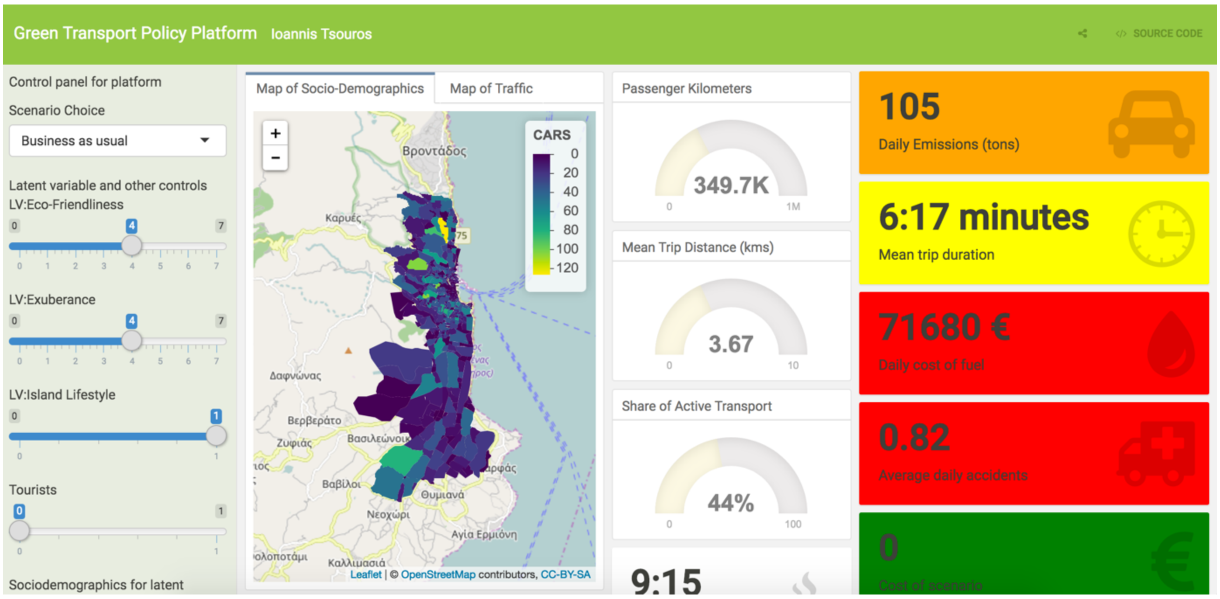


Figure 39 Platform Screenshot

Chapter 8: Conclusion

This chapter concludes the thesis, discusses the impacts of the main findings on policy, and provides directions for further research. Section 8.1 discusses the contributions of the thesis. Section 8.2 presents the key findings derived in the thesis, findings beyond the state-of-the-art that respond to major questions unanswered so far. Section 8.3 discusses the policy implications coming from the models as well as the usage of the platform. 8.4 provides directions for future research.

8.1 Summary and Contributions

This thesis creates of a policy platform tool which supports the decision-making process regarding more sustainable transport choices. It is motivated by: a) the growing concern about global warming and the long-term effect it has on the environment and the living capacity of the planet; b) the need for a comprehensive analysis of different types of policy measures that are widely used to address the adverse effect that the transportation sector growth has on the environment; and c) the need for these measures to be applied to local communities and cities accounting for the particularities of each locale, while ensuring maximum applicability and acceptance.

The thesis uses three main axes of analysis to support the creation of the platform. The first axis is concerned with the lifestyle of the study area, which is used as a case study for the platform. Through different analytic and modeling tools, we measure the effect of lifestyle in every-day transport-related decisions and activities. The hypothesis that different lifestyle can affect these choices is tested through a comparison of similar data from Chios and Athens, Greece. The second axis contains the assessment of active transport related measures in the study area through a series of KPIs. For this analysis, a simulation model of the study area was designed and implemented. The third axis of the analysis is the modeling of future fleet purchase choices. This axis incorporates the various new fuel technologies that can lead to different emission profiles.

This thesis harvests the power of a multitude of collected data. The data collection process itself is organized in an innovative manner: a satellite data collection approach that constitutes of a core of a socio-demographic household and personal survey and it is supported by a number of “satellite” surveys and experiments including an activity diary, menu-based SP experiments and attitudinal questionnaires. This data collection approach is coupled with innovative means of data collection such as using GPS loggers to monitor travel and activities of respondents, using data from social media and other publicly available data.

Regarding the analytical tools and the econometric models, the contributions of the thesis rely on the utilization of well-acclaimed tools and models (hybrid choice models, stochastic frontier models, latent class choice models) and the extension of more traditional tools (aggregate 4-step model). The end product of the thesis, the green policy platform is an additional contribution; it was designed and developed in the context of the thesis from scratch, it is open-source and available to the local government and scientific community.

8.2 Main findings: Going beyond the state-of-the-art

The analysis and the modeling process of the thesis resulted in a series of major and minor findings. This section discusses the main conclusions both in the specific analysis axes of the thesis and in the general context of the research questions that motivated the thesis.

The daily rhythms section (Chapter 4) of the thesis provided sufficient insight into the effect of the location specific lifestyle on the everyday transport-related decisions and activities of individuals. This insight is tested by using two different datasets, one from the capital of Greece, Athens which is a densely populated urban environment. The other one from the island of Chios, Greece which is the 5th largest Greek island, where the observed lifestyle of individuals is more relaxed, affected by environmental, lifestyle and built environment factors. The analysis initiates by comparing mode choice and tour structure between the two locations. The structure and the form of the two questionnaires, in the urban and island locations vary: the urban case scenario is a travel diary survey while the Chios questionnaire is an activity diary. To address this limitation which could potentially complicate analysis, the travel diary questionnaire data was re-organized to fit the activity diary sequence and data format. The physical environment is a significant difference in the two areas, which is reflected by the higher share of walking in the island area. Walking takes a larger proportion when associated with leisure activities in both areas, but this share is higher among islanders. Also, the small percentages of public transport in the island area can be attributed to both the low level of service in Chios and the smaller mean distances traveled. The trip organization also differs between the two regions. People in the urban area tend to prefer to conduct a secondary trip, while islanders prefer an intermediate stop, making the tour structure more complicated impacting accordingly the transport network overall performance. The stochastic frontier analysis reveals that concerning temporal departure from and arrival at home the location is not the primary factor affecting times. However, a strong correlation exists between the duration of work, education and shopping activities and early morning departure times in the urban area, while no significant correlation exists in the island area. Also, leisure activities are correlated with late morning departure times in the island. Both these findings are indicative of a different, more relaxed lifestyle in the island area.

Based on this finding, the latent class choice analysis confirms that there is an underlying factor affecting tour organization that spans between the two locations. People identified as belonging to the island lifestyle class tend to make more intermediate trips and avoiding secondary trips during the day. The major finding of the modeling process is that the relaxed lifestyle class spans among the two datasets; with island respondents, more likely to belong to this class, but with people in the urban area also belonging to the class. This is a significant finding because it does not geographically limit the effect of the latent class of Lifestyle but rather identifies this presence in both areas.

The simulation model developed in the thesis is the backbone of the active transport measures analysis. While a significant part of the literature review revealed the analytical and exploratory power of activity-based and microsimulation models, it was decided to design and implement a hybrid version of a macroscopic, aggregate model. The reason behind this decision is both theoretical and practical. Practical limitations, for example the richness and level-of-detail of data needed to design an activity-based model was not available for the study area and theoretical concerns about the output of the data relevant to the policy analysis led us to implement a "hybrid" version of the model. This hybrid version uses the standard, aggregate simulation model architecture combined with activity-based model modules (such as the population synthesis) and enriched with data feeds (for example sense of place analysis in the gravity model section).

The first main policy measure studied is the creation of bike lanes. Information from the literature review and similar practices, as well as, feedback from local public consultations drive the effort to design bike lanes that are part of an integrated bike lane network and avoid the isolated interventions of minor and not connected bike lanes. For these reasons the bike lanes assessed in the chapter are designed to be built from the center of Chios town to nearby towns such as Vrontados and Karfas. Also the bikelanes are designed to be on coastal roads or through picturesque paths (Kampos) in an effort to support tourists or locals that wish to cycle through attractions and in pleasurable routes. Results positively assess the creation of bike lanes, although a more in-depth cost benefit analysis is needed to globally assess the importance and the drawbacks of such infrastructure. For example, deciding to implement an expensive bike lane infrastructure weight the high cost against cyclists safety and convenience.

The other main policy measure studied in the thesis is the creation of pedestrian roads in the city center. This is also a well-acclaimed measure, though it did raise some thoughts and criticism during the public consultations, especially among business owners in the center of the town. This group of measures can achieve the higher reduction in passenger kilometers and emissions, considering the already high share of walking among study area residents and the restriction of usage of private vehicles that is proposed by the bundle of measures. This bundle can also significantly improve the quality of urban life, highlight the nowadays congested and noisy city center and act as a tourist attraction for specific tourist groups in the study area. It is also the less costly measure and can be implemented with minimal intervention.

Other results include the capabilities of the model to account for seasonality, given that the study area's population doubles during summer months, the combination of modules from Chapter 4 and 5 (shop hours and effect on traffic, re-allocation of land-use zones, extensive pedestrianization and its effect on the commercial zones and economic activity) and the effect of a major external zone relocation (airport or port) in the traffic situation of the study area.

Chapter 6 discusses future fleet purchase preferences through a hybrid choice model. The respondents were presented with a modular approach to future fleet purchase; different levels of vehicle attributes were available, and the respondent created the ideal vehicle. The characteristics included: engine size, car size, car type, fuel technology and automation level. The responded also provided answers to psychometric questions. The survey was conducted in the context of two plausible future macroeconomic scenarios.

Three latent variables were identified through factor analysis to be the most influential on the fuel technology choice of the respondents: Environmental consciousness, Exuberance (the quality of growing profusely; luxuriance) and Technology savviness. The modeling framework presented in Chapter 6 supports the simultaneous investigation of the three latent variable effect on the actual choice. The thesis presents two hybrid choice models; one that investigates the effect of the Environmental Consciousness latent variable and one that investigates the effect of Exuberance. This isolated analysis has inherent weaknesses, but it is a more fit approach for the needs of the platform, and it allows the in-depth investigation of this effect given the demanding data needs that two or three latent variable hybrid choice models have.

Medium sized city cars, with an engine size in the range from 1200 to 1600 CC, gas fueled and a level up from basic edition are the most popular vehicles according to the choice model. These are the levels that have the higher coefficients of the model. Of course, the price of the constructed vehicle has an adverse effect on the choice. The effect of the latent variable Exuberance, which reflects the symbolic attitudes towards cars, is negative on the choice to purchase a hybrid vehicle. On the other hand, Environmental Consciousness is strongly associated with the intention of buying a hybrid fueled vehicle and a small engine sized vehicle.

Results from the pilot usage of the platform reveal interesting findings. It is of great importance that the platform has been already put to test and usage by local authorities. This pilot test of the platform supported the organization and proposal phase of a successful regional project that is concerned with urban planning of Chios town and specific modules of the platform are used to support the proposal especially regarding proposed pedestrianizations and changes in traffic direction and the design of active transport friendly infrastructure.

8.3 Policy Implications

Transportation researchers are discussing the policy implications of various models, analyses, innovative technologies and products for many decades. Major research effort has put into achieving a successful integration between transportation and land use models, temporal and spatial data models, modelling the human behavior, facilitating data collection procedure and discussing how innovative concepts and products can contribute to bringing change in the transportation sector.

8.3.1 Location specific analysis does matter

One of the main findings of this thesis is the result of the analysis conducted at Chapter 4. The result of this analysis confirms the hypothesis that there is a distinct set of underlying rules that govern an individual's decisions, what we call lifestyle, that is closely affected but not exclusively dictated by the geographical location of their residence. This statement has direct policy implications. Policy makers should consider the particularities and uniqueness of a study area before transferring or applying successful policy measures. This consideration should not be based solely on socio-demographic data, but should carefully explore the local culture, lifestyle, and habitudes. This exploration of the local particularities should be conducted using quantitative and qualitative tools, the synthesis of which can bring an optimal result to the analysis and the correct application of policy measures. In this thesis, using the methodological framework of the GreTIA project (Gretia, 2015), the qualitative tools such as public consultations and in-depth interviews with study area decision makers and citizens were proven precious instruments.

8.3.2 What is we are seeking by sustainable transport?

The main goal of sustainable transport is to mitigate the risks and the external cost of transportation, as a sector. A big part of this mitigation process lies within the reduction of Global Greenhouse Gas emissions. However, even if this goal is the primary goal of sustainable transport, or of all relevant research, goals like improvement of quality of urban life, traffic congestion, road accidents and noise pollution should not be understated in the approaches to minimize the external cost of transportation.
A good example is the case study of this thesis. Chios, as the study area, is not a congestion-ridden city. Air quality counts have revealed that the air quality in the city is excellent and small variations exist only at the times of large passenger ferries birthing at Chios port.

However, during the public consultations, a lot of stakeholders, citizens and public authorities expressed their concern regarding the negative effects of transportation in everyday life. Designing a policy evaluation tool that can be both applicable to other circumstances, transferable and considers the hierarchy of problems and risks of the study area was one of the main challenges of this thesis.
A general comment on this process and the balance between the general applicability of the platform and the correct focus on the study area's issues is that in models and decision-making tools found in literature and practice there is an observed over statement of measures aiming to reduce GHG emissions. This is understandable, but it should be made clear that actions towards reducing GHG emissions should be aimed and tailor made for the specific case, while taking into consideration the co-existing issues, problems, particularities. In a lot of cases reducing GHG emissions means increasing the share of public transport or car sharing. In other cases, it means reducing trips and adjusting commercial hours, improving active transport infrastructure or providing incentives towards using sustainable or multimodal options. In our opinion this is a very sophisticated process and the need for a collaborative decision-making process surpasses the limits of a policy or a decision-making tool. Participatory design, which involves citizens in the decision-making process, may be a way to further ensure that there is a spherical understanding of the stakeholder needs, beliefs and goals.

8.3.3 Combining policy measures

The thesis structure, the policy platform architecture and the way that some of the research results are discussed may give the impression to the reader that the different policy measures that are assessed are mutually exclusive or that there is some antagonism between them. This is not entirely accurate, though to some extent there is a comparison between the policy measures given that the platform has the capability to compare different measures and scenarios and the thesis main subject is about assessing green transport policy. The idea of combining policy measures to form policy packages of bundles is discussed in a series of research papers and has been successfully implemented in the past in various locations (see Chapter 2). In the context of the thesis, the comparison between the measures promoting active transport and the effect of a different fleet mixture, both in the context of the study area rhythms, generates interesting results and serves a twofold purpose. On the one hand, it demonstrates that active transportation can overperform "greener" fuel technologies in a realistic and ready-to-implement way and on the contrary that, while respecting the local scale and built environment, the implementation of measures that may seem radical.

Table 35 Shades of Green

Policy		KPIs								
Policy Goal	Policy Measure	Active Transport Split	Passenger kms	Vehicle kms	Mean trip duration	Mean trip distance	Daily trips	Accidents	Daily fuel cost (€)	Daily emissions (tons)
BAU		0.41	349697	285700	6:17	3.67	95285	0.81	71680	105
Avoiding journeys	5% reduction in overall trips by shifting work schedule and shop hours	0.41	332212	271415	6:17	3.67	90521	0.77	68069	100
	10% reduction in overall trips by shifting work schedule and shop hours	0.41	314727	257130	6:17	3.67	85757	0.73	64512	95

	(accounting for increase in working from home)									
Modal shift to active transport	Bikelane to Vrontados	0.54	341762	288650	6:48	5.78	95285	0.68	58880	87.32
	Bikelane to Karfas	0.56	353506	300600	6:54	5.84	95285	0.67	56320	86.98
	Bikelane to Kampos	0.54	343360	290000	6:49	5.8	95285	0.68	58880	87.72
	All bikelanes	0.57	354471	302450	7:02	5.93	95285	0.66	55040	85.52
	Pedestrianization of port route	0.53	338818	285200	6:07	3.65	95285	0.68	60160	88.15
	Pedestrianization of city center	0.53	339198	285520	6:27	3.95	95285	0.68	60160	88.25
	All pedestrianization	0.57	359757	306960	7:45	7.93	95285	0.67	55040	86.8
Reducing carbon intensity of fuels	Future scenario – Optimistic	0.41	349697	285700	6:17	3.67	95285	0.81	65020	96
	Future scenario – Neutral	0.41	349697	285700	6:17	3.67	95285	0.81	68500	99.6

The results of the implementation of policy measures (corresponding to specific policy objectives groups) are presented in Table 35. The impact of these measures is assessed via nine KPIs, demonstrated via different shades of green (the greener impact is darker). The user can observe that particular policy measures have advantages and disadvantages when compared via the KPIs. Interesting comparative examples include: a) the excellent performance of the "modal shift to active" scenarios – all measures result in an over 50% modal split of active modes. Drawbacks include the longer trip distances and duration in almost all cases; b) the fact that even a 10% reduction in everyday trips, when influencing trip chaining behavior by shifting work schedules and shop hours, does not overperform the active transport policy measures in terms of daily emissions and fuel cost; and c) the failure of future fleet mixture scenarios to match the reduction of fuel cost and carbon emissions achieved by the active transport scenarios.

8.4 Future research

This thesis investigates the various levels and dimensions of sustainable transport, using a multitude of analytical tools to assess policy bundles and to form useful conclusions on the topic. The methods and the tool used to derive these results are solid, and there is sufficient data to back-up the findings in the study area. However, a series of the presented tools and methods are used in an exploratory manner. The application of the model results is calibrated in a series of ways in the study area, and the models are replicable, although it focuses on the advantages of creating tailor-made models and tools for a specific location or city with unique characteristics and particularities. Further research should focus on four different directions.

8.4.1 Data collection

Data collection was a distinct part of this thesis. A part of the data was collected using innovative means such as GPS devices, smartphone apps, and public APIs. Latest developments in the data collection process in transportation include the use of smartphone applications to accompany activity diaries, even to substitute them in some research. The future of the data collection process is most probably the improvement of these data collection tools in the direction of a seamless, accurate and non-intrusive data collection process that removes the burden from the respondent and minimizes data collection time and costs. The omnipresence and usage of the smartphone has significant implications in the transportation research sector, and especially in the data collection process. There is a series of commercial and research applications (citations) that already achieve a high standard of data collection. The interconnection of different platforms, smartphone apps and sensors can lead to a powerful data collection matrix that will be able to harvest user information in non-intrusive ways, pool data from social media and other relevant sources while respecting user privacy and anonymity.

8.4.2 Activity-based modeling

This thesis uses a hybrid version of the traditional 4-step model, used for many decades in transport research. While this model is an aggregate approach, in the context of Chapter 5 we achieved a level of disaggregated analysis by using the additional step of a synthetically generated population at the first step of the model. This adds a user-oriented dimension to the methodology. The benefits of activity-based modeling have been well-documented in the scientific literature (see section 2.3). Given what is discussed in the previous paragraph, the ongoing open source modelling software, open data and developed models, one can view the future of activity based modelling in a dynamic, open platform that is able to pull data automatically from various sources and update the model parameters on the run, while simultaneously calibrating and benchmarking the model via traffic counts and other live sensors.

8.4.3 Future mobility

Contemporary analysis and future mobility planning and sensing are focused on two areas that could potentially influence and radically transform mobility and passenger transportation as we know it: Mobility-as-a-Service (MaaS) and Connected and Autonomous Vehicles (CAV).

MaaS tranforms the transport economic sector by shifting the focus from privately owned means of transport to mobility solutions that are perceived as a service; from ownership to usership. This concept has specific implications for individuals, public and private transport companies, organizations and governments as it is enabled by

a single operator that ensures seamless transportation from point a-to-b, with ticketing, payment, security and safety all managed by this single operator. The MaaS concept is fueled by the omnipresent available data, the rise of e-services, ride-sharing, sharing economy in general and the general anticipation of driverless vehicles.
Driverless vehicles also aim to transform transportation in an unprecedented way. The use of public, driverless and connected vehicles as the main mode of transport, especially in densely populated urban areas is a solution to many problems that the transportation sector faces, a major reduction in the external costs of transportation and a practical realization of the essence of the question: "Should I own my personal vehicle? Does this have a financial benefit? Does this benefit the society?".

8.4.4 The effect of latent variables - Robustness of the existing modeling frameworks

A lot of scientific work is concerned with the effect of latent traits, attitudes, and perceptions, in the decision-making process. Research papers have approached this effect with methodological (citations) and conceptual approaches. There is an ongoing discussion about the usefulness (citation Hess) and the robustness (citation Walker) of the latent variable models. It is evident that user segmentation or user profiling is a very useful analytical tool that can assist the decision-making process or policy decisions. Future work on the effect of latent variables should concentrate on the psychometric part of the methodology. A multidisciplinary approach, with psychologists and sociologists contributing to the questionnaire design, would result in better-structured questions. Also, methodological and computational improvements are already allowing for the calculation of a wide range of interactions between variables and respondents, with Bayesian techniques, multi-level modeling and use of optimal algorithms in the calculating part of the methodology facilitating the process.

8.4.5 Future of sustainable transport

The future of sustainable transport is closely linked to the future of sustainability as a notion. It is surely related to the question of what future world do we want to live in.

Global warming and climate change are very real threats to the ecosystem and humanity, and there does not seem to be enough organized response to this threat. The environmental issue is not a matter of a clean habitat, green parks or the preservation of wildlife. It is a matter of survival, of equal access and rational use of natural resources and social equality and justice. A number of environmental refugees are going to become a major issue during the next decades. The "green" marketing strategies, promoting certain products or services as environmentally friendly or sustainable is not a robust, organized response to climate change, it is rather a facade that is focused on marketing or promoting utilizing the environmentally conscious individuals. This applies to transportation as well. We must be very careful in assessing different policy bundles, products or services. A sustainable transportation system demands radical changes in the way that everyday social life is organized, the way humans interact with the urban and built environment, the economic system and its flaws, the rising tide of the technological process and the evolving ethics around the world.

References

1. Abou-Zeid, M., and M. ben-Akiva (2012a). Well-being and activity-based models. Transportation, Published online, DOI 10.1007/s11116-012-9387-8, Available on: http://www.springerlink.com/content/640k475tv3572014/fulltext.pdf ,
2. Abou-Zeid, M., Ben-Akiva, M., 2011. The effect of social comparisons on commute well-being. Transp. Res. Part A Policy Pract. 45, 345–361. doi:10.1016/j.tra.2011.01.011
3. Abou-Zeid, M., M. Ben-Akiva ,and M. Bierlaire (2009). Happiness and travel behaviour modification. Paper presented at European Transport Conference (ETC), October 2008.
4. Abou-Zeid, M., R. Witter, M. Bierlaire, V. Kaufmann, and M. Ben-Akiva (2012b). Happiness And Travel Mode Switching: Findings From A Swiss Public Transportation Experiment. Transportation Policy, 19(1), pp. 93–104.
5. Amekudzi, A.A., Jotin Khisty, C., Khayesi, M., 2009. Using the sustainability footprint model to assess development impacts of transportation systems. Transp. Res. Part A Policy Pract. 43, 339–348. doi:10.1016/j.tra.2008.11.002
6. Antoniou, C., Yannis, G., Papadimitriou, E., Lassarre, S., 2016. Relating traffic fatalities to GDP in Europe on the long term. Accid. Anal. Prev. 92, 89–96. doi:10.1016/j.aap.2016.03.025
7. Arentze, T.A., Timmermans, H.J.P. (2008). A need-based model of multi-day, multi-person activity generation. Transportation Research Part B (in this special issue).

8. Arentze, T.A. and H.J.P. Timmermans (2004). A Learning-Based Transportation Oriented Simulation System. Transportation Research Part B, 38 (7), pp. 613-633.
9. Arya Pal S. (1999). Air Pollution Meteorology and Dispersion, Oxford University Press.
10. Asensio, C., López, J.M., Pagán, R., Pavón, I., Ausejo, M., 2009. GPS-based speed collection method for road traffic noise mapping, Transportation Research Part D: Transport and Environment. Transport and Environment, Transportation Research Part D. doi:10.1016/j.trd.2009.03.008
11. Ashish, A. (2004) A comparison of weekend and weekday travel behavior characteristics in urban areas. Thesis, University of South Florida, 2004.
12. Auld, J. (2012). Agent-based Dynamic Activity Planning and Travel Scheduling Model: Data Collection and Model Development. Ph.D. Thesis, University Of Illinois At Chicago.
13. Auld, J., and A. Mohammadian (2011). Planning-Constrained Destination Choice in Activity-Based Model. Transportation Research Record: Journal of the Transportation Research Board, Vol. 2254, pp. 170-179.
14. Auld, J., Mohammadian, A.K., 2012. Activity planning processes in the Agent-based Dynamic Activity Planning and Travel Scheduling (ADAPTS) model. Transp. Res. Part A Policy Pract. 46, 1386–1403. doi:10.1016/j.tra.2012.05.017
15. Axhausen, K., A. Zimmerman, S. Schönfelder, G. Rindsfüser, and T. Haupt. Observing the rhythms of daily life: a six-week travel diary. Transportation Vol. 29 No.2, 2002, pp. 95–124.
16. Axsen, J., and K. S. Kurani. Hybrid, plug-in hybrid, or electric—What do car buyers want? Energy Policy, Vol 61, 2015, pp. 532–543.
17. Axsen, J., Bailey, J., Castro, M.A., 2015. Preference and lifestyle heterogeneity among potential plug-in electric vehicle buyers. Energy Econ. 50, 190–201. doi:10.1016/j.eneco.2015.05.003

18. Backer, E. (2007). VFR Travel - an examination of the expenditures of VFR travellers and their hosts. Current Issues in Tourism, 10 (4), p.369.
19. Backer, E. (2009). The VFR Trilogy. Refereed paper in J.Carlseen, M. Hughes, K. Holmes & R. Jones (Eds). See Change: Proceedings of the CAUTHE Conference, 10-13 Feb, 2009, Fremantle, WA, Australia.
20. Badland, H., Duncan, M., Oliver, M., 2010. Examining commute routes: applications of GIS and GPS technology. … Heal. Prev. … 327–330. doi:10.1007/s12199-010-0138-1
21. Bagley, M. and P. Mokhtarian. The impact of residential neighborhood type on travel behavior: a structural equation modeling approach. The Annals of Regional Science, Vol. 36, 2002, pp. 279–297.
22. Bagley, M.N., Mokhtarian, P.L., 2002. The impact of residential neighborhood type on travel behavior: A structural equations modeling approach. Ann. Reg. Sci. 36, 279–297. doi:10.1007/s001680200083
23. Bansal, P., K.M. Kockelman, and A. Singh. Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. Transp. Res. Part C Emerg. Technol. Vol 67, 2016, pp. 1–14.
24. Bansal, P., Kockelman, K.M., Singh, A., 2016. Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. Transp. Res. Part C Emerg. Technol. 67, 1–14. doi:10.1016/j.trc.2016.01.019
25. Barsi, T., C. Faergemann, and L.B. Larsen (2010). Road Traffic Accidents with Two-Wheeled Motor Vehicles During a Five-Year Period in Odense, Denmark. Traffic Injury Prevention, pp. 283-287, DOI: 10.1080/15389580214621.
26. Ben-Akiva, M., (2007). Happiness and Activity-Based Models. Presented at the European Transport Conference, Leeuwenhorst, The Netherlands.
27. Ben-Akiva, M., J.L. Bowman, and D. Gopinath (1996). Travel Demand Model System For The Information Era. Transportation, 23, pp. 241–266.

28. Ben-Akiva, M., McFadden, D., Abe, M., Böckenholt, U., Bolduc, D., Gopinath, D., Morikawa, T., Ramaswamy, V., Rao, V., Revelt, D., Steinberg, D., 1997. Modeling Methods for Discrete Choice Analysis. Mark. Lett. 8, 273–286. doi:10.1023/a:1007956429024
29. Ben-Akiva, M., Mcfadden, D., Train, K., Walker, J., Bhat, C., Bierlaire, M., Bolduc, D., Boersch-Supan, A., Brownstone, D., Bunch, D.S., Daly, A., De Palma, A., Gopinath, D., Karlstrom, A., Munizaga, M.A., 2002. Hybrid Choice Models: Progress and Challenges. Mark. Lett. 13, 163–175. doi:10.1023/A:1020254301302
30. Benson, P. E. (1992). A review of the development and application of the CALINE3 and 4 Models, Atmospheric Environment, 26, 379–390.
31. Benson, P.E., (1984). CALINE4—a dispersion model for predicting air pollutant concentrations near roadways. Office of Transportation Laboratory, California Department of Transportation, Sacramento, USA.
32. Bhat, C., and F. Koppelman (2000). Activity-Based Travel Demand Analysis: History, Results And Future Directions. Paper presented at the 79th Annual Meeting of the Transportation Research Board, Washington, DC.
33. Bhat, C.R., 1997. An Endogenous Segmentation Mode Choice Model with an Application to Intercity Travel. Transp. Sci. 31, 34–48. doi:10.1287/trsc.31.1.34
34. Bhat, C.R., and R. Gossen (2004). A Mixed Multinomial Logit Model Analysis of Weekend Recreational Episode Type Choice. Transportation Research Part B, Vol. 38, pp. 767- 787.
35. Bhat, C.R., and R. Misra (1999). Discretionary Activity Time Allocation of Individuals between In- Home and Out-of-Home and Between Weekdays and Weekends. Transportation, Vol. 26, 1999, pp. 193-209.

36. Bhat, C.R., and S. Srinivasan (2005). A Multidimensional Mixed Ordered-Response Model for Analyzing Weekend Activity Participation. Transportation Research Part B, Vol. 39, pp. 255-278.
37. Bhat, C. R., J. Y. Guo, S. Srinivasan, and A. Sivakumarc (2004). Comprehensive Econometric Microsimulator for Daily Activity-Travel Patterns. Transportation Research Record: Journal of the Transportation Research Board, No. 1894, Transportation Research Board of the National Academies, Washington, D.C., pp. 57–66.
38. Bhat, C.R., K.G. Goulias, M.R. Pendyala, R. Paleti, R. Sidharthan, L. Schmitt, and H. Hu (2012). A Household-Level Activity Pattern Generation Model for the Simulator of Activities, Greenhouse Emissions, Networks, and Travel (SimAGENT) System in Southern California. TRB 2012.
39. Bibri, S.E., Krogstie, J., 2017. Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustain. Cities Soc. doi:10.1016/j.scs.2017.02.016
40. Bieger, T., Wittmer, A. (2006) Air transport and tourism – Perspectives and challenges for destinations, airlines, and governments Journal of Air Transport Management (12) 40-46.
41. Bien, A. 2004. A simple user's guide to certification for sustainable tourism and ecotourism. The International Ecotourism Society (http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=1028822, last accessed March 2012)
42. Bien, Amos (2005). CESD/TIES, Marketing Strategy for Sustainable and Ecotourism Certification Eco-Currents, June 2005.
43. Boubel, R.W., Fox, D.L., Turner, D.B. & Stern A.C. (1994). Fundamentals of Air Pollution, 3rd Edition. Academic Press.
44. Boulter P.G. & McCrae I.S. (2007). The Links between Microscale Traffic Emissions and Air Pollution Models. PPR269, Published Project Report.

45. Bowman, J., and M. Ben-Akiva (1999). The Day Activity Schedule Approach To Travel Demand Analysis. Paper presented at the 78th Annual Meeting of the Transportation Research Board, Washington, DC.
46. Bowman, J., and M. Ben-Akiva (2001). Activity-Based disaggregate travel demand model system with activity schedules. Transportation Research A, 35A (2001), pp. 1–28.
47. Bowman, J.L., M. Bradley, and J. Gibb (2006). The Sacramento Activity-based Travel Demand Model: Estimation and Validation Results. Paper presented at the European Transport Conference, Strasbourg, France, September 18-20.
48. Bradley, M., J. Bowman, T. Lawton (1999). A Comparison Of Sample Enumeration And Stochastic Microsimulation For Application Of Tour-Based And Activity-Based Travel Demand Models. Paper for the European Transport Conference, Cambridge, UK, September.
49. Bradley, M., J. L. Bowman and B. Griesenbeck (2010). SACSIM: An applied activity-based model system with fine-level spatial and temporal resolution. Journal of Choice Modeling, Vol, 3(1) 2010.
50. Bradley, M., M. Outwater, N. Jonnalagadda, and E. Ruiter (2001). Estimation of an activity-based micro-simulation model for San Francisco. Paper presented at the 80th Annual Meeting of the Transportation Research Board, Washington, DC.
51. Bradley, M.A., J.L. Bowman, and B. Griesenbeck (2006). Development And Application Of The SACSIM Activity-Based Model System. Paper presented at the 11th World Conference on Transport Research, June, 2007, Berkeley, California, USA.
52. Bradley, M. and P. Vovsha (2005). A Model For Joint Choice Of Daily Activity Pattern Types Of Household Members. Transportation, 32, pp. 545–571 DOI: 10.1007/s11116-005-5761-0.

53. Bricka, S., Sen, S., Paleti, R., Bhat, C., 2012. An analysis of the factors influencing differences in survey-reported and GPS-recorded trips. Transp. Res. part C … 21, 67–88. doi:10.1016/j.trc.2011.09.005
54. Bricker, K., Sarnoff, P., & Schultz, J. (2009, October 14). Parks, recreation, tourism: Sustainability, trends, resources and Challenges [PowerPoint slides]. National Recreation and Parks Association Congress. Salt Lake City, UT. Butterworth-Heinemann.
55. Broach, D., 2004. Gliebe. "Where do cyclists ride? A route choice Model Dev. with Reveal. Prefer. GPS data 46, 2012.
56. Broach, J., Dill, J., Gliebe, J., 2012. Where do cyclists ride? A route choice model developed with revealed preference GPS data. Transp. Res. Part A Policy Pract. 46, 1730–1740. doi:10.1016/j.tra.2012.07.005
57. Brohman, J. (1996) New directions in tourism for third world development, Annals of Tourism Research, Vol. 23, No. 1, 48-70.
58. Buehler, R., and J. Pucher (2011). Sustainable Transport in Freiburg: Lessons from Germany's Environmental Capital. International Journal of Sustainable Transportation, 5, pp. 43–70.
59. C.R. Bhat An endogenous segmentation mode choice model with an application to intercity travel Transportation Science, 31 ,1997, pp. 34–48
60. Campbell, A.R., Ryley, T., Thring, R., 2012. Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom. Transp. Res. Part A Policy Pract. 46, 1318–1327. doi:10.1016/j.tra.2012.05.004
61. Campbell, A.R., T. Ryley, and R. Thring. Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom. Transp. Res. Part A Policy Pract., Vol 46, 2012, pp. 1318–1327.
62. Castillo, H., Pitfield, D.E., 2010. ELASTIC - A methodological framework for identifying and selecting sustainable transport indicators. Transp. Res. Part D Transp. Environ. 15, 179–188. doi:10.1016/j.trd.2009.09.002

63. Caulfield, B., 2014. Re-cycling a city – Examining the growth of cycling in Dublin. Transp. Res. Part A Policy Pract. 61, 216–226. doi:10.1016/j.tra.2014.02.010
64. Center on Ecotourism and Sustainable Development (CESD): http://www.ecotourismcesd.org/
65. Chafe, Zoë and Honey, Martha (2004). Consumer Demand and Operator Support for Socially and Environmentally Responsible Tourism, CESD/TIES Working Paper No. 104a, February 2004. (http://www.travelersphilanthropy.org/resources/documents/Consumer_Demand_Report.pdf, last accessed March 2012)
66. Choo, S., H. Lee, and D. Hong (2012). Exploring Weekend Travel Behavior in a Developing Country: An Empirical Study of Seoul. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC.
67. Chorus, C.G., Kroesen, M., 2014. On the (im-)possibility of deriving transport policy implications from hybrid choice models. Transp. Policy 36, 217–222. doi:10.1016/j.tranpol.2014.09.001
68. Cort??s, C.E., Gibson, J., Gschwender, A., Munizaga, M., Z????iga, M., 2011. Commercial bus speed diagnosis based on GPS-monitored data. Transp. Res. Part C Emerg. Technol. 19, 695–707. doi:10.1016/j.trc.2010.12.008
69. Culpan, R. (1987) International tourism model for developing economies, Annals of Tourism Research, Vol. 14, 541-552.
70. Dagsvik, J.K., Wennemo, T., Wetterwald, D.G., Aaberge, R., 2002. Potential demand for alternative fuel vehicles. Transp. Res. Part B Methodol. 36, 361–384. doi:10.1016/S0965-8564(01)00013-1
71. Daly, A. & Zannetti P. (2007) Air Pollution Modeling – An Overview. Chapter 2 of AMBIENT AIR POLLUTION (P. Zannetti, D. Al-Ajmi, and S. Al-Rashied, Editors). Published by The Arab School for Science and Technology (ASST)

(http://www.arabschool.org.sy) and The EnviroComp Institute (http://www.envirocomp.org/).

72. Davakis, E., Nychas, S.G. , Andronopoulos, S., Bartzis J.G. (2004). Validation study of the dispersion Lagrangian particle model DIPCOT over complex topographies using different concentration calculation methods, International Journal of Environment and Pollution, 20(1-6), 33-46
73. Davidson, W., R. Donelly, P. Vovsha, J. Freedman, St. Ruegg, J. Hicks, J. Castiglione, and R. Picado (2007). Synthesis Of First Practices And Operational Research Approaches In Activity-Based Travel Demand Modeling. Transportation Research Part A: Policy and Practice, Volume 41, Issue 5, June 2007, Pages 464–488.
74. Daziano, R.A., Bolduc, D., 2011. Incorporating pro-environmental preferences towards green automobile technologies through a Bayesian hybrid choice model. Transportmetrica. doi:10.1080/18128602.2010.524173
75. Devillaine , F., M. Munizaga, M. Trépanier (2012). Detection of Public Transport User Activities Through the Analysis of Smartcard Data. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC.
76. Devillaine, F., Munizaga, M., Trépanier, M., 2012. Detection of public transport user activities through the analysis of smartcard data. Transp. Res. Board 91st Annu. Meet. 1–17.
77. Downward, P., and L. Lumsdon (1999), The Determinants of the Day Excursion Coach Travel: A Qualitative Market Analysis. Services Industries Journal 19:158–168.
78. Downward, P., S. Rhoden, and L. Lumsdon (2006), Transport for Tourism; Can Public Transport Encourage a Modal Shift in the Day Tourist Market. Journal of Sustainable Tourism 14:139–156.

79. Du, J., Aultman-Hall, L., 2007. Increasing the accuracy of trip rate information from passive multi-day GPS travel datasets: Automatic trip end identification issues. Transp. Res. Part A Policy Pract. 41, 220–232. doi:10.1016/j.tra.2006.05.001
80. Eberhardt, M. and E. Pamuk. The Importance of Place of Residence: Examining Health in Rural and Nonrural Areas. Am J Public Health, Vol. 94, No. 10, 2004, pp. 1682–1686.
81. Eberhardt, M.S., Pamuk, E.R., 2004. The importance of place of residence: Examining health in rural and nonrural areas. Am. J. Public Health. doi:10.2105/AJPH.94.10.1682
82. EcoGreen Hotel: www.ecogreenhotel.com, last accessed March 2012
83. Eliasson, J., Proost, S., 2015. Is sustainable transport policy sustainable? Transp. Policy 37, 92–100. doi:10.1016/j.tranpol.2014.09.010
84. Ellison, A.B., Daniels, R., 2012. Capturing Speeding Behaviour in School Zones Using GPS Technology 93510036, 1–16.
85. ELTIS (2009). Heavy EcoDriving - Malmö/Sweden Case Study. Report, European Platform on Mobility Management – SMILE program, Accessible at: http://www.eltis.org/docs/studies/Malmo%2011-9.pdf
86. Eluru, N., A. Pinjari, R. Pendyala, and C. Bhat (2009). A Unified Model Of Activity Type Choice, Activity Duration, Activity Timing, Mode Choice And Destination Choice. University of Texas at Austin, http://www.caee.utexas.edu/prof/bhat/ABSTRACTS/UnifiedModelActivity-Type_Aug2009.pdf
87. EPA (2001). EPA's New Generation Mobile Source Emissions Model: Initial Proposal and Issues, EPA420-R-01-007, retrieved from http://www.epa.gov/OMS/models/ngm/r01007.pdf.

88. EPA (2004). Assessing Air Quality: Modeling, in: Risk Assessment and Modeling -Air Toxics Risk Assessment Reference Library Volume 1 - Technical Resource Manual, retrieved from http://www.epa.gov/ttn/fera/risk_atra_vol1.html.
89. EPA (2005). Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule, Federal Register /Vol. 70, No. 216, 68217-68261.
90. EPA (2012). Technology Transfer Network Support Centre for Regulatory Atmospheric Modeling. Preferred/Recommended Models, retrieved from http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod.
91. Erhardt, G.D., B. Charlton, J. Freedman, J. Castiglione, and M. Bradley (2008). Enhancement and Application of an Activity-Based Travel Model for Congestion Pricing. Paper presented at TRB Innovations in Travel Modeling conference, June 23-25, in Portland, OR.
92. Ferdous, N., N. Eluru, C.R. Bhat, I. Meloni (2010). A Multivariate Ordered-Response Model System For Adults' Weekday Activity Episode Generation By Activity Purpose And Social Context. Transportation Research Part B, 44, pp. 922–943.
93. Font, Xavier (2002a) Critical Review of Certification and Accreditation in Sustainable Tourism.
94. Font, Xavier (2002b) Environmental Certification in Tourism and Hospitality: Progress, Process and Prospects Tourism Management 23(3): 197-205
95. Font, Xavier (2003) Labelling & Certification: Benefits & Challenges for Sustainable Tourism.
96. Font, Xavier and Harris, Catherine (2004).Rethinking Standards from green to sustainable,
97. Frase, P., 2016. Four futures: visions of the world after capitalism. Verso, Brooklyn, NY.

98. Friman, M., and B. Edvardsson (2003), A Content Analysis of Complaints and Compliments. Managing Service Quality 13:20–26.
99. Godish T. (1991). Air Quality, Lewis Publishers, pp. 422.
100. Gong, H., Chen, C., 2012. A GPS / GIS method for travel mode detection in New York City. Comput. Environ. Urban Syst. 36, 131–139. doi:10.1016/j.compenvurbsys.2011.05.003
101. Goodwin, H. (2002). The Case for Responsible Tourism. Chapter in Ethical Tourism: Who Benefits? Hodder and Stoughton Eds.
102. Goodwin, P.B. (1986), A panel analysis of changes in car ownership and bus use. , Traffic Engineering and Control, October, 27, pp. 519-525
103. Goulias, K., Davis, A., J.H, L., Polydoropoulou, A., Tsirimpa, A., Tsouros, I., n.d. Measurement of sense of place and comparison with social media data in a Greek island, in: 1st International Conference on Experiential Tourism. Santorini, Greece.
104. Goulias, K., Kim, T.-G., 2001. Multilevel Analysis of Activity and Travel Patterns: Accounting for Person- and Household-Specific Observed and Unobserved Effects Simultaneously. Transp. Res. Rec. J. Transp. Res. Board 1752, 23–31. doi:10.3141/1752-04
105. Goulias, K.G., 1999. Longitudinal analysis of activity and travel pattern dynamics using generalized mixed Markov latent class models. Transp. Res. Part B Methodol. 33, 535–557. doi:10.1016/S0191-2615(99)00005-3
106. Goulias, K.G., and T.G. Kim (2001). Multi-Level Analysis Of Activity And Travel Patterns: Accounting for Person- and Household-Specific Observed and Unobserved Effects Simultaneously. Transportation Research Record, 1752, pp. 23–31.
107. Goulias, K.G., Bhat, C.R., Pendyala, R.M., Chen, Y., Paleti, R., Konduri, K.C., Huang, G., Hu, H.H., 2011. Simulator of activities, greenhouse emissions, net-

works, and travel (SimAGENT) in Southern California: Design, implementation, preliminary findings, and integration plans, in: 2011 IEEE Forum on Integrated and Sustainable Transportation Systems, FISTS 2011. pp. 164–169. doi:10.1109/FISTS.2011.5973624

108. Goulias, K.G., Bhat, C.R., Pendyala, R.M., Chen, Y., Paleti, R., Konduri, K.C., Lei, T., Tang, D., Yoon, S.Y., Huang, G., Hu, H., Barbara, S., Angeles, L., 2012. Simulator of Activities , Greenhouse Emissions , Networks , and Travel (SimAGENT) in Southern California Simulator of Activities , Greenhouse Emissions , Networks , and Travel (SimAGENT) in Southern California. Transportation (Amst). 1, 1–24.

109. Goulias, K.G. and R. Kitamura (1992). Travel Demand Forecasting with Dynamic Micro¬simulation. Transportation Research Record, No. 1357, Transportation Research Board of the National Academies, Washington, D.C., pp. 8 - 17.

110. Goulias, K.G. C. Bhat, R. Pendyala, C. Yali, R. Paleti, K. Konduri, H. Guoxiong, H. Hsi-Hwa . Simulator of activities, greenhouse emissions, networks, and travel (SimAGENT) in Southern California. Paper presented at the January 2012 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 22-26, 2012

111. Goulias K.G. Longitudinal analysis of activity and travel pattern dynamics using generalized mixed Markov latent class models. Transportation Research, Part B, 33(8), 1999, pp. 535-557

112. Graham, B. (1995) Geography and air transport. Chichester: John Wiley & Sons.

113. Greene, W.H., Hensher, D.A., 2003. A latent class model for discrete choice analysis: Contrasts with mixed logit. Transp. Res. Part B Methodol. 37, 681–698. doi:10.1016/S0191-2615(02)00046-2

114. Gunn, C. (ed), (1988) Tourism Planning (2nd ed.). New York: Taylor and Francis.

115. Guo, J. Y., S. Srinivasan, N. Eluru, A. Pinjari, R. Copper- man, and C. R. Bhat. Activity-Based Travel-Demand Analysis for Metropolitan Areas in Texas: CEMSELTS Model Estimations and Prediction Procedures, 4,874 Zone System CEMDAP Model Estimations and Procedures, and the SPG Software Details. Report 4080-7. Texas Department of Transportation, Oct. 2005. www.ce.utexas.edu/prof/ bhat/REPORTS/4080_7.pdf

116. Hall, D. (1998), Urban Transport, Environmental Pressures and Policy Options. In The New Europe: Society and Environment, D. Pinder, ed., pp. 435–454. Chichester: Wiley.

117. Hansen, Amy (2007) The Ecotourism Industry and the Sustainable Tourism Eco-Certification Program (STEP) (http://irps.ucsd.edu/assets/021/8446.pdf, last accessed March 2012)

118. Harris, S.M. (2007). Does sustainability sell? Market responses to sustainability certification. Management of Environmental Quality: An International Journal 18(1), 50-6

119. He, L., Chen, W., Conzelmann, G., 2012. Impact of vehicle usage on consumer choice of hybrid electric vehicles. Transp. Res. Part D Transp. Environ. 17, 208–214. doi:10.1016/j.trd.2011.11.005

120. HEI (2010). Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects. HEI Special Report 17. Health Effects Institute, Boston, MA.

121. Henriques, N., Bento, C., 2013. Integration of GPS Traces and Digital Elevation Maps for Improving Bicycle Traffic Simulation Behavior. 92th Annu. Meet. Transp. Res. Board 2013.

122. Herrera, J.C., Work, D.B., Herring, R., Ban, X. (Jeff), Jacobson, Q., Bayen, A.M., 2010. Evaluation of traffic data obtained via GPS-enabled mobile

phones: The Mobile Century field experiment. Transp. Res. Part C Emerg. Technol. 18, 568–583. doi:10.1016/j.trc.2009.10.006

123. Hertz (2011), 2010 - Green Initiatives at the Hertz Corporation, The Hertz Corporation, Michigan, USA

124. Hess, S., Daly, A., Batley, R., 2018. Revisiting consistency with random utility maximisation: theory and implications for practical work. Theory Decis. doi:10.1007/s11238-017-9651-7

125. Honey, Martha (2002). Ecotourism & Certification: Setting Standards in Practice. Island Press,

126. Honey, Martha (2008). Ecotourism and Sustainable Development: Who Owns Paradise? (Second ed.). Washington, DC: Island Press. pp. 29–31. ISBN 1597261254 ISBN 978-1597261258.

127. Hood, J., E. Sall, and B. Charlton (2011). A GPS-Based Bicycle Route Choice Model For San Francisco, California. Transportation Letters: The International Journal of Transportation Research. Volume 3, issue 1, pp. 63-75.

128. Howard, D., 2014. Public Perceptions of Self-driving Cars: The Case of Berkeley, California. MS Transp. Eng. 2014, 21.

129. Howard, D. Public Perceptions of Self-driving Cars: The Case of Berkeley, California. MS Transp. Eng. 2014.

130. Hoyer, K. (2000). Sustainable tourism or sustainable mobility? The Norwegian case., Journal of Sustainable Tourism, 8(2), 147–159.

131. Hurtubia, R., Nguyen, M.H., Glerum, A., Bierlaire, M., 2014. Integrating psychometric indicators in latent class choice models. Transp. Res. Part A Policy Pract. 64, 135–146. doi:10.1016/j.tra.2014.03.010

132. Inskeep, E., (ed.), (1991) Tourism Planning: An Integrated and Sustainable Development Approach. New York: Van Nostrand Reinhold.

133. International Organization for Standardization (ISO), www.iso.org (last accessed on April 1st, 2012)

134. IPCC, 2013. IPCC Fifth Assessment Report (AR5). IPCC s. 10-12.
135. Jackson, G., & Morpeth, N. (1999). Local Agenda 21 and community participation in tourism policy and planning: Future or fallacy. Current Issues in Tourism, 2(1), 1–38.
136. Jacobson M.Z. (2002). Atmospheric Pollution. History, Science and Regulation, Cambridge University Press, pp.399.
137. Jiang, G., Z. Yuan, C. Yang, and Z. Li (2012). Capturing the Interdependencies Between Bicycle Usage and Activity Patterns: Case Study of Bengbu, China. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC.
138. Jin, S., Qu, X., Zhou, D., Xu, C., Ma, D., Wang, D., 2015. Estimating cycleway capacity and bicycle equivalent unit for electric bicycles. Transp. Res. Part A Policy Pract. 77, 225–248. doi:10.1016/j.tra.2015.04.013
139. Jones, S.G., Fisher, B.E.A., Gonzalez-Flesca, N., Sokhi, R. (2000). The use of measurement programmes and models to assess concentrations next to major roads in urban areas, Environmental Monitoring and Assessment, 64, 531–547.
140. Jonnalagadda, N., J. Freedman, W. Davidson, J. Hunt (2001). Development Of A Micro-Simulation Activity-Based Model For San Francisco – Destination And Mode Choice Models. Transportation Research Record, 1777, Washington, DC, pp. 25–30.
141. Jungers B.D., Kear T., Niemeier D. (2006). A Survey of Air Quality Dispersion Models for Project Level Conformity Analysis, UC Davis-Caltrans Air Quality Project, Task Order No. 44, retrieved from http://aqp.engr.ucdavis.edu/Documents/Dispersion-Model-Report-Fnl.pdf.
142. Jönsson, L. (2010). Planning in Malmö. Streets and Parks Department, City of Malmö.

143. Kamargianni, M., A. Polydoropoulou, and K. Goulias. Teenager's Travel Patterns for School and After-School Activities. Procedia - Social and Behavioral Sciences, Vol. 48, 2012, pp. 3635–3650.
144. Kamargianni, M., Polydoropoulou, A., 2014. Generation {Y}'s {Travel} {Behavior} and {Perceptions} of {Walkability} {Constraints}. Transp. Res. Rec. J. Transp. Res. Board pp 59----71. doi:10.3141/2430-07
145. Kamargianni, M., Polydoropoulou, A., Goulias, K.G., 2012. "Teenager's Travel Patterns for School and After-School Activities." Procedia - Soc. Behav. Sci. 48, 3635–3650. doi:10.1016/j.sbspro.2012.06.1326
146. Kapros, S, and G Proios. Traffic study in Kampos area of Chios. Chios, 2008.
147. Kasemsuppakorn, P., Karimi, H.A., 2013. A pedestrian network construction algorithm based on multiple GPS traces. Transp. Res. Part C Emerg. Technol. 26, 285–300. doi:10.1016/j.trc.2012.09.007
148. Kato, H., Matsumoto, M. (2008). Intra-household interaction in a nuclear family: A utility-maximizing approach. Transportation Research Part B (in this special issue).
149. Kestenbaum, D. (2009), Green certification for the transportation sector: Evaluation of a pilot certification program for the motorcoach industry, Transportation Research Centre, University of Vermont.
150. Kim, H.J., D.H. Kim, and J.H. Chung (2004). Weekend Activity and Travel Behavior in a Developing Country: Empirical Study Using Multilevel Structural Equation Models. Transportation Research Record, 1894.
151. Kitamura, R. and S. Fujii (1998). Two Computational Process Models of Activity-travel Behavior. In T. Gärling, T. Laitila and K. Westin (eds.) Theoretical Foundations of Travel Choice Modeling, Pergamon Press, Oxford, pp. 251-279.

152. Krizek, K., Waddell, P., 2002. Analysis of Lifestyle Choices: Neighborhood Type, Travel Patterns, and Activity Participation. Transp. Res. Rec. 1807, 119–128. doi:10.3141/1807-15

153. ktelchios.gr. About KTEL. Chios, 2010.

154. Kyriakidis, M., Happee, R., Winter, J.C.F. De, 2015. Public opinion on automated driving : Results of an international questionnaire among 5 , 000 respondents. Transp. Res. Part F Traffic Psychol. Behav. 32, 127–140. doi:http://dx.doi.org/10.2139/ssrn.2506579

155. Lamont, M. (2009), Independent Bicycle Tourism: A whole tourism systems perspective., Tourism Analysis, Vol. 14, pp. 605-620

156. Larson, P.D., Viáfara, J., Parsons, R. V., Elias, A., 2014. Consumer attitudes about electric cars: Pricing analysis and policy implications. Transp. Res. Part A Policy Pract. 69, 299–314. doi:10.1016/j.tra.2014.09.002

157. Lightfoot, S., Burchell, J., 2004. Green hope or greenwash? The actions of the European Union at the World Summit on sustainable development. Glob. Environ. Chang. doi:10.1016/j.gloenvcha.2004.07.002

158. Litinas, N., Kapros, S., Polydoropoulou, A., 2009. Change of Values and Transportation Needs: Towards a New Transportation Strategic Planning Methodology Nicolaos Litinas, Seraphim Kapros and Amalia Polydoropoulou. Chapter 6, 1–22.

159. Liu, F., J.E. Evans, T. Rossi (2012). Recent Practices in Regional Modeling of Non-Motorized Travel. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC.

160. Liu, R., and Y. Deng (2008). Developing Statewide Weekend Travel Demand Forecast and Mode Choice Models for New Jersey. Paper presented at the 88th Annual Meeting of the Transportation Research Board, Washington, DC.

161. Lohmeyer, A. Baechlin W. and Ketzel M. (2000). The Draft of the New German Guideline VDI 3782/8 to Model Automobile Exhaust Dispersion, Environmental Monitoring and Assessment 65, 381–387.
162. Lumsdon, L. (1996), Cycle tourism in Britain. Insights 1996 (March), D27-D32
163. Lumsdon, L., and S. Page (2004), Tourism and Transport-Issues for the New Millennium. Oxford: Elsevier.
164. Lyviakis, G. The greek geography of crisis. Eleftherotypia, 2009: 14.
165. Management & Marketing, Leeds Metropolitan University, (http://ecoclub.com/news/050/expert.html#1, last accessed March 2012)
166. Manski, C.F., Sherman, L., 1980. An empirical analysis of household choice among motor vehicles. Transp. Res. Part A Gen. doi:10.1016/0191-2607(80)90054-0
167. McDonald S, Oates C, Young CW, Hwang K. 2006. Toward sustainable consumption: Researching voluntary simplifiers. Psychology and Marketing
168. McFadden, D., 1999. Rationality for economists? J. Risk Uncertain. 19, 73–105. doi:10.1023/A:1007863007855
169. McFadden, D., 2001. Disaggregate Behavioral Travel Demand's RUM Side A 30-Year Retrospective. Travel Behav. Res. Lead. edge 2000, 17–64. doi:10.1.1.26.6944
170. Mcnally, M.G., 2007. The Four Step Model, in: Handbook of Transport Modeling. pp. 35–52. doi:https://escholarship.org/uc/item/0r75311t
171. Melas D. (2007). Atmospheric Diffusion and Dispersion, Aristotle University of Thessaloniki, Department of Physics, Atmospheric Physics Laboratory (in Greek).
172. Mendonidi, A. Chios town as an special case, living and evolving without urban planning since 1923. Post-graduate thesis, Athens: NTUA, 2009.

173. Miller, E.J. (2005). Propositions for modelling household decision-making. In: Lee-Gosselin, M., Doherty, S. (Eds.), Integrated Land-Use and Transportation Models: Behavioural Foundations. Elsevier, New York, pp. 21–59.
174. Miller, E.J., Roorda, M.J., 2003. Propotype model of household activity travel scheduling. Transportation Research Record: Journal of the Transportation Research Board 1831, 114–121.
175. Motoaki, Y., Daziano, R.A., 2015. A hybrid-choice latent-class model for the analysis of the effects of weather on cycling demand. Transp. Res. Part A Policy Pract. 75, 217–230. doi:10.1016/j.tra.2015.03.017
176. Mousiopoulos N. (1997). Mathematical Models of Atmospheric Pollution, Zitis Publishers, pp. 107 (in Greek).
177. Moussiopoulos, N., Sahm, P., Karatzas, K., Papalexiou, S., Karagiannidis, A. (1997). Assessing the impact of the New Athens airport to urban air quality with contemporary air pollution models, Atmospheric Environment, 31(10),1497–1511
178. Murakami, E., Wagner, D.P., 1999. Can using Global Positioning System (GPS) improve trip reporting? Transp. Res. Part C Emerg. Technol. 7, 149–165. doi:10.1016/S0968-090X(99)00017-0
179. Nellthorp, J., et al. (2001). Valuation conventions for UNITE, UNIfication of accounts and marginal costs for transport efficiency. UK: University of Leeds.
180. Nomoi 2010. economic and social analysis of the greek prefectures, Athens: EFG - Eurobank, 2010.
181. Noppers, E.H., Keizer, K., Bockarjova, M., Steg, L., 2015. The adoption of sustainable innovations: The role of instrumental, environmental, and symbolic attributes for earlier and later adopters. J. Environ. Psychol. 44, 74–84. doi:10.1016/j.jenvp.2015.09.002
182. Nordlund, A., Jansson, J., Westin, K., 2016. New Transportation Technology: Norm Activation Processes and the Intention to Switch to an Electric/Hybrid

Vehicle, Transportation Research Procedia. Presentation at the Transport Research Arena, Warsaw, Poland. doi:10.1016/j.trpro.2016.05.334

183. Ottman, J. (1992), Industry's Response to Green Consumerism, Journal of Business Strategy, (July/August), 3-7.

184. Outwater, M.L., and B. Charlton (2008). The San Francisco Model In Practice: Validation, Testing, And Application. Innovations in travel demand modeling: summary of a conference, vol 2, Number 42 in Transportation Research Board Conference Proceedings, pp. 24–29.

185. Outwater M.L., and B. Charlton (2006). The San Francisco Model In Practice: Validation, Testing, And Application. Paper presented at the Innovations in Travel Modeling 2006 Conference, Austin, TX, 21–23, May 2006.

186. Papinski, D., Scott, D.M., Doherty, S.T., 2009. Exploring the route choice decision-making process: A comparison of planned and observed routes obtained using person-based GPS. Transp. Res. Part F Traffic Psychol. Behav. 12, 347–358. doi:10.1016/j.trf.2009.04.001

187. Pattabhiraman, V., M. Ben-Akiva, and M. Abou-Zeid (2012). A Needs-Based Utility Maximizing Model of Activity Location, Duration, and Frequency. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC

188. Payre, W., Cestac, J., Delhomme, P., 2014. Intention to use a fully automated car: Attitudes and a priori acceptability. Transp. Res. Part F Traffic Psychol. Behav. 27, 252–263. doi:10.1016/j.trf.2014.04.009

189. PB Consultant (2005). The MORPC Travel Demand Model: Validation and Final Report. February 10, 2005.

190. Pendyala, R., 2002. Time Use and Travel Behavior in Space and Time. In: W. Chen, ed. Transportation Systems Planning: Methods and applications. s.l.:CRC Press.

191. Pendyala, R., 2003. Time Use and Travel Behaviour in Space and Time, in: Transportation System Planning: Methods and Application, New Directions in Civil Engineering. CRC Press. doi:doi:10.1201/9781420042283.ch2
192. Pendyala, R., C.K. Konduri , Y. Chiu, M. Hickman, H. Noh, P. Waddell , L. Wang, D. You and B. Gardner (2012). An Integrated Land Use – Transport Model System With Dynamic Time-Dependent Activity-Travel Microsimulation. Paper presented at the 91st Annual Meeting of the Transportation Research Board, Washington, DC.
193. Pendyala, R., T. Yamamoto,and R. Kitamura. On the formulation of time-space prisms to model constraints on personal activity-travel engagement. Transportation, 29, 2002, pp. 73–94.
194. Pendyala, R.M. (2004). Phased Implementation of a Multimodal Activity-Based Travel Demand Modeling System in Florida. Final Report. Volume II: FAMOS Users Guide. Research Center, Florida Department of Transportation, Tallahassee. www.eng.usf.edu/~pendyala/publications/report/FAMOS%20Users%20Guide.pdf
195. Pendyala, R. M., R. Kitamura, A. Kikuchi, T. Yamamoto, and S. Fujii (2005). FAMOS: The Florida Activity Mobility Simulator. Transportation Research Record: Journal of the Transportation Research Board, No. 1921, Transportation Research Board of the National Academies, Washington, D.C., pp. 123–130.
196. Pendyala, R.M., Y. Chiu, M. Hickman, P. Waddell, and B. Gardner (2010). Towards an Integrated Model of Location Choices, Activity-Travel Behavior, and Dynamic Traffic Patterns. 3rd International Conference on Innovations in Travel Modeling (ITM), Tempe, Arizona, May 10-12, 2010.
197. Pendyala, R.M., Yamamoto, T., Kitamura, R., 2002. On the formulation of time-space prisms to model constraints on personal activity-travel engagement. Transportation (Amst). 29, 73–94. doi:10.1023/A:1012905110686

198. Petersen and Rumsey (1987). User's Guide for PAL 2.0 A Gaussian Plum Algorithm for Point, Area, Line Sources, EPA/600/S8-87/009May 1987.
199. Petschnig, M., Heidenreich, S., Spieth, P., 2014. Innovative alternatives take action – Investigating determinants of alternative fuel vehicle adoption. Transp. Res. Part A Policy Pract. 61, 68–83. doi:10.1016/j.tra.2014.01.001
200. Pierce, P., Isakov, V., Haneke,B. and James Paumier J. (2008). Emission and Air Quality Modeling Tools for Near-Roadway Applications, EPA/600/R-09/001.
201. Pinjari, A., N. Eluru, R. Copperman, I.N. Sener, J.Y. Guo, S. Srinivasan, C.R. Bhat (2006). Activity-Based Travel-Demand Analysis for Metropolitan Areas in Texas: CEMDAP Models, Framework, Software Architecture and Application Results. Technical Report. Available on: http://www.utexas.edu/research/ctr/pdf_reports/4080_8.pdf
202. Plötz, P., Schneider, U., Globisch, J., Dütschke, E., 2014. Who will buy electric vehicles? Identifying early adopters in Germany. Transp. Res. Part A Policy Pract. 67, 96–109. doi:10.1016/j.tra.2014.06.006
203. Potoglou, D., Kanaroglou, P.S., 2007. Household demand and willingness to pay for clean vehicles. Transp. Res. Part D Transp. Environ. 12, 264–274. doi:10.1016/j.trd.2007.03.001
204. Pucher, J., and R. Buehler (2007). At the Frontiers of Cycling: Policy Innovations in the Netherlands, Denmark, and Germany. Bloustein School of Planning and Public Policy Rutgers University.
205. Pucher, J., and R. Buehler (2008). Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. Transport Reviews, Vol. 28, No. 4, pp. 495–528.
206. R.S. Anderson (2005). MORPC Model Validation – Summary.

207. Reumers, S., Liu, F., Janssens, D., Cools, M., Wets, G., 2012. Semantic Annotation of Global Positioning System Traces: Activity Type Inference, Journal of the Transportation Research Board. TRB. Washington, DC.
208. Ricardo Hurtubia, My Hang Nguyen, Aurélie Glerum, Michel Bierlaire, Integrating psychometric indicators in latent class choice models, Transportation Research Part A: Policy and Practice, Volume 64, 2014, Pages 135-146
209. Ritchie, B. W. (1998). Bicycle tourism in the South Island of New Zealand: Planning and management issues. Tourism Management, 19(6), 567–582
210. Ritchie, B. W., & Hall, C. M. (1999). Bicycle tourism and regional development: A New Zealand case study. Anatolia: An International Journal of Tourism and Hospitality Research, 10(2), 89–112
211. Roorda, M.J., Carrasco, J.A., Miller, E.J., (2009). An Integrated Model Of Vehicle Transactions, Activity Scheduling And Mode Choice. Transportation Research Part B.
212. Roorda, M.J., Doherty, S.T., Miller, E.J., (2005). Operationalizing Household Activity Scheduling Models: Addressing Assumptions And Using New Sources Of Behavioural Data. In: Lee-Gosselin, M., Doherty, S. (Eds.), Integrated Land-Use and Transportation Models: Behavioural Foundations. Elsevier, Oxford, pp. 61–85.
213. Roorda, M.J., Miller, E.J., Mohammadian, A. (2000). Toronto Area Car Ownership Study: A Retrospective Interview And Its Applications. Transportation Research Record: Journal of the Transportation Research Board 1719, 69–76.
214. Russel A. & Dennis, R. (2000). NARSTO critical review of photochemical models and modeling, Atmospheric Environment, 34, 228-2324.
215. SAE International, 2014. Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems. SAE Int. J3016, 1–12. doi:10.4271/J3016_201609

216. Sall, E.A. and C.R. Bhat (2007). An Analysis of Weekend Work Activity Patterns in the San Francisco Bay Area. Transportation, Vol. 34, pp. 161-175.
217. Sallis, J.F., Frank, L.D., Saelens, B.E., Kraft, M.K., 2004. Active transportation and physical activity: Opportunities for collaboration on transportation and public health research. Transp. Res. Part A Policy Pract. 38, 249–268. doi:10.1016/j.tra.2003.11.003
218. Santos, G., Behrendt, H., Teytelboym, A., 2010. Part II: Policy instruments for sustainable road transport. Res. Transp. Econ. doi:10.1016/j.retrec.2010.03.002
219. Sasic, A., Habib, K.N., 2013. Modelling departure time choices by a Heteroskedastic Generalized Logit (Het-GenL) model: An investigation on home-based commuting trips in the Greater Toronto and Hamilton Area (GTHA). Transp. Res. Part A Policy Pract. 50, 15–32. doi:10.1016/j.tra.2013.01.028
220. Schreyer, C., et al. (2004). External costs of transport—Update study. October 2004, INFRAS/IWW, University of Karlsruhe, Zurich.
221. Schuitema, G., Anable, J., Skippon, S., Kinnear, N., 2013. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. Transp. Res. Part A Policy Pract. 48, 39–49. doi:10.1016/j.tra.2012.10.004
222. Schönfelder, S., Axhausen, K., Antille, N., 2002. Exploring the Potentials of Automatically Collected GPS Data for Travel Behaviour Analysis: A Swedish Data Source.
223. Seigneur C. & Dennis R. (2011). Atmospheric Modeling, in: G. M. Hidy et al. (eds.), Technical Challenges of Multipollutant Air Quality Management, DOI 10.1007/978-94-007-0304-9_9, Springer Science+Business Media, pp. 299-337.
224. Sen, A., Smith, T.E., 1995. Gravity Models of Spatial Interaction Behavior. Springer Science & Business Media. doi:10.1007/978-3-642-79880-1

225. Shafiei, E., Thorkelsson, H., Ásgeirsson, E.I., Davidsdottir, B., Raberto, M., Stefansson, H., 2012. An agent-based modeling approach to predict the evolution of market share of electric vehicles: A case study from Iceland. Technol. Forecast. Soc. Change 79, 1638–1653. doi:10.1016/j.techfore.2012.05.011
226. Shiftan, Y., and M. Ben-Akiva (2011). A Practical Policy-Sensitive, Activity-Based, Travel-Demand Model. Special issue of Annals of Regional Science of the 3rd Israel-Netherlands Workshop in Regional Science.
227. Shiftan, Y., M. Ben-Akiva, K. Proussaloglou, G. de Jong, Y. Popuri, K. Kasturirangan, and S. Bekhor (2003). Activity-Based Modeling as a Tool for Better Understanding Travel Behaviour. 10th International Conference on Travel Behaviour Research, Lucerne, 10-15 August 2003.
228. Simonsen, P. and Jorgenson, B. (1996), Cycling tourism: environmental and economical sustainability, Bornholm Research Centre, Denmark
229. Skippon, S., Garwood, M., 2011. Responses to battery electric vehicles: UK consumer attitudes and attributions of symbolic meaning following direct experience to reduce psychological distance. Transp. Res. Part D Transp. Environ. 16, 525–531. doi:10.1016/j.trd.2011.05.005
230. Skippon, S.M., 2014. How consumer drivers construe vehicle performance: Implications for electric vehicles. Transp. Res. Part F Traffic Psychol. Behav. 23, 15–31. doi:10.1016/j.trf.2013.12.008
231. Smith, B. W. SAE levels of driving automation. http://cyberlaw.stanford.edu/blog/2013/12/sae-levels-driving-automation. Accessed Aug. 1, 2016.
232. Spissu, E., A.R. Pinjari, R.M. Pendyala, and C.R. Bhat (2009). A Copula-Based Joint Multinomial Discrete-Continuous Model Of Vehicle Type Choice And Miles Of Travel. Transportation 36(4), pp. 403–422.

233. Srinivasan, S., Bhat, C.R., 2008. An exploratory analysis of joint-activity participation characteristics using the American Time Use Survey. Transportation 35 (3), 301–328.
234. Stabler, M., Papatheodorou, A. and Sinclair, M. T. (2010) The Economics of Tourism, second edition, London: Routledge.
235. Steg, L., 2005. Car use: Lust and must. Instrumental, symbolic and affective motives for car use. Transp. Res. Part A Policy Pract. 39, 147–162. doi:10.1016/j.tra.2004.07.001
236. Stopher, P.R., Greaves, S.P., 2007. Household travel surveys: Where are we going? Transp. Res. Part A Policy Pract. 41, 367–381. doi:10.1016/j.tra.2006.09.005
237. Stopher Peter R.andCollins, A., 2005. Conducting a {GPS} Prompted Recall Survey over the Internet, in: 84th Annual Meeting of the Transportation Research Board.
238. Summala, H., 2007. Towards understanding motivational and emotional factors in driver behaviour: Comfort through satisficing, in: Modelling Driver Behaviour in Automotive Environments: Critical Issues in Driver Interactions with Intelligent Transport Systems. pp. 189–207. doi:10.1007/978-1-84628-618-6_11
239. Sun, Y., Toledo, T., Rosa, K., Ben-Akiva, M., Flanagan, K., Sanchez, R., Spissu, E., 2013. Route Choice Characteristics for Truckers. Transp. Res. Rec. J. Transp. Res. Board 2354, 115–121. doi:10.3141/2354-12
240. Swait, J. Structural equation model of latent segmentation and product choice for cross-sectional revealed preference choice data Journal of Retail and Consumer Services, 1 (2) 1994, pp. 77–89
241. Swarbrooke, J. and Horner, S., 2007. Consumer behaviour in tourism. 2nd ed. Oxford:

242. Tierney, P., Hunt, M. & Latkova, P. (2011). Do Travelers Support Green Practices and Sustainable Development, Journal of Tourist Insights, 2(2):5.
243. Tilahun, N.Y., Levinson, D.M., Krizek, K.J., 2007. Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey. Transp. Res. Part A Policy Pract. 41, 287–301. doi:10.1016/j.tra.2006.09.007
244. Timmermans, H.J.P., J. Zhang (2009). Modeling Household Activity Travel Behavior: Examples Of State Of The Art Modeling Approaches And Research Agenda. Transportation Research Part B, 43 (2), pp. 187–190.
245. Tsouros, I., A. Polydoropoulou, and A. Tsirimpa. A hybrid choice model for alternative fuel car purchase. Presentation at the International Choice Modelling Conference, Austin, TX, 2015
246. Tsouros, I., Goulias, K., Polydoropoulou, A., Tsirimpa, A., 2015a. Rhythms in urban and island areas: How does lifestyle affect daily dynamics?, in: 95th Annual Meeting of the Transportation Research Board. Washington, DC.
247. Tsouros, I., Polydoropoulou, A., 2014. Data-Rich Environments: Integrating GPS traces with GIS cognitive maps for a sustainable transport analysis, in: 2nd International Conference on Sustainable Mobility. Volos, Greece.
248. Tsouros, I., Polydoropoulou, A., 2017. Who Will Buy Alternative Fueled or Automatic Vehicles: A Modular, Behavioral Modelling Approach, in: Transportation Research Board 96th Annual Meeting.
249. Tsouros, I., Polydoropoulou, A., Goulias, K., 2015b. GPS Data Collection for Active Transport Modes and Design of Real Life Experiments, in: 7th International Conference on Transport Research. Athens, Greece.
250. Tsouros, I., Polydoropoulou, A., Tsirimpa, A., 2015c. A Hybrid Choice Model for Alternative Fuel Car Purchase, in: 14th International Conference on Travel Behaviour Research, London, UK.

251. Tsouros, I., Polydoropoulou, A., Tsirimpa, A., 2015d. A Hybrid Choice Model for Alternative Fuel Car Purchase, in: International Choice Modelling Conference.
252. UNEP (2005) Marketing Sustainable Tourism Products. United Nations Environment Programme, Paris, France.
253. UNEP (2006). Tourism Certification as a Sustainability Tool: Assessment and Prospects http://www.fairtourismsa.org.za/pdffiles/tourism_certification_as_sustainability_report.pdf, last accessed March 2012)
254. United Nations Environmental Programme (UNEP): http://www.unep.fr/scp/tourism/sustain/ , last accessed 2012.
255. United Nations General Assembly, 2015. Transforming our world: The 2030 agenda for sustainable development, https://sustainabledevelopment.un.org/content/documents/7891Transforming%20Our%20World. pdf. doi:10.1007/s13398-014-0173-7.2
256. Van Doren, C., and S. Lollar (1985), The Consequences of Forty Years of Growth. Annals of Tourism Research 12:467–489.
257. Vardoulakis S., Fisher B.E.A, Pericleous K., Gonzalez-Flescac N. (2003). Modeling air quality in street canyons: a review, Atmospheric Environment, 37, 155–182.
258. Vieira, J., Moura, F., & Viegas, J. M. (2007). Transport policy and environmental impacts: The importance of multi-instrumentality in policy integration. Transport Policy, 14(5), 421-432.
259. Vij, A., Walker, J.L., 2016. How, when and why integrated choice and latent variable models are latently useful. Transp. Res. Part B Methodol. 90, 192–217. doi:10.1016/j.trb.2016.04.021
260. Vovsha, P., E. Petersen, and R. Donnelly (2002). Micro-Simulation In Travel Demand Modeling: Lessons Learned From The New York Best Practice Model. Transportation Research Record, 1805 (2002), pp. 68–77.

261. Wackernagel, M., & Rees, W. (1995). Our ecological footprint: reducing human impact on the earth. New Society Publishers.
262. Wang, B.-C., Chou, F.-Y., & Lee, Y.-J. (2012). Ecological footprint of Taiwan: A discussion of its implications for urban and rural sustainable development. Computers, Environment and Urban Systems, 2009. Elsevier Ltd.
263. Wang, D., and J. Li (2009). A Model Of Household Time Allocation Taking Into Consideration Of Hiring Domestic Helpers. Transportation Research Part B, 43 (2), pp. 204–216.
264. Wending, B., 2014. Automated Vehicle Standards and Best Practices - Definitions & Taxonomy , 2014 Automated Vehicles Symposium. Presentation at theAutomated Vehicles Symposium, San Francisco, CA.
265. William H. Greene, David A. Hensher, A latent class model for discrete choice analysis: contrasts with mixed logit, Transportation Research Part B: Methodological, Volume 37, Issue 8, 2003, Pages 681-698
266. Wolf, J., Guensler, R., Bachman, W., 2001. Elimination of the travel diary: Experiment to derive trip purpose from global positioning system travel data. Transp. Res. Rec. 1768, 125–134. doi:10.3141/1768-15
267. Wolf, J., Loechl, M., Myers, J., Arce, C., 2003. Trip Rate Analysis in {GPS}-Enhanced Personal Travel Surveys, Transport Survey Quality and Innovation. Transport Survey Quality and Innovation. doi:10.1108/9781786359551-028
268. Woodcock, J., Banister, D., Edwards, P., Prentice, A. M., & Roberts, I. (2007). Energy and transport. Lancet, 370(9592), 1078-88.
269. World Tourism Organization (WTO): http://unwto.org/, last accessed March 2012.
270. World Travel & Tourism Council (WTTC): http://www.wttc.org/, last accessed March 2012.
271. WWF (2000) Tourism Certification: An Analysis of Green Globe 21 and Other Tourism Certification Programmes. UK, Synergy

272. Xenias, D., Whitmarsh, L., 2013. Dimensions and determinants of expert and public attitudes to sustainable transport policies and technologies. Transp. Res. Part A Policy Pract. 48, 75–85. doi:10.1016/j.tra.2012.10.007
273. Ye, X., R.M. Pendyala, and G. Gottardi (2007). An Exploration of the Relationship between Mode Choice and Complexity of Trip Chaining Patterns. Transportation Research Part B, Vol. 41, 2007, pp. 96-113.
274. Young, W., Hwang, K, McDonald, S. and Oates, C.J. (2008). Sustainable consumption: green consumer behavior when purchasing products (http://www.idea.leeds.ac.uk/documents/Young.pdf, last accessed March 2012).
275. Zannetti P. (1990). Air Pollution Modeling. Theories, Computational Methods and Available Software, Computational Mechanics Publications, pp. 444.
276. ZEUS (2000). Procurement And Demonstration Of Clean Vehicles Within The Framework Of An EU Project. Final Report.
277. Zhang, J., Fujiwara, A. (2006). Representing household time allocation behavior by endogenously incorporating diverse intra-household interactions: a case study in the context of elderly couples. Transportation Research Part B 40 (1), 54–74.
278. Zhang, J., Fujiwara, A. (2008). Models of household activity and travel behaviors with group decision-making mechanisms in Japan. In: Synthesis Report for the workshop on ''Group Behavior, Proceedings of the 11th International Conference on Travel Behaviour Research, Kyoto, August 16–20.
279. Zhang, J., Timmermans, H.J.P., Borgers, A. (2002). A utility-maximizing model of household time use for independent, shared and allocated activities incorporating group decision mechanisms. Transportation Research Record, 1807, pp. 1–8.

280. Zhou, J., Lin, J., Cui, S., Qiu, Q., & Zhao, Q. (2012). Exploring the relationship between urban transportation energy consumption and transition of settlement morphology: A case study on Xiamen Island, China. Habitat International, Elsevier Ltd.
281. Ziegler, A., 2012. Individual characteristics and stated preferences for alternative energy sources and propulsion technologies in vehicles: A discrete choice analysis for Germany. Transp. Res. Part A Policy Pract. 46, 1372–1385. doi:10.1016/j.tra.2012.05.016
282. Zoepf, S.M., Keith, D.R., 2016. User decision-making and technology choices in the U.S. carsharing market. Transp. Policy. doi:10.1016/j.tranpol.2016.01.010
283. Zorn, L., E. Sall, and B. Charlton. (2011). Incorporating Discrete Characteristics and Network Relationships of Parking into the SF-CHAMP Travel Model. Paper presented at TRB Innovations in Travel Modeling conference, May 12-13, in Tempe, AZ.
284. Zubrin, R. (2007). Energy victory: winning the war on terror by breaking free of oil. Amherst, New York: Prometheus Books

Appendix A – Household Questionnaire

Available online (in Greek): http://daphne-new.chios.aegean.gr/~surveys/gretiaL

Appendix B – Member Questionnaire

Available online (in Greek): http://daphne-new.chios.aegean.gr/~surveys/member_sample

Appendix C – Activity Diary

Available online (in Greek): http://daphne-new.chios.aegean.gr/~surveys/activity_sample

Appendix D – Future fleet purchase experiments

Available online (in Greek): http://daphne-new.chios.aegean.gr/~surveys/CAV