ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΙΓΑΙΟΥ

ΤΜΗΜΑ ΝΑΥΤΙΛΙΑΣ ΚΑΙ ΕΠΙΧΕΙΡΗΜΑΤΙΚΩΝ ΥΠΡΕΣΙΩΝ

ΔΙΑΤΡΙΒΗ

για την απόκτηση διδακτορικού διπλώματος του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών

Θεοφανή Χατζηιωαννίδου

Προσομοίωση συστήματος μεταφορών ακτοπλοΐας και αεροπλοΐας Αιγαίου Αρχιπελάγους με χρήση προηγμένων μοντέλων δημοσίων συγκοινωνιών

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Χίος, 2021

UNIVERSITY OF THE AEGEAN

DEPARTMENT OF SHIPPING TRADE AND TRANSPORT

THESIS

for acquiring the doctor of philosophy diploma at the Department of Shipping Trade and Transport

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Transport simulation of maritime and aviation network in the Aegean Archipelagos using public transport modelling concepts

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Δηλώνω υπεύθυνα ότι είμαι η αποκλειστική συγγραφέας της υποβληθείσας Διδακτορικής Διατριβής με τίτλο «Προσομοίωση συστήματος μεταφορών ακτοπλοΐας και αεροπλοΐας Αιγαίου Αρχιπελάγους με χρήση προηγμένων μοντέλων δημοσίων συγκοινωνιών». Η συγκεκριμένη Διδακτορική Διατριβή είναι πρωτότυπη και εκπονήθηκε αποκλειστικά για την απόκτηση του Διδακτορικού διπλώματος του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών. Κάθε βοήθεια, την οποία είχα για την προετοιμασία της, αναγνωρίζεται πλήρως και αναφέρεται επακριβώς στην εργασία. Επίσης, επακριβώς αναφέρω στην εργασία τις πηγές, τις οποίες χρησιμοποίησα, και μνημονεύω επώνυμα τα δεδομένα ή τις ιδέες που αποτελούν προϊόν πνευματικής ιδιοκτησίας άλλων, ακόμη κι εάν η συμπερίληψή τους στην παρούσα εργασία υπήρξε έμμεση ή παραφρασμένη. Γενικότερα, βεβαιώνω ότι κατά την εκπόνηση της Διδακτορικής Διατριβής έχω τηρήσει απαρέγκλιτα όσα ο νόμος ορίζει περί διανοητικής ιδιοκτησίας και έχω συμμορφωθεί πλήρως με τα προβλεπόμενα στο νόμο περί προστασίας προσωπικών δεδομένων και τις αρχές Ακαδημαϊκής Δεοντολογίας.

Εκτενής περίληψη

Οι στόχοι της διπλωματικής εργασίας είναι η ανάλυση, η εξήγηση, η οπτικοποίηση και η παροχή πληροφοριών για το σύστημα θαλάσσιων επιβατικών μεταφορών στο Αιγαίο Αρχιπέλαγος. Στο πλαίσιο αυτό, επισημαίνονται τα δυνατά σημεία του συστήματος, οι αδυναμίες του, ο ανταγωνισμός και η συμπληρωματικότητα από τις εναέριες συνδέσεις. Η παρούσα πρόταση - προσέγγιση βασίζεται στην ανάπτυξη ενός λεπτομερούς μοντέλου μεταφορών με αξιοποίηση τεχνικών προσομοίωσης δημοσίων συγκοινωνιών. Το μοντέλο αυτό που αναπτύχθηκε για τη συγκεκριμένη περιοχή, επιτρέπει την αξιολόγηση της υφιστάμενης κατάστασης αλλά και την προσομοίωση σεναρίων πολιτικών σχεδιασμού και την αξιολόγησή τους ως προς την βελτίωση του συστήματος. Ως παράδειγμα πολιτικών σχεδιασμού, εξετάζεται το σενάριο υλοποίησης δύο νέων νησιωτικών κόμβων διαμεταφοράς, ως προς την αποδοχή τους από τους χρήστες του συστήματος και την αποτελεσματικότητά τους στην βελτίωση της διασύνδεσης μεταξύ των νησιών.

Για τις ανάγκες αυτής της εργασίας συλλέχθηκε ένας μεγάλος όγκος δεδομένων και πληροφοριών, οι οποίες επεξεργάστηκαν κατάλληλα προκειμένου να περιγράφουν με τη μέγιστη δυνατή ακρίβεια το σύστημα μεταφορών της περιοχής σε ένα λεπτομερές μοντέλο μεταφοράς. Στατιστικές μεταφορών και τουρισμού, ενσωματωθήκαν στο μοντέλο με τρόπο που να επιτρέπουν την ανάλυση της ζήτησης για μεταφορές στα νησιά σε δύο μεγάλες κατηγορίες: τους ημεδαπούς και τους αλλοδαπούς τουρίστες κατά τη διάρκεια της καλοκαιρινής περιόδου αιχμής. Χρησιμοποιούνται προηγμένες τεχνικές μοντελοποίησης δημόσιων συγκοινωνιών και αλγόριθμοι πολυτροπικής ανάθεσης των μετακινήσεων για την προσομοίωση αλυσίδων

ταξιδίου με ενδεχόμενες μετεπιβιβάσεις και τον εντοπισμό των σημαντικών κόμβων διαμεταφοράς της περιοχής. Οι έρευνες σχετικά με τα μοτίβα κινητικότητας από τα αρχεία κινητών τηλεφώνων και σχετικά με τις προτιμήσεις ταξιδιού συνδυάζονται για να βελτιώσουν και να ολοκληρώσουν τη διαδικασία μοντελοποίησης και για διασταύρωση των αποτελεσμάτων.

Το σύστημα μεταφοράς προσομοιώνεται για μία ολόκληρη εβδομάδα (Δευτέρα με Κυριακή) στο μοντέλο, για να συμπεριλάβει θαλάσσια ταξίδια μικρών αλλά και μεγαλύτερων αποστάσεων. Το σύστημα μεταφορών του Αρχιπελάγους αναλύεται ως προς τη ζήτηση και ως προς τα θέματα χωρητικότητας των μέσων ταξιδίου. Επιπλέον, δίνεται ιδιαίτερη έμφαση στο θέμα της διασυνδεσιμότητας μεταξύ των νησιών, στους υφιστάμενους κόμβους διαμεταφορών στην περιοχή, καθώς και στον ανταγωνισμό και τη συμπληρωματικότητα μεταξύ των επίγειων, των θαλάσσιων και των εναέριων μέσων. Το συγκοινωνιακό πρότυπο που αναπτύχθηκε προσφέρει ευκαιρίες για περαιτέρω ανάλυση που περιλαμβάνει βελτιστοποίηση δικτύου, προβλέψεις και σενάρια πολιτικής με γνώμονα τη αειφορία του συστήματος των μεταφορών και την συνοχή στις νησιωτικές περιοχές.

Η συμβολή της τρέχουσας ανάλυσης είναι η γνώση, η κατανόηση και η εκτίμηση του συστήματος μεταφοράς ενός Αρχιπελάγους και των συνδέσεών του με την ηπειρωτική χώρα και με μακρινές χώρες. Συζητούνται πτυχές του συστήματος μεταφορών, η πλευρά της ζήτησης και οι αποφάσεις ταξιδιού. Η κριτική αξιολόγηση παρέχεται με αναλύσεις και οπτικοποιήσεις μέσω ενός μοντέλου προσομοίωσης των μεταφορών.

Οι ιδιαιτερότητες του συστήματος μεταφορών του Αιγαίου Αρχιπελάγους στοιχειοθετούν την συμβολή και προσδίδουν καινοτομία στις μεθοδολογίες που χρησιμοποιήθηκαν στην έρευνα της παρούσας Διατριβής και συγκεκριμένα στους ακόλουθους τρεις τομείς: Δεδομένα, Μοντέλα και Πολιτική. Η καινοτομία στον τομέα των Δεδομένων περιλαμβάνει την αξιοποίηση δεδομένων μεγάλου όγκου από τα αρχεία κινητής τηλεφωνίας του έτους 2013 για τον εντοπισμό των μοτίβων κινητικότητας στο αρχιπέλαγος. Επιπλέον, σχεδιάστηκε και υλοποιήθηκε ένα καινοτόμο ερωτηματολόγιο έρευνας δηλωμένης προτίμησης για την επιλογή διαδρομής για τις εσωτερικές μετακινήσεις. Η συμβολή στον τομέα των Μοντέλων αφορά τη χρήση προηγμένων τεχνικών προσομοίωσης δικτύου δημόσιων συγκοινωνιών προσαρμοσμένων ανάλογα για ταξίδια μεγάλων αποστάσεων προς στα νησιά. Στη θέση των συμβατικών βημάτων μοντελοποίησης επιλογής μέσου μεταφοράς και ανάθεσης στο δίκτυο, εισάγεται μια προσέγγιση στη βάση της επιλογής πολύτροπων διαδρομών για την προσομοίωση αλυσίδων διατροπικών ταξιδιών. Εφαρμόζεται μοντελοποίηση διακριτών επιλογών για την πρόθεση χρήσης λιμενικών κόμβων ως σημείων μετεπιβίβασης στην νησιωτική περιοχή, η οποία παράγει εκτιμήσεις αξίας χρόνου στα επιμέρους τμήματα του ταξιδιού με διάκριση μεταξύ του χρόνου διαδρομής επί του πλοίου και του χρόνου αναμονής μετεπιβίβασης σε συγκεκριμένους λιμένες. Στον τομέα της Πολιτικής, εισάγονται έννοιες από το σχεδιασμό των δημόσιων μεταφορών με έμφαση στην ολοκλήρωση του δικτύου με ένα σύστημα νησιωτικών κόμβων διαμεταφοράς, στρατηγικά χωροθετημένων στο αρχιπέλαγος. Αποδεικνύεται η συμπληρωματικότητα των δρομολογίων και των μέσων μεταφοράς στην περιοχή και προωθείται η συγκεκριμένη πολιτική για την επίτευξη του αποτελέσματος ενοποιημένου δικτύου.

Η διατριβή διαρθρώνεται σε τρία κυρίως Μέρη (Α, Β και Γ), πλέον της Εισαγωγής και Ιστορικού που παρατίθενται στην αρχή και των Συμπερασμάτων που ανακεφαλαιώνονται στο τέλος. Το Μέρος Α παρουσιάζει τη μοντελοποίηση της του πολυτροπικού δικτύου (προσφορά) και την ανάλυση των ελλείψεων στις συνδέσεις. Το Μέρος Β περιγράφει τη μοντελοποίηση της ζήτησης των μεταφορών που προκύπτει από τον συνδυασμό στατιστικών συγκεντρωτικών δεδομένων και μεγάλων δεδομένων από αρχεία κινητών τηλεφώνων. Το Μέρος Γ παρουσιάζει στοιχεία προτιμήσεων ταξιδιού μέσω μιας έρευνας διακριτών επιλογών και επιπλέον παρουσιάζει μια εφαρμογή του μοντέλου στην προσομοίωση μιας πολιτικής νησιωτικών κόμβων διαμεταφορών. Πιο αναλυτικά οι στόχοι του κάθε μέρους της εργασίας έχουν ως εξής:

Ο στόχος του Μέρους Α είναι να εξετάσει την υφιστάμενη λειτουργία του συστήματος υπερνησιωτικών μεταφορών στο Αρχιπέλαγος του Αιγαίου εφαρμόζοντας προηγμένα εργαλεία προσομοίωσης δικτύων με τεχνικές που χρησιμοποιούνται για τη μοντελοποίηση των δημόσιων μεταφορών. Η περιοχή μελέτης ορίζεται ως το Αιγαίο Αρχιπέλαγος με το σύμπλεγμα των νησιών του και τις συνδέσεις τους με την ηπειρωτική Ελλάδα. Από το μοντέλο εξάγονται δείκτες απόδοσης του δικτύου και στατιστικά στοιχεία για το σύστημα συνολικά. Η διερεύνηση που γίνεται στοχεύει στον εντοπισμό των αδυναμιών του δικτύου μεταφορών στην περιοχή μελέτης που αντιστοιχούν στην υπάρχουσα κατάσταση για την καλοκαιρινή περίοδο 2013, όπως για παράδειγμα ελλιπείς συνδέσεις, ζεύγη προέλευσης-προορισμού που δεν εξυπηρετούνται, νησιωτικοί προορισμοί με δύσκολη πρόσβαση κλπ. Το μοντέλο περιλαμβάνει με λεπτομέρεια όλα τα εβδομαδιαία δρομολόγια με τα ακριβή χρονοδιαγράμματα για όλες τις τακτικές συνδέσεις επιβατηγών πλοίων και αεροπλάνων στο Αιγαίο Αρχιπέλαγος και προσομοιώνει με μεγάλη λεπτομέρεια την πλευρά της προσφοράς. Για το λόγο αυτό, αυτή η εφαρμογή μπορεί να χρησιμεύσει επιπλέον ως εργαλείο προγραμματισμού ταξιδιών, προσφέροντας πληροφορίες για βέλτιστες διαδρομές, συνδέσεις, δρομολόγια, σημεία μετεπιβίβαση, χρόνους αναμονής κ.λπ. σε ανά ημέρα και επιθυμητή ώρα αναχώρησης από την προέλευση ή άφιξης στον προορισμό.

Ο στόχος του μέρους Β της διατριβής είναι να διερευνήσει το υπάρχον σύστημα μεταφοράς επιβατικών ροών στο αρχιπέλαγος Αιγαίου που ταξιδεύουν δια θαλάσσης και αέρος κατά την περίοδο αιχμής του καλοκαιριού του 2013. Λόγω των ειδικών συνθηκών της περιοχής μελέτης και του αρχιπελαγικού συγκροτήματος, οι επιτόπιες έρευνες για την εκτίμηση της ζήτησης επιβατών καθίστανται περίπλοκες και ακόμα αδύνατες από οικονομικής πλευράς. Εναλλακτικά, επιλέχθηκε να αναπτυχθεί ένα τυπικό μοντέλο βαρύτητας για την ζήτηση των μετακινήσεων με βάση συγκεντρωτικά στατιστικά δεδομένα που διατίθενται τόσο για τις θαλάσσιες μεταφορές όσο και για τις αεροπορικές μεταφορές στην περιοχή του Αιγαίου. Παρ 'όλα αυτά, υπάρχουν περιορισμοί και αβεβαιότητες στην ανάπτυξη των μητρώων προέλευσης-προορισμού Π-Π από συγκεντρωτικά στατιστικά δεδομένα. Η ανάλυση μεγάλων δεδομένων από αρχεία κινητών τηλεφώνων δείχνει την ανάγκη αναθεώρησης του αρχικού προσεγγιστικού μοντέλου ζήτησης εφαρμόζοντας μια κατάτμησης της ζήτησης σε κατηγορίες μετακινούμενων. Επίσης, η ανάλυση δείχνει ότι θα πρέπει να ληφθούν υπόψη και να μελετηθούν πιο περίπλοκα μοτίβα ταξιδιού και μεγαλύτερες αλυσίδες επιμέρους διαδρομών, τόσο κατά την αξιολόγηση της υφιστάμενης κατάστασης λειτουργίας του συστήματος όσο και για την εκτίμηση των επιπτώσεων από την εφαρμογή πολιτικών εναλλακτικού σχεδιασμού.

Ο στόχος του μέρους Γ είναι να συμπληρώσει τα προηγούμενα μέρη με μια ανάλυση συμπεριφοράς των επιβατών και τις επιλογές ταξιδιού τους μέσω μιας έρευνας. Πιο συγκεκριμένα η έρευνα αυτή αναμένεται να συμπληρώσει το συγκοινωνιακό πρότυπο με στοιχεία διακριτών επιλογών ταξιδιού και να διερευνήσει τις πτυχές και τις προτιμήσεις λήψης αποφάσεων σχετικών με τις μετακινήσεις. Η ανάλυση που παρουσιάστηκε στο Μέρος Α της έρευνας, έδειξε ότι το υπό μελέτη δίκτυο, έχει πολύ καλή σύνδεση με τα ηπειρωτικά λιμάνια της Αττικής και της Βόρειας Ελλάδας, αλλά υπάρχουν ελλείψεις στη διασύνδεση μεταξύ νησιών που εξυπηρετούνται από διαφορετικές ακτοπλοϊκές γραμμές. Στο Μέρος Γ, προτείνεται και προσομοιώνεται στο μοντέλο ένα σύστημα μικρών κόμβων μετεπιβίβασης. Αυτή η πολιτική αξιολογείται για αναμενόμενες βελτιώσεις στη διασυνδεσιμότητα εντός του Αρχιπελάγους. Η προσέγγιση αυτή μπορεί να εφαρμοστεί σε παρόμοια συστήματα μεταφορών Αρχιπελαγικών περιοχών.

Extended abstract

The objectives of the Thesis are to analyse, explain, visualise and deliver insights on the passenger ferry transport system of the Aegean Archipelagos. The strong points of this system, its weaknesses, the competition and complementarity from air, are discussed. Policy testing and new configurations are possible through a transport simulation model developed for the specific area. An example is given for the acceptance and effectiveness of new connections through two insular minor transfer hubs aiming at improving the interconnection among the islands.

Vast information is gathered and processed adequately to describe the transport system of the area in a detailed transport model. Transport and tourism statistics integrated into the model, assist to estimate the segmentation of the travellers to the islands, in domestic and foreign tourists during the peak summer season. Advanced public transport modelling techniques and

multimodal assignment algorithms are used to simulate trip interchanges and to identify the important transfer hubs of the area. The surveys on mobility patterns from mobile phone records and on travel preferences are combined to complete the modelling process and also for cross-evaluation.

The transport system is simulated for one week in the model, to capture both short and longer distance passenger trips by sea. Insights of the transport system of the Aegean Archipelagos are gained regarding travel patterns, demand and capacity issues. The interconnectivity among the islands is analysed together with the existing transport hubs in the area, competition and complementarity between sea and air modes. The transport model offers opportunities for further analysis that include optimisations, forecasts and policy scenarios for more sustainability and cohesion in the insular areas.

The contribution of the current analysis is knowledge, understanding, and appreciation of the transport system of an Archipelagos and its connections to the mainland and to distant countries. Aspects of the transport system, the demand side and travel decisions are discussed. Critical analysis is provided with analytics and visualisations through a transport model.

The particularities of the transport system of the Aegean Archipelagos add contribution and innovation qualities in the methodologies used in the research of the current Thesis for the following three areas: Data, Model and Policy. Innovation in the Data area includes big data exploitation from mobile phone records in the year 2013 to identify mobility patterns in the archipelagos. Furthermore, an innovative stated preference survey questionary was designed and used on path choice for internal trips. Contribution in the Model area concerns the use of advanced public transport simulation modelling techniques adjusted accordingly for long-distance trips to the islands. In place of the conventional mode choice and assignment to the transport network modelling steps, a multimodal path choice modelling approach is introduced to simulate intermodal trip chains. Discrete choice modelling is applied for the willingness to use port hubs as interchange points in the insular area producing VOT estimations of the trip components with a distinction between in-vessel ride time and transfer wait time at specific ports. In the area of Policy, concepts from public transport planning are introduced focusing on network integration with a system of insular hubs strategically located in the archipelagos. The complementarity of the routes and the modes are justified and promoted to bring the network effect.

The Thesis is structured in three main parts (A, B and C), additionally to the Introduction and Background part and the Conclusions part. Part A presents the modelling of the supply side and analysis of missing links or connections. Part B describes the modelling of the demand side derived by combining statistical aggregated data and big data from mobile phone records. Part C presents elements of disaggregated travel choices through a survey, the model application and policy analysis. More specifically, the three main parts of the Thesis have the following aims:

Part A aims to examine the existing transport system for passenger ship and airplane services in the Aegean Archipelagos by applying advanced transport simulation tools and techniques used for Public transport modelling of the supply side. The study area is defined as the Aegean Sea with its islandic complex and their connections to the Greek mainland. Network performance indicators and statistics are produced for the system overall. The research aims to identify the weaknesses of the transport network in the study area corresponding to the existing situation for the 2013 summer period, such as missing connections, origin-destination pairs not serviced, or difficult to reach destinations. The model includes in detail all the weekly itineraries with their exact time-tables for all the regular Aegean Sea passenger connections and it simulates at a fine level the supply side. For this reason, this application additionally serves as a useful tool for trip scheduling purposes by offering details on shortest routes, connections, itineraries, transfer points, shipping companies etc. on specific dates and time intervals.

Part B of the Thesis aims to investigate the existing transport system for passenger flows in the Aegean archipelagos travelling by sea and air during the peak period of the summer of 2013. Due to the special conditions of the study area and its polynesian complex, on-site surveys for the passenger demand assessment are becoming complicated and inefficient. Alternatively, it was opted to set up in a typical gravity model based on aggregated statistical data available for both maritime and air transport modes operating in the Aegean region. Nevertheless, there are limitations and uncertainties involved in developing an OD matrix from aggregated statistical data. The analysis of big data from mobile phone records shows the need to revise the initial demand model and establish a new demand segmentation. Also to consider more complicated trip patterns and longer trips chains in path formulations, to improve the assessment of the current situation and allow detailed policy testing.

The aim of Part C is to complete the former Parts with a behavioural analysis of the passengers and their travel choices through a survey. More specifically it is anticipated with this survey to complement our work on the simulation model of the existing situation and the mobile phone activity analysis with behavioral characteristics of the passengers and to explore their decision-making aspects and preferences. The analysis presented in Part A of the Thesis, indicated that the network under study, has a very good connection with the mainland ports of Attica and Northern Greece but there are shortcomings in the interconnection among islands that are serviced by different routes. In Part C, a system of minor insular transport interchange hubs is proposed and tested with the help of the transport model. This policy is tested for anticipated improvements in the interconnectivity within the Archipelagos.

Acknowledgements

I would like to thank Professor Amalia Polydoropoulou for providing guidance and support throughout the course of this research. Also, for encouraging me to prepare papers and to participate with this work and with her contribution in scientific conferences and journals.

Special thanks to Professor Kostas Panou for his timely reviews and always positive inputs and ideas that helped me to improve the current work by placing an emphasis on the big picture perspective of this research.

I would like to thank also Professor Serafeim Kapros for his fruitful comments in the research overview, the particularities of the transport system of the archipelagos and moreover on the part of the survey design.

The contribution of the mobile network operator, Vodafone Greece, for providing data on mobile phone activity for the needs of this analysis was more than valuable. The data was anonymized by Vodafone Greece with respect to individual privacy and delivered under the provision of exclusive use solely for the scope of this research.

“Travel can be a desired end, not just a means”

P.L. Mokhtarian

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INTRODUCTION

TRANSPORT SIMULATION OF MARITIME AND AVIATION NETWORK IN THE AEGEAN ARCHIPELAGOS USING PUBLIC TRANSPORT MODELLING CONCEPTS

1. INTRODUCTION AND BACKGROUND

1.1. Main research hypothesis

The purpose of this research is to investigate whether advanced public transport (PT or PuT) simulation models can better explain the complex multi-domain architecture of transportation supply and demand in an Archipelago like the Aegean. The current Thesis presents arguments that advanced PT simulation techniques are capable of this, via a series of adjustments to better address the various trip segments, their interconnections, possible transfers and taking into account users' preferences. Also, by capitalizing on the advancements of the transport simulation software tools that are able to simulate complex and large multimodal networks. A central hypothesis is to reformulate the questions of modal split and assignment to the network in two steps of the 4step traditional process into the single question of multimodal path choice processed in one modelling step.

By analyzing the complex, multi-domain, regional transportation system of the Aegean Sea through the use of these models, it is possible to identify underlying factors that can be used to explain the dynamics surrounding other Archipelagos. For example, during peer-reviewing processes of parts of the current research, experts from the US have suggested that the Aegean is a good case to explore such issues, with possible application of learnings to places in the Americas such as Florida and the Bahamas, and the Caribbean. The issue of ferry routes and network planning is of significant interest in America as well as in other cases in Europe (North Sea and Baltic Sea) and Asia (Indonesia). These experts also suggest that the current Thesis is very relevant to the issue of network redesign for American ferry networks to explore better use of hub operations, for example in the Caribbean. For example, Nassau in the Bahamas is a more centrally placed hub, but there are many issues with ferry network design across this region that needs to be further investigated.

The outcomes of this research imply that using detailed public transport modelling techniques with stops, transfer times, itineraries, connections, possible interchanges, time schedules, vessel capacities, sea and air modes etc., with some adjustments for long-distance trips and trips chains, offers a better alternative to the traditional modelling tools for the in-depth study of an archipelagic transport system. The example of policy testing of a proposed insular hub system applies in many similar cases in the world. More policy, route and optimization issues can be tested in the same way.

1.2. Overview of Literature Review

Transport modelling is the recommended method to assess transport initiatives, strategies and policies (ATAP, 2016). It provides the technical means to quantify, visualise and understand existing and future issues of the transport sector. Through an overview of the various parameters and aspects of the transport systems, models offer opportunities to reverse fragmentations and move towards integration and sustainability (Furnish P. and Wignall D., 2009). Elsewhere in the bibliography is mentioned that transport model results give fundamental knowledge in the analysis of the existing situation of a transport system and the assessment of the future situation. They can forecast the impacts of proposed transport policies, strategies, new plans and infrastructures. Overall transport models are powerful support tools for decision-makers of the transport and environment sector (JASPERS: Joint Assistance to Support Projects in European Regions, 2014).

The core study area is the Aegean Archipelagos with its insular complex and its connections to the Greek peninsula as well as to distant countries of abroad. The particularities of the area lie in its geography with the dense archipelagic formulation, its 1,4million inhabitants, its location in the eastern Mediterranean Sea and its extended coastline which is a major attraction for holiday trips from all over the world. This unique case in Europe, creates special needs for high-quality transport services, where the role of coastal shipping is critical for the territorial cohesion of the insular areas, their economic and touristic development. (Adamantiadis M. and Triantafyllos S., 2014, Danchev S. *et al*, 2014)

The Aegean Archipelagos maritime transport system in the East Mediterranean region, is consisting of 65 inhabited islands and 80 insular ports, 48 sealine routes and 15 transport operators, approximately 4 million passenger trips by sea per month in the summer season excluding strait connections, in-vessel travel times between 3 and 13 hours. The network has a very good connection with the mainland ports of Attica and Northern Greece but there are shortcomings in the interconnection among islands that are serviced by different routes. In this research, two new insular interchange points to improve interconnectivity within the Archipelagos are proposed and tested. The maritime network of this area is complemented by a dense network of 26 insular airports which is a large number, reflecting the peculiarities of the Greek geography (Tsekeris T. 2011). The interchange hubs for combined trips by air and sea are identified and their role in the transport system is highlighted.

The transport system is simulated for one week in the model, to capture both short and longer distance passenger trips by sea. Insights of the transport system of the Aegean Archipelagos are gained regarding travel patterns, demand and capacity issues. The interconnectivity among the islands is analysed together with the existing transport hubs in the area, competition and complementarity between sea and air modes. The transport model offers opportunities for further analysis that include optimisations, forecasts and policy scenarios for more sustainability and cohesion in the insular areas.

The contribution of the current analysis is knowledge, understanding, and appreciation of the transport system of the Aegean Archipelagos and its connections to the mainland and distant countries. Aspects of the transport system, the demand side and travel decisions are discussed. Critical analysis is provided with analytics and visualisations through a transport model. Policy assessment with quantified results and thematic maps through scenario testing on the transport model is made possible.

Currently, the only relevant passenger transport model developed for the specific study area is presented in the works of Pantazis et.al 2013, 2018 and it is focusing on coastal shipping. A research gap is noted in the lack of an integrated multimodal approach to explain and model the passenger demand side as well. The approach presented in this Thesis intends to fill in the gap as it combines the supply side with the demand side and furthermore it considers their interaction.

In the approach of Polydoropoulou and Litinas, 2007 the issue of mode choice and competition between sea and air modes is discussed. In their work, they are using a case study in Northern Aegean and more specifically the connection between the island of Chios and Athens. They develop a discrete choice MNL model for three modes i.e., conventional ferry, high-speed ferry and aeroplane with the help of a survey. The difference between their approach and the current one is that this Thesis introduces the path choice approach rather than the mode choice one which actually assumes in rough a unimodal travel choice. It argues that sea and air modes are complementary in the study area rather than competitive and intermodality can be further intensified by introducing transfer facilities and services at the islands.

In the report "Critical times for the coastal transport of the Greek islands. The problem and possible solutions for 2014". Adamantiadis and Triantafyllos propose a set of measures for improving the maritime network. These measures are: i) definition of an optimum network of island connections and peripheral transport hubs by applying a hub & spoke system; ii) route extensions to Eastern Mediterranean neighbouring countries (Turkey, Cyprus, Egypt and Libya); and iii) enhancement of combined and multimodal transport of passengers and goods. The study and its arguments are not justified using a transport simulation tool, but they are based on an assessment and planning method called Delphi. This type of survey allows experts to unfold their ideas and perceptions around a specific topic through stakeholders' and experts' interviews. This approach is more common to the coastal shipping industry and market analysis rather than the transportation engineering and planning tools.

In his paper Tsekeris, 2011, "Greek Airports: Efficiency Measurement and Analysis of Determinants" is assessing the performance of the Greek airports and discusses specifically the role of the insular airports of the Aegean Archipelagos. He argues that the large number of 25 airports on the Aegean islands (out of the 39 in Greece in total) has a great impact on the territorial cohesion and the socio-economic development of this region; particularly by servicing the domestic and international tourist movements during the summer period. Among other conclusions, he proposes coordination of the insular airports and the establishment of regional-oriented hubs in the Aegean Archipelagos. Nevertheless, his proposals are not analysed further and justified with the use of a transport model.

In their study Accessibility of islands: Towards a new geography based on transportation modes and choices Karampela et al. 2014, they discuss the relationship between geographical distance and access opportunities with transport modes in the Aegean Archipelagos. In their study, they consider both ferries and aeroplanes. They develop a formula as an accessibility index from the Attika region, that combines travel times and frequencies per mode, weighted by the modal share of passengers per insular destination. This work focuses on the existing situation and the connections to the mainland. Future policies, interconnections between the islands and demand modelling issues are not discussed.

In the more recent years, Birgillito et. al. 2018 are analysing passenger mobility in a discontinuous territory, using as an example the strait connection between Sicily and Calabria. They argue that in cases like this, the transport model specifications need to be adjusted and expanded adequately in order to describe in a precise way the trip components in the formulation of intermodal paths. Also, they investigate how this trip chain influences travel choices. The study concludes that the users perceive the various trip components with different disutilities and values of time respectively. Seamless mobility for geographically fragmented areas such as the insular ones, requires interventions at the intermodal passenger transfer hubs. The case study is limited to land and maritime combinations and to a specific area of trait connection where also commuting trips are recorded. In the current thesis some of these concepts apply as well but they are extended to model the formulation of more complex trip chains with a bigger variety of destinations, modes and paths. Moreover, it is confirmed that transfer times are rated higher as disutilities than the in-vessel travel times.

1 Introduction

The most detailed and most recently developed transport model that includes the region of the Aegean Sea is the transport model of Greece, completed in 2019 for the National Transport Plan (NTP). NTP had a very detailed demand side of the trips to the islands but a simplified public transport modelling approach of the supply side of the insular transport system. The coastal and air connections were modelled in a generic way called TSys based public transport assignment. In this approach the headways and/or the timetables of the itineraries are not considered. Therefore, the wait times are not a component of the transport simulation and of the user decisions, passenger transfers cannot be modelled appropriately and quantified. Interchanges from sea to air and more complex paths cannot be simulated and they are disregarded. There is a unimodal modelling approach of the insular part of the trips in the region of the Aegean Archipelagos. This approach is focusing on the mode choice rather than on the path choice. Also, capacity issues cannot be addressed adequately as TSys based assignment is not capacity restrained by the fleet force, vessel and aircraft capacities and schedule frequencies. For the abovementioned reasons, the current Thesis argues that the use of the public transport capacity restrained timetable-based assignment, offers a more detailed and advanced approach that is suitable for policy testing in the insular area.

There is a lack of more recent relevant references for the specific area of the Aegean Sea apart from the works of Hatziioannidu and Polydoropoulou (2015, 2016, 2020 etc.) that are also presented in this thesis. This consist of a research gap by itself since transport modelling applications and modules are advancing continuously and rapidly, as well as because smartphone mobility applications and route recordings could in the near future be the source of valuable information on trip patterns for validation of the finding regarding trip chains, secondary destinations and mode interchanges. Transport modelling tools with their latest advancements with new modules and capabilities are not tested in the area in the most recent years.

In a case from New Zealand, Ceder et.al. 2011, in order to develop an assessment of the existing operation of commuter ferry networks to the Auckland Central Business District (CBD) during the AM peak period of 7 AM to 9 AM, an analysis was carried out on the connectivity of existing ferry routes to the CBD with outward-bound bus services from within the CBD. The Analysis of Passenger- Ferry Routes Using Connectivity Measures was conducted by the University of Auckland using PT modelling techniques. This is another relevant study but it applies to short-distance commuting trips.

The of use of a transport model for the optimisation of ferry services has been tested in a case study from Indonesia in 2017. The project was launched by the Delft University of Technologies and its findings are presented in the book “Freight Transport Modeling in Emerging Countries”, chapter “Optimizing the efficiency of the future maritime transport network of Indonesia” by R.Verhaeghe, R.Halim and L.Tavasszy. They are using Omnitrans package for their analysis which focuses on freight but includes also passenger ferries and mixed cargo. With the objective to analyse and provide options that reduce costs and improve service, the authors conclude that redesigning a part of the network with route consolidation techniques has the following potential benefits: a reduction in the operating costs by 25%, a reduction of 27% in passenger travelled kms, more equally distributed visit frequencies of the study area ports which lead to a reduction of disparities among the islands and port cluster areas.

1.3. Contribution and innovation

The contribution and innovation of the Thesis lie in the following three areas ie. Data, Model and Policy as depicted in the following graph:

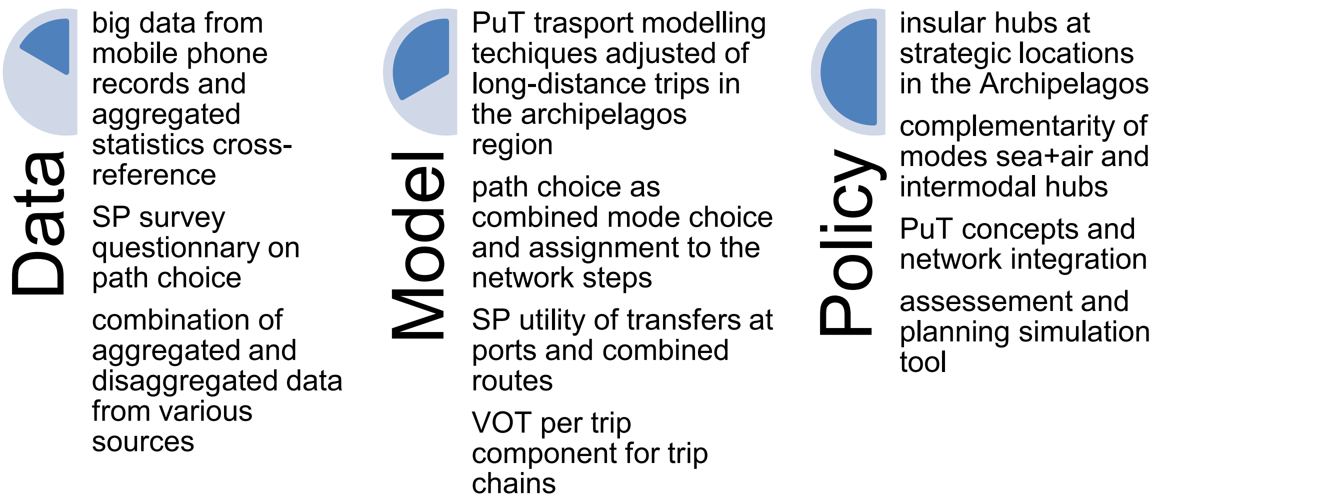

Figure IN1. Thesis contribution and innovation graph

Data about transport demand and travel choices are essential for the current research and public transport modelling. Innovation in the Data area includes the use of big data from mobile phone records in the year 2013 for the identification of mobility patterns in the archipelagos. These patterns show significant discrepancies in the mobility of local and foreign tourists with locals travelling 20% comparatively longer distances by sea; also, that foreigners account for 25% or more of the total demand for coastal shipping trips to the islands. A stated preference survey on path choice for internal trips with an interchange to capture the disutilities of complex trip chains is introduced. The combination of aggregated and disaggregated data from various sources including statistical data, big data from mobile phones and SP survey data, concludes the contribution of the Thesis in the area of Data.

Contribution of the Thesis in the Model area covers the use of advanced public transport simulation modelling techniques adjusted accordingly for long-distance trips in the archipelagos for a detailed simulation of the transport system allowing assessment of the existing situation and of future policy scenarios. Innovation exists in introducing a multimodal path choice modelling step in place of the traditional mode choice and assignment to the network steps for the simulation of complex trip chains for holiday trips to the islands. The use of discrete choice modelling to assess willingness to use port hubs as interchange points in the archipelagos and estimating the value of travel time on the level of trip components such as in-vessel time and transfer wait time rather than for the total cumulative travel time are also innovative.

In the area of Policy, the Thesis introduces concepts from public transport planning in the Aegean Archipelagos with emphasis on network integration. The contribution here concerns the justification of a system based on a small number of insular hubs at strategic locations in the Archipelagos that allows better interconnections and enhance the network effect. In this direction, the complementarity of the passenger maritime and aviation modes is proved and an intermodal policy with insular hubs is justified. The contribution of the areas Data and Model are integrated into Policy, delivering valuable assessment and planning methods and tools in archipelagic regions. Overall, the particularities of the Aegean Archipelagos region and its transport system render the methodologies used in the areas of Data, Model and Policy of the Thesis, innovative.

1.4. Individual research questions

Individual research questions are listed here and explained as follows:

1. What are the strong points of the transport system of the Aegean and what are its weaknesses? Is the existing transport network integrated and to what extend? Is there complementarity of the transport modes in the area?

These questions are discussed throughout the Thesis but more particularly in Parts A and C. The strong points and the weaknesses of the system are thoroughly discussed in the bibliography but not always addressed in a quantified and numerically justified way as this Thesis does. Part A offers a detailed analysis of the supply side allowing the identification of the strong points of the network with very good and frequent connections to the mainland of Greece and a fairly good level of service for travelling to the majority of the islands. There is excess passenger capacity of sea modes even in the peak summer season while mode alternatives and respective fare options are available for the majority of the destinations.

The shortcomings of the network are observed primarily in the connections between the islands that don't lie on the same major route. The level of network integration can be described as poor with route structures of direct services and lack of organised and coordinated mode and route complementarity. Some missing links or connections are identified as well as isolated destinations. The air connections are strongly restricted by capacity in the high season and double insularity remains an issue that needs attention.

Even in the existing situation with unorganized and uncoordinated transport services in the archipelagos region, the complementarity of the two main modes, i.e. coastal shipping and aviation, is inevitable. This is explained and justified in Part C. The role of the intermodal insular hubs is highlighted and quantification of the effect is offered together with measures to enhance the complementarity of the modes and seamless interchanges for the trips to the islands.

2. Is the mode choice modelling technique sufficient to describe and simulate the transport system of an Archipelagos, or using multimodal paths instead is more suitable?

This question is discussed and solved in Parts B and C. Modelling separately land+air and land+sea paths is not an adequate solution as a significant share of trips are not properly represented with this approach. This introduces a multimodal and intermodal dimension in the current research that needs to be properly addressed in the model as well. It extends beyond the combination of a private or public mode for the land part of the trips to the Aegean Archipelagos and a public transport mode from the mainland transport hubs to the islands either by sea or air. Therefore, the conventional mode choice modelling technique is not sufficient to model the system in detail.

3. Can we model sufficiently the transport system of an Archipelagos when poor quality data is available and uncertainties exist in regard to modal share, trip chains, external to internal trip ratio, destination choice, demand segmentation into domestic and foreign tourists? Are big data from mobile phones a useful source of information on the question above as well as for identifying trip patterns in the Archipelago?

The topic of modelling the transport system of the archipelagos when only poor data is available refers mainly to underlying uncertainties on the demand side and characteristics of the trips. The question is yes, it is possible to calibrate the transport model and cover the demand side adequately using a large set of statistical data on the aggregated level, adding disaggregated data surveys of limited scale, exploiting big data from mobile phone records, combining the various datasets and defining some assumptions when necessary. Most of these issues are concluded in Part C but there are arguments in all other parts of the Thesis as well. The magnitude of the internal trips in an Archipelagos, in lack of sufficient data, is only partially solved in Part B when developing the demand model. Indications on the effect of internal trips exist also in the mobile phone records' analysis.

The use of big data from mobile phone records analysis is justified and presented in Part B. Mobile phone records is proved a useful source of information in the lack of detailed data and field surveys in this particular region. In the case of extracting geolocation anonymously of the travellers through their mobile phone devices, the spatial discontinuity in the Archipelagos turns into an advantage that allows clear tracing of passengers travelling by sea. The analysis of these records delivers insights on the mobility patterns in the study area and trip characteristics segmented for two major categories tourists, domestic and foreigners.

4. Are concepts of Public Transport planning applicable in the Aegean Archipelagos and similar areas?

This question is addressed in Part C of the Thesis where concepts of public transport planning focusing on the network structure and services relevant to the study area are presented. Arguments are provided for the applicability of specific network configurations in the Archipelagos. The identification of the existing traditional public transport route structures in such areas and possible shifts to more contemporary network configurations are discussed.

5. Does an advanced public transportation modelling approach address adequately any technical matter related to the challenge of double insularity in an Archipelago context?

The double insularity challenge in an Archipelago context is discussed thoroughly in the bibliography with many different approaches but it is rarely explained with numbers. The findings of other papers and research works are confirmed with the analysis of Part A and furthermore, with the transport model tool applied here it can be quantified and highlighted for specific OD pairs within the study area. Using detailed public transport modelling techniques, with some adjustments for long-distance trips and trip chains, offers a better alternative to the traditional modelling tools for researchers and practitioners who want to study an archipelagic transport system in detail. The introduced modelling approach, provides insights into the system and allows testing of various policy scenarios, for system improvements.

6. Would a transport policy of introducing minor islandic hubs in the study area improve network integration and the double insularity conditions in an Archipelago area? Are the users willing to transfer at insular hubs rather than at the traditional mainland ports? Is such a policy for implementing minor insular hubs justified by simulating and scenario testing in the transport model?

The answers to these questions are given in Part C of the Thesis and in the overall conclusions. Willingness to use the new system with two minor hubs is reflected in the discrete choice survey and on the frequency of use question of the survey. The changes in the network are tested in the transport model and the new trip chains are visualized and quantified.

1.5. Particularities of the study area of the Aegean Archipelagos

The Aegean Archipelagos maritime transport system in the East Mediterranean region, is consisting of 65 inhabited islands and 80 insular ports, 48 sealine routes and 15 transport operators.

The particularities of the area lie in its geography with the dense archipelagic formulation, its 1,4million inhabitants, its location and its extended coastline which is a major attraction for holiday trips from all over the world.

The role of coastal shipping is critical for the territorial cohesion of this region, its economic and touristic development. Approx. 4 million passenger trips are serviced by sea per month in the summer season excluding strait connections. In-vessel travel times vary between 3 and 13 hours.

The transport system of the area is complemented by 26 insular airports with domestic and international flight connections.

1.5.1. Location, identity and history of the study area

The Aegean Sea (Greek: Αιγαίο Πέλαγος (Aigaío Pélagos) on the east most side of the Mediterranean Sea was known in Ancient Greece as Archipelago, meaning the principal sea. It has more than 1,000 islands and islets. Most of them are in the jurisdiction of Greece, while a small minority belong to Turkey. Only 65 of the islands of the Greek territory are inhabited and this analysis is focussing on these particular ones. The word “archipelago” is established for other cases worldwide to describe a large insular group or chain, after the plethora and formation of the islands of the Aegean Sea.

Ancient civilizations of the islands Crete, Minoan, Cyclades and later on Mycenaean and Athens at the hinterland of the Aegean were cultivated in this region of Europe since c. 3500 BC[1]. Consequently, it is considered the cradle of modern Western culture. The early Aegean civilizations enhanced, shipping, trade and transport together with writing, mythology, arts, architecture and culture forming the Aegean legacy.

1.5.2. Geographical and spatial particularities of the area

The Aegean Archipelago is roughly 612 km long and 299 km wide, the sea has a total area of nearly 215,000 square km[2]. The orientation of the main ports and the major settlements are towards the Greek mainland, with the exceptions of Rhodes, Kos, Samos, Chios and Lesvos that are closer to Turkey and have their orientation towards Minor Asia.

The main positive aspects of the geography of the region are the mild climate, the extended coastline and consequently the wealth resources deriving from the sea, agriculture and tourism that in some cases near self-sufficient economies to a degree. The islands of the Aegean are

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[1] https://en.wikipedia.org/wiki/Minoan_civilization
[2] https://www.newworldencyclopedia.org/entry/Aegean_Sea

among the worlds' top-rated holiday destinations and they attract a constantly increasing (until 2019) number of tourists from Europe and from other continents.

Negative aspects of the geographical particularities of the area are lack of territorial cohesion, spatial discontinuities between the capital cities (or settlements) of the islands, limitations and shortcomings of the transport network and accessibility challenges. Moreover, there are dependencies in energy, water, goods and administration, higher education and health care, from the mainland.

Isolation and double insularity which concerns the connections of the islands to the central portals and the interconnections among the islands as two major components of accessibility, need to be assessed and analyzed in the region. It is highlighted that the way the transport network has empirically evolved during the years, may offer have a very good connection to the major ports and airports of the mainland, mainly the Attica region, but poor interconnection between the islands especially those not laying on the same ferry route. These cases eg. Chios-Andros, Limnos-Samothraki etc. despite their spatial proximity, are distant in terms of accessibility.

Moreover, the weather conditions (waves and winds) some days of the year do not allow passenger ships to reach the insular ports especially during the wintertime while also approach by air at specific insular airports is also problematic due to the winds at various seasons of the year and in combination with the small aircraft sizes of some routes.

Another particularity of the area is the seasonality issue that influences drastically the demand for travel between summer and wintertime, the trip patterns, the trip purposes and also the transport network and service provisions.

All the above-mentioned compose the picture of a unique case and a study area with challenges in addressing accessibility and mobility issues for assessment and planning. It is not a representative study area but it can be identified with similar archipelagic ones in the UK, Indonesia, Bahamas, Norway and elsewhere, given that the necessary adjustments will be made in the approach and methodologies proposed in this Thesis.

1.5.3. Demographics of the Aegean Archipelagos region

According to the new administrative division of Greece, the islands of the Aegean Sea and Crete consist of 3 of the 13 administrative regions of the country. Below are the demographic data of the Region of Aegean islands and Crete according to the 2011 census.

Administrative region NUTS[3] 2021	Resident Population (2011)
NUTS0 Greece total	10,816,286
NUTS1 EL4_Islands of the Aegean and Crete	1,131,311
NUTS2 EL41_Region of Northern Aegean	199,231
NUTS2 EL42_Region of Southern Aegean	309,015
NUTS2 EL43_Region of Crete	623,065

Source: own processing based on ELSTAT data of the 2011 Census

The seat of Northern Aegean is Mytilene of Lesvos, the seat of Southern Aegean is Ermoupolis of Syros and the seat of Crete is Heraklion. The Southern Aegean region includes Cyclades and Dodecanese. The Islands of the Aegean and Crete aggregate 10% of the total population of Greece excluding the islands of Argosaronikos, Kythira and Antikythira that belong to the Attika administrative region, excluding Sporades islands that belong to the Thessaly region and excluding Thasos and Samothraki islands that belong to Eastern Macedonia and Thrace region. If the abovementioned islands are included in the calculations, then the total population of the study area summarise to approximately 1,4 million residents.

The more densely populated areas and settlements are on the coast of the islands and especially at the main ports. The hinterland areas of the islands are only sparsely inhabited much less habituated.

1.5.4. Evolution of the touristic demand and trends

The evolution of international tourists' arrivals in Greece is presented in the following graph and it shows a great increase over the decades. Between 1995-2010 the increase was 3% per year on average while after 2010 tourists' demand for traveling to Greece from other countries has been intensified.

[3] Eurostat classification NUTS system representing nomenclature of territorial units for statistics

Figure IN2. Evolution of international tourist arrivals to Greece

Source: own processing based on ELSTAT data

In the last decade international tourists' demand increased by 9% yearly average. This trend held up until 2019 before the outbreak of the Covid pandemic that limited drastically the mobility and especially long-distance holiday trips, globally. The domestic demand for tourism in Greece has been constant with some fluctuations in the last ten years up until the pandemic, meaning that this market share did not follow the trend of the foreign tourists. This fact reflects the economic recession years in Greece after the debt crisis began in 2010. The following graphs present the trends mentioned above.

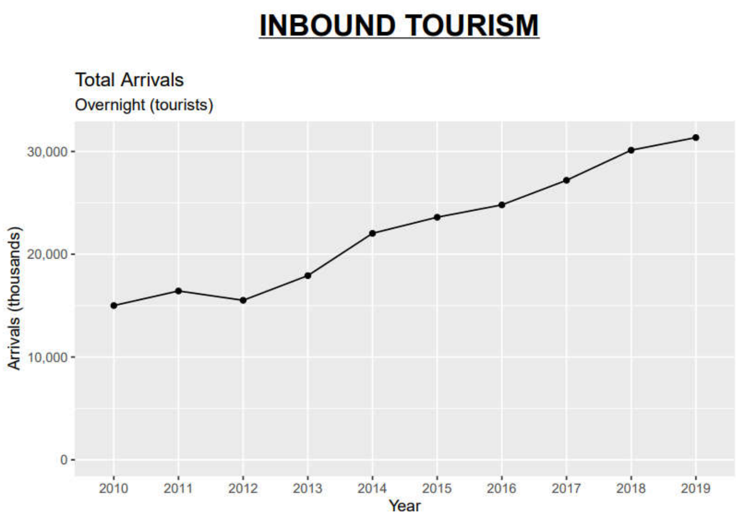


Figure IN3. Inbound tourism 2010-2019

Source: UNWTO

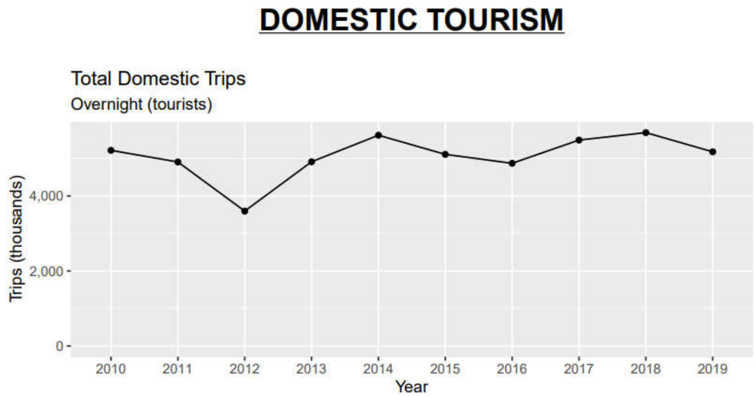


Figure IN4. Domestic tourism 2010-2019

Source: UNWTO

According to the UNWTO estimations and forecasts[4], the tourists market globally will rebound to the levels of 2019 in the years to come after the Covid pandemic crisis namely in 2023-2024. Despite the current uncertainties in international travelling, it is possible that tourism will continue to grow after a short reset period. This will affect also the tourists' market with destination to the Greek islands. Respectively, the transport system of the Aegean Archipelagos with its hinterland could face more challenges in the future if no new and innovative policies, measures and configurations are going to be implemented for the summer peak season. The current methodology introduces a planning tool that allows policy testing, sizing and scalability provisions of the infrastructure of the future towards sustainable solutions in the region of the Aegean, which would be very useful if tourism continues growing dynamically after 2024 in the study area.

1.5.5. Seasonality of the travel demand to the islands of the Aegean

The seasonality of the tourists' demand for travel to the specific holiday destinations of the Aegean Archipelagos is a strong phenomenon. Despite the policies and incentives to expand the demand season in spring and autumn, the trends remain the same. The vast majority of visitors are travelling to the islands from May till September while the demand is strongly peaking in July and August. The figure below depicts the seasonality trends in a series of years and although it is summarising the arrivals of foreign visitors in hotel establishments in Greece it is indicative of the same trend that applies also in the study area of the Aegean Archipelagos which is the major attraction of holiday trips in Greece.

[4] UNWTO World Tourisms Barometer Volume 19 • Issue 5 • September 2021

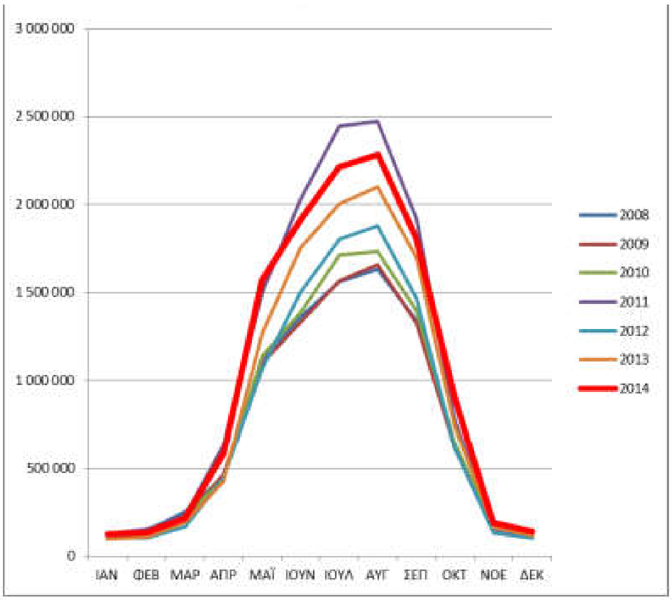


Figure IN5. Seasonality of arrivals of foreign visitors in hotel establishments in Greece 2008-2014

source: ELSTAT

Seasonality in this specific area is connected to holidays as the main trip purpose. The reason for the phenomenon lie in the climate conditions, the school holidays period in Europe, organization of production time in Europe and respective vacations' period among others. The major effect of seasonality in the tourism industry in the area is the strongly peaking demand for trips that affect coastal shipping, airline industry, road and rail infrastructure. Most of the transport infrastructure, facilities and services work at the capacity level in the core study area and its hinterland as the region of immediate impact or in some cases they even work over congestion, with delays at the major transport hubs and negative consequences in the natural environment as well as in the landscape. The effect of the peaking travel demand is depicted in the following figure.

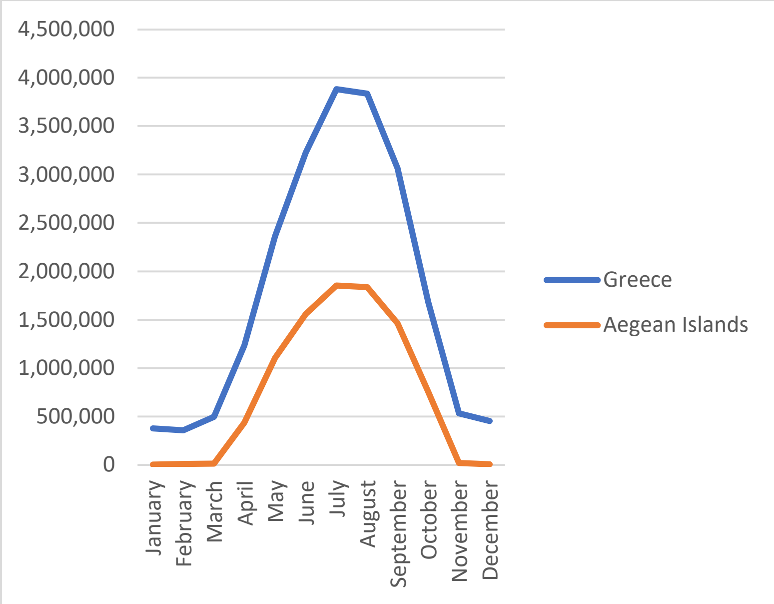


Figure IN6. Seasonality of international passenger arrivals at airports in 2019

source: own processing based on data from INSETE

The transport system of the study area is operating with different network and services during the summer season compared to the winter season. In winter, the travel demand to the islands of the Aegean Sea is dropping drastically and the transport services are limited and only serve accessibility and cohesion purposes. In winter mode most of the coastal shipping and airline connections in the area are subsidised by the state, the so-called “thin lines”. Not only the travel demand but also the travel patterns in the area change in winter. This includes demand segmentation consisting almost inclusively of domestic trips, trip purposes, destination choices, travel distances etc.

The current analysis is focusing on the summer peak period but the same methodology could be adjusted and applied likewise to the winter season. This would allow the analysis of the performance of the transport system during the winter months, identification of shortcomings, new network configuration and policy testing for the off-peak season.

1.6. Publications

1.6.1. Conference presentations and publications

Parts of this thesis have been published and presented in conferences:

Passenger Demand And Patterns Of Tourists' Mobility In The Aegean Archipelago With Combined Use Of Big Datasets From Mobile Phones And Statistical Data From Ports And Airports, WCTR 2016 Shanghai, Hatziioannidu F. and Polydoropoulou A. (published by Elsevier in Transportation Research Procedia, Volume 25C, 2017, Pages 2314-2334)

Transport simulation of passenger ships in the Aegean Archipelagos using public transport modelling concepts, 2015 ECONSHIP, Chios, Hatziioannidu F. and Polydoropoulou A.

Travel Preferences for Alternative Islandic Ferry Transport Hubs in the Aegean Archipelago for Tourism, TRB 2020, Washington D.C., held virtually, Hatziioannidu F. and Polydoropoulou A.

Ferry passengers' acceptance of transfer hubs at islandic ports of the Aegean Archipelago with discrete choice modelling, SIGA2 2021, Antwerp (held virtually), Hatziioannidu F. and Polydoropoulou A.

Transport modelling of the ferry network in the Aegean Archipelagos and its airline alternatives; analytics, visualisations and insights, IAME 2021 Hatziioannidu F. and Polydoropoulou A. (submitted for review and publication by Elsevier in Maritime Transport Research)

Identifying Passenger Demand for Alternative Ferry Transport Hubs, 2022 Hatziioannidu F. and Polydoropoulou A. (under publication by Elsevier, Research in Transportation Economics, Journal Transport Research Forum)

1.6.2. Previous works relevant to the Thesis

EMR-MOS: Elaboration of the East Mediterranean Motorways of the Sea Master Plan, 2009, Hatziioannidu F. as transport modelling expert with Centre for Research and Technology-Hellas CERTH

ADRIATICMOS: Developing motorways of the sea system in Adriatic Region, 2012, Hatziioannidu F. as transport modelling expert with National Technical University of Athens NTUA

INTERMODADRIA: Support intermodal transport solutions in the Adriatic Area, 2013, Hatziioannidu F. as transport modelling expert with National Technical University of Athens NTUA

PART A: THE SUPPLY SIDE

TRANSPORT SIMULATION OF MARITIME AND AVIATION NETWORK IN THE AEGEAN ARCHIPELAGOS USING PUBLIC TRANSPORT MODELLING CONCEPTS

2. INTRODUCTION AND BACKGROUND OF PART A

This part of the Thesis aims to examine the existing transport system for passenger ship services in the Aegean Archipelagos by applying advanced transport simulation tools and techniques used for Public transport modelling of the supply side. The study area is defined as the Aegean Sea with its islandic complex and its connections to the Greek peninsula. Network performance indicators and statistics are produced for the system overall. The current analysis aims to identify the weaknesses of the transport network in the study area corresponding to the existing situation for the 2013 summer period, such as missing connections, origin-destination pairs not serviced, or difficult to reach destinations. The model includes in detail all the weekly itineraries with their exact time-tables for all the regular Aegean Sea passenger connections and it simulates at a fine level the supply side. For this reason, this application additionally serves as a useful tool for trip scheduling purposes by offering details on shortest routes, connections, itineraries, transfer points, shipping companies etc. on specific dates and time intervals.

2.1. Problematic and scope of this approach in the specific study area

Under this approach, the existing transport system for passenger flows in the Aegean archipelagos is explored with the use of advanced transport network simulation tools. More specifically, techniques that are used in Public transport modelling are introduced, which although having been developed for urban networks, they still apply for long-distance systems with some adjustments. The system itself is considered to be very complex consisting of numerous private operators with their fleets consisting of various vessel types, with services and main lines that have been developed empirically and well established over the course of time in order to accommodate the demand of a strongly peaking touristic summer period. For this reason, a detailed simulation model focusing on Public Transport for maritime PAX connections was developed.

Furthermore, this part aims to identify the weaknesses of the specific transport system in the existing situation, corresponding to the summer period of 2013, such as missing links and not serviced Origin-Destination pairs, isolated or difficult to reach destinations. Network performance indicators and statistics are extracted for the system as a whole. Additionally, the model serves as a useful tool for trip scheduling purposes, offering detailed information on shortest routes, connections, itineraries, transfer points, shipping companies at specific dates and time intervals. The study area is defined with the Aegean Archipelagos being its core area and the Greek peninsula as its hinterland and immediate area of influence.

In the first part of the paper, the Transport Model of the Aegean Archipelagos PAX network is presented accompanied with the justification of the selected approach of Public Transport modelling. This includes the presentation of the transport modelling core study area, its zoning system and network including sealine and flight services for the summer period of 2013. In the assessment part results of overall network performance and statistics for the specific period are provided, as well as analysis of network coverages, fleet, vessel types, operators, services and capacity issues. The weaknesses of the system are identified and missing link analysis is conducted employing a clustering approach. Furthermore, the added value use of the specific transport model as a trip scheduling platform for the Aegean islands is presented.

2.2. Overview of Literature Review

A passenger maritime and air transport system has basically similar characteristics to any other public transport (PT) system in terms of objectives, constraints, and integration consideration. Next, the following cases from the international experience and literature are presented, e.g. for combined ferry services with bus, coordinated ferry schedules among various operators, missing links analysis, Greek airports connectivity and hub system, island hopping services worldwide, etc.

In a case from New Zealand, in order to develop an assessment of the existing operation of commuter ferry networks to the Auckland Central Business District (CBD) during the AM peak period of 7 AM to 9 AM, an analysis was carried out on the connectivity of existing ferry routes to the CBD with outward-bound bus services from within the CBD. The Analysis of Passenger-Ferry Routes Using Connectivity Measures was conducted by the University of Auckland using PT modelling techniques.

In Taiwan, ferry companies are increasingly allying themselves with other ferry companies as a means of forming more complete networks, in order to operate more efficiently. The more complex ferry fleet routing and scheduling processes are important for the operations of each company separately, but also have a positive bearing on the alliance as a whole. In the elaboration of coordinated routes and itineraries for ferry companies under alliances, network flow techniques are employed to construct coordinated scheduling models for optimizing schedules for the allied ferry companies.

UNECE (United Nations Economic Commission for Europe) has developed a comprehensive methodological basis for the definition of common criteria regarding the identification of bottlenecks, missing links and quality of service in infrastructure networks. According to this UNECE report, bottlenecks and missing links are manifestations of inadequate quality of transport service. Nevertheless, the report focuses on road, rail and inland waterways networks without any reference to the maritime and air transport network.

In the report “Critical times for the coastal transport of the Greek islands. The problem and possible solutions for 2014”, a set of measures is proposed for improving the maritime network. These measures are: Definition of an optimum network of island connections and peripheral transport hubs by applying a hub & spoke system; Route extensions to Eastern Mediterranean neighboring countries (Turkey, Cyprus, Egypt and Libya); Enhancement of combined / multimodal transport of passengers and goods.

In the report “Greek Airports: Efficiency Measurement and Analysis of Determinants” it is emphasized that in terms of the location, the presence of the majority (25 of them on the islands of the Aegean Archipelagos) of airports in islands signifies their crucial role in terms of territorial cohesion and their economic and social development, particularly by servicing the domestic and international tourist movements during the summer period. Among other conclusions, the establishing of regional-oriented hubs in the Aegean region is proposed, so as to exploit economies of size and enhance the scale of operations.

An internet search provides information on ”island-hopping” possibilities for various islandic formulations throughout the world such as: Spain with the Canary Islands, Croatia for the Dalmatian coast, Norway from Bergen to Krakhella in Solund, Sweden for the Stockholm archipelago and Bohuslän archipelago, Japan for the Fiji Island Hopping, United Kingdom for island hopping in Guernsey and the Bailiwick, Canada with Vancouver, Howe Sound, Indonesia etc.

3. METHODOLOGY AND APPROACH OF PART A

3.1. Transport model of the Aegean Archipelagos passenger network

3.1.1. General concepts of Public Transport modelling applied in the study area

In this research the transport network was modeled using techniques applied in Public transport modelling. The ports are modelled as stop points, where Public transport lines stop for passenger boarding. Public transport lines correspond to the various sealine and flight connections and routes provided by a significant number of operators offering transport services in the study area during the summer period of 2013. Due to the complex system consisting of various private operators, the complicated routes not always using symmetrical patterns and the large set of itineraries which are not always running at regular daily times, the services are divided at vessel level so that each Line (spatial course) corresponds to a specific ship. A similar technique is applied for air transport passenger routes. For the same reasons, the timetable-based procedure was selected over the headway-based procedure. The timetable-based approach takes the accurate timetable into consideration and thus, is particularly appropriate in such cases, when headways are long and timetable adherence is important for transfers and overall trip scheduling.

For the detailed modelling of the sealines at ship level per operator and accompanying timetables, a significant array data such as ship routes, vessel information, fleet per operator and timetables were required. Extensively utilized data sources included: the ship operators' internet web pages and information desks, Piraeus Port Authority, minor port Authorities, the Ministry of Shipping, Marine Traffic AIS system for vessel monitoring and the Hellenic Statistical Authority.

For the detailed modelling of the airlines per operator and accompanying timetables, a significant volume of data such as flight information, types of aircraft per operator and timetables was required. As source of this information very detailed data was used, which was acquired from the Hellenic Civil Aviation Authority offices at each islandic airport and the Hellenic Statistical Authority.

The Public transport network is complemented with the Private transport network of the land side. The modeling of the Private transport network consists of the insertion of all major road links that connect the hinterland to the specific inland ports and airports which serve as gateways to the Aegean Archipelagos via maritime PAX and Ro-PAX lines and via passenger airlines. This technique is commonly known as Park and Ride (P&R)- when the trip chain consists of a Private transport section and a Public transport section. By applying this approach a detailed path analysis and accurate travel times are achieved, which offers us the possibility of pre-trip scheduling information from each major Greek city of the peninsula to each Aegean islandic destination and the reverse. The road network was modelled to result in real travel times and distances, using a number of data and information sources such as Open Street Maps shapefiles and Google maps directions-speeds.

3.1.2. Transport model core study area

Large Aegean archipelagos complexes and smaller islands defining the core study area are:

- Eastern Aegean Islands: Agios Efstratios, Thasos, Ikaria, Lesvos, Limnos, Oinousses, Samos, Samothrace, Chios, Psara
- Sporades: Alonissos, Skiathos, Skopelos, Skyros
- Cyclades: Amorgos, Anafi, Andros, Antiparos, Delos, Ios, Kea, Kimolos, Kythnos, Milos, Mykonos, Naxos, Paros, Santorini, Serifos, Sikinos, Sifnos, Syros, Tinos, Folegandros, and the "Small Cyclades", consisting of Donoussa, Irakleia, Koufonisia and Schinoussa
- East Cyclades: Amorgos, Anafi, Andros, Antiparos, Delos, Ios, Kea, Mykonos, Naxos, Paros, Santorini, Sikynos, Syros, Tinos, Folegandros
- Western Cyclades: Kythnos, Serifos, Sifnos, Kimolos, Milos
- Dodecanese: Astypalea, Kalymnos, Karpathos, Kasos, Kastellorizo, Kos, Lipsi, Leros, Nisiros, Patmos, Rhodes, Symi, Tilos, Chalki
- Saronic Islands: Agistri, Aegina, Poros, Salamina, Spetses, Hydra

3.1.3. Density passenger ship maps from Marine Traffic

At this point, in order to display the big picture of the PAX and Ro-PAX network of the wider study area, vessel density charts by MarineTraffic.com are presented. In particular, these charts show passenger ship activity in the greater Aegean Sea area for the period of July - December 2013. The following figures present these density charts depicting high-speed vessel activity in yellow and passenger ship activity in blue.

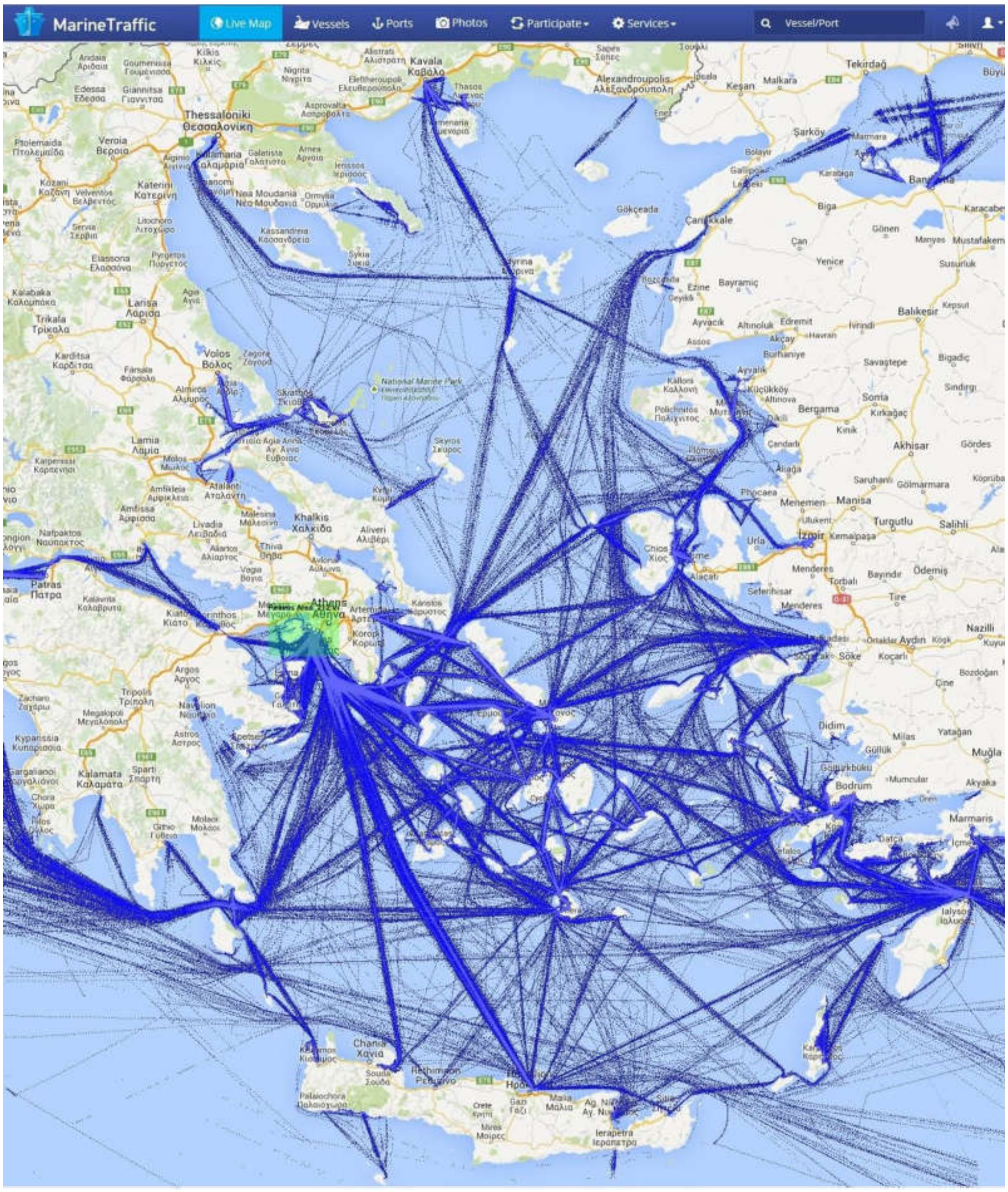


Figure A1. Density charts by MarineTraffic showing passenger ship activity in blue (July -December 2013)

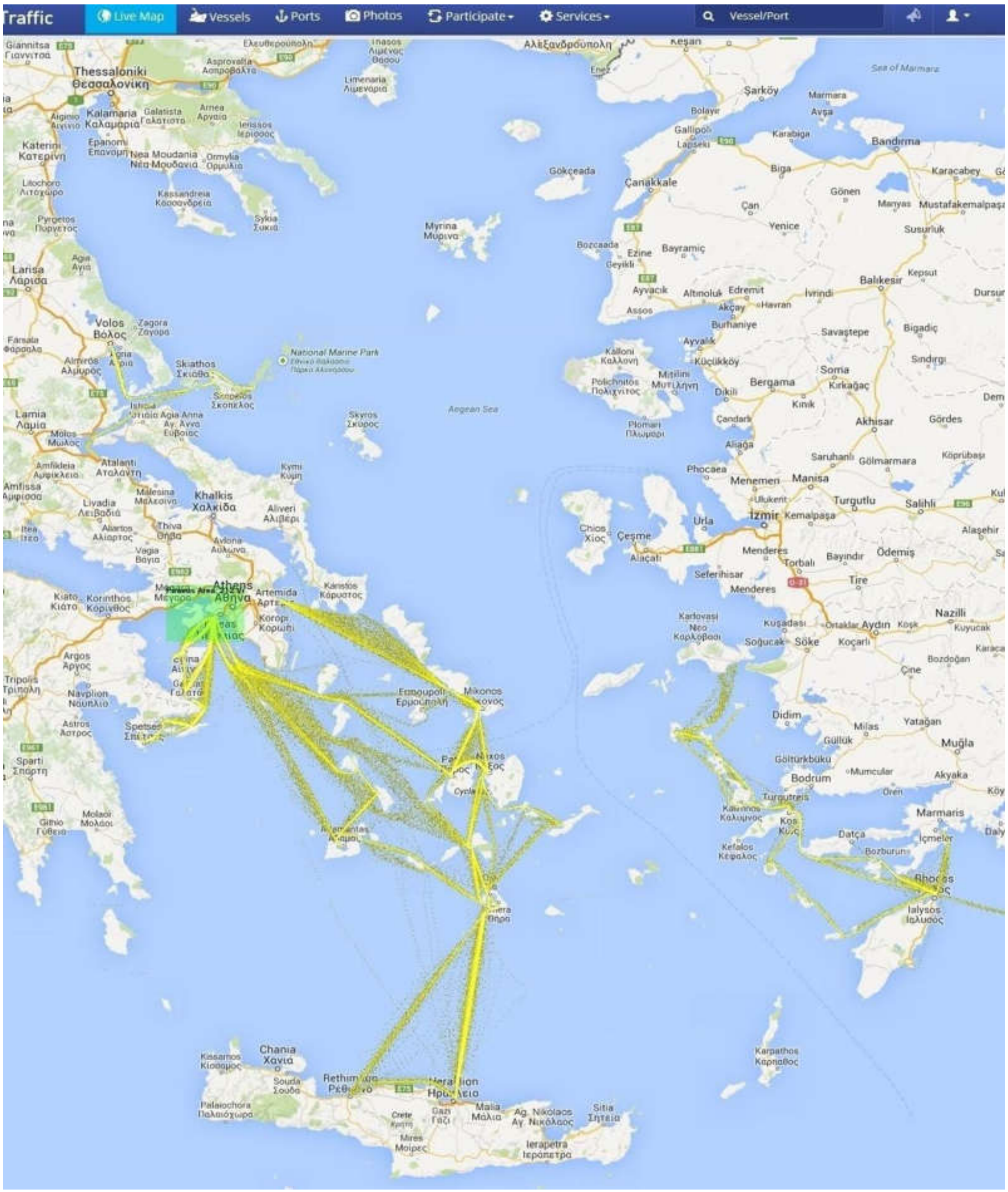


Figure A2. Density charts by MarineTraffic showing high speed vessel activity in yellow (July - December 2013)

3.1.4. Transport model zoning system

The zoning system in this transport model is divided into internal zones, external zones and distant zones. It consists of 152 zones in total. The internal zones serve for the islands of the Aegean Archipelagos, the external zones serve for the Greek mainland regions and the distant zones serve for the countries abroad that are connected to the islands with direct flights. The division of the zoning system is summarized as follows:

- 70 internal zones : Aegean Islands as internal zones

- 44 external zones : Greek inland regions in NUTS 3 level ("Νομός") as external zones
- 38 distant zones : 38 foreign countries connected via direct flights with the Aegean Islands

The total of internal and external zones amounts to 114, with 70 Aegean islands as internal zones and 44 Greek inland regions in NUTS 3 level as external zones. The islands of the Aegean Sea were modelled at distinct island level as internal zones for all the inhabited islands in the study area, while the Greek peninsula and Crete (the only study area island incorporating several administrative units) are modelled at region level as external zones. The external zones are divided according to the EU standard administrational and territorial units of NUTS 3 level existing in 2013 and they are related to the regional administrative units known in Greek by the term "Νομός". A detailed description of the external zoning system is included in Annex A. The transport zoning system of the internal and the external zones is depicted in the following figure.

Figure A3. Transport zoning system of internal and external zones in the study area

The total number of distant zones amounts to 38, including all European countries and several additional countries which were linked to the islands of the Aegean Sea via direct connections during the summer season of 2013. The list of the distant transport zones is presented in the following table while in the next figure the connected countries are graphically presented on a map.

Table A1. Distant zones

Country	Country	Country
Albania	Ireland	Romania
Austria	Israel	Russia
Belarus	Italy	Serbia
Belgium	Kazakhstan	Slovakia
Cyprus	Latvia	Slovenia
Czech Republic	Lebanon	Spain
Denmark	Lithuania	Sweden
Estonia	Luxembourg	Switzerland
Finland	Malta	Turkey
France	Netherlands	Ukraine
Germany	Norway	United Arab Emirates
Hungary	Poland	United Kingdom
Iceland	Portugal	

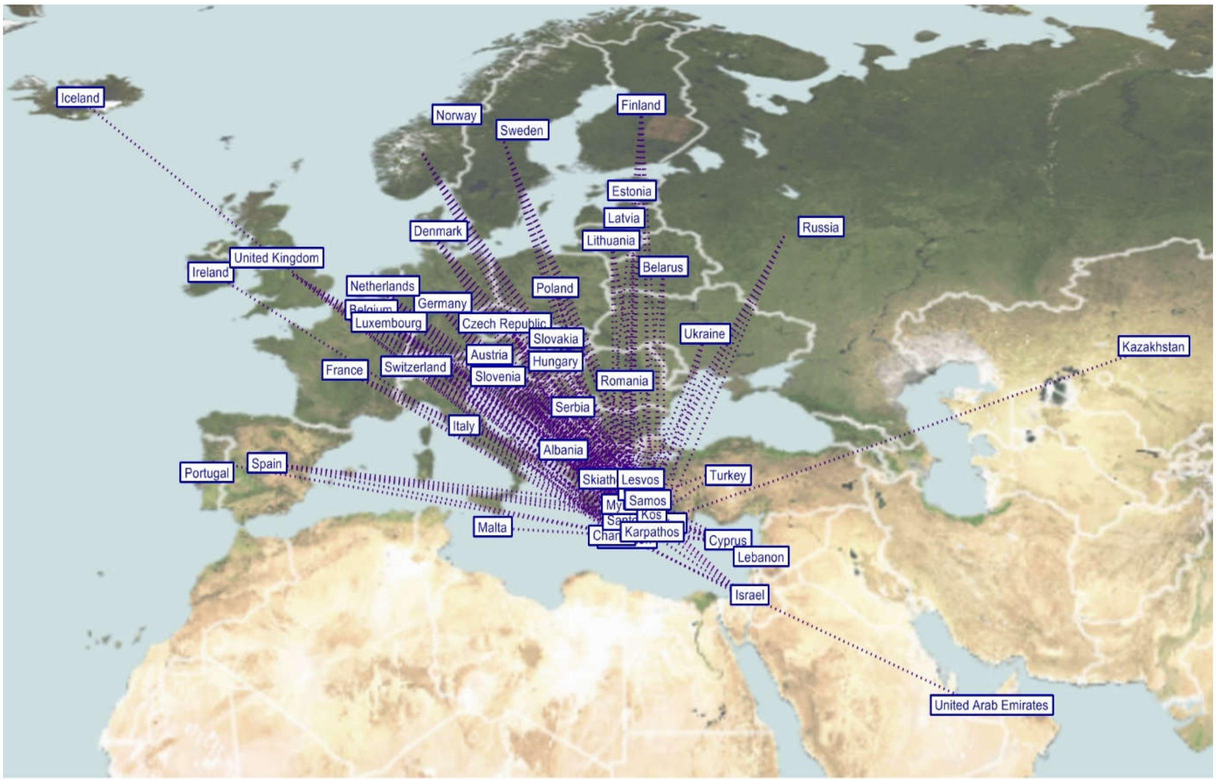


Figure A4. Transport zoning system of distant zones

3.1.5. Transport model nodes and links

The network was modelled on the basis of nodes and links. Especially for the maritime network, nodes represent ports and links represent existing (summer 2013) maritime connections from port to port, on which the itineraries of the various operators are running.

A total of 90 ports were included in the transport model of the study area. They include the major inland ports of Piraeus, Rafina, Lavrio, Agios Konstantinos, Kymi, Volos, Thessaloniki, Kavala, Keramoti, Alexandroupoli and minor Peloponnesian ports on the Aegean Sea offering connections to the island of Kythira. They also include a large number of islandic ports of the Aegean Archipelagos. A detailed list of the connected islands and their ports is included in Annex A.

Strait connections and Argo-Saronic Gulf connections form exceptional cases, characterized by high frequencies and differing significantly from the regular long-distance PAX and Ro-PAX services. They were added in the model network as special maritime connections serving as private transport links with low speed. Such examples are Kavala- Thassos, Chios- Oinousses, Paros- Antiparos, Marmaris (Turkish coast)- Rhodes, Piraeus- Salamina etc.

A total of 27 domestic airports were included in the transport model of the study area. They include the major inland airports of Athens, Thessaloniki, Kavala and Alexandroupolis. They also include a large number of islandic airports of the Aegean Archipelagos. A detailed list of the connected islands and their airports is included in Annex A.

In addition to the maritime and airborne network, major road links were included in the model. The purpose of including the road network in this specific application was to model in detail the landside part of the trip chain connecting each transport zone of the Greek peninsula to the Aegean islands. The modelled road links are connected with the inland ports and airports of the peninsula as gateways providing access to the Aegean Archipelagos using techniques of Park and Ride (P&R). The modelled network links and the connected ports are depicted in the following figures.

Figure A5. Modelled network links and connected ports (summer 2013)

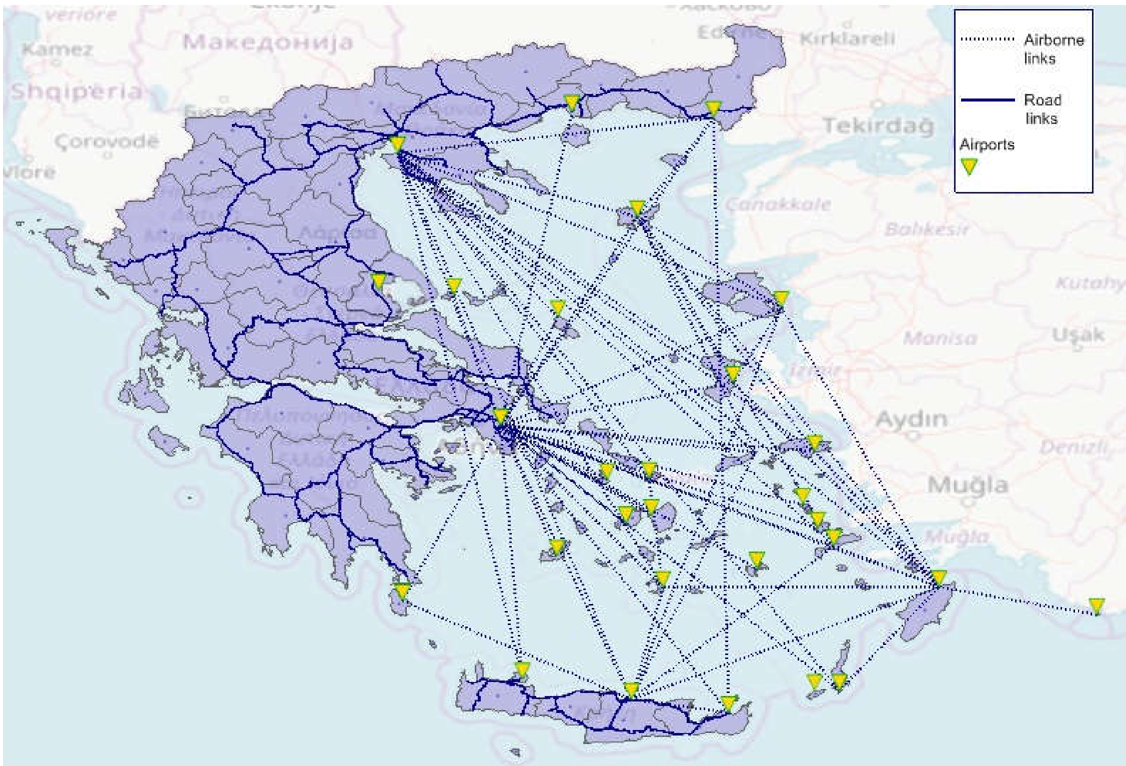


Figure A6. Modelled network links and connected islandic airports (summer 2013)

3.1.6. Transport model PuT stops

All of the ports and airports of the study area are modelled as Public Transport Stop Areas in the Aegean transport system. In case there are ports and airports in the same transport zone, then they are grouped in the same main PuT Stop where trip interchanges are possible. Theoretically these Stops offer opportunities for multimodal trips. This is realized in this model for combined car and maritime trips or/ and combined car and flight trips. A formulation of more complicated interchanges between the maritime and the air transport system is possible but it has been restricted since multimodality in large distance passenger trips requires punctual scheduling, which is not guaranteed by the various private uncoordinated operators. In addition, last-mile accessibility connections between ports and airports constitutes a problematic issue in the islands of the Aegean Sea. In most cases. there is no connecting public transport service i.e. bus, for transfers between ports and airports in the islands. Nevertheless, in all islands there is a well-operating taxi service with taxi ranks existing at all ports and airports which offers transportation between ports and airports at a low price. This issue could better be addressed in the near future through car-sharing solutions on a commercial basis and demand responsive transport services. Overall the system of stop areas in our model consists of the following:

- 77 connected ports
- 27 connected airports
- 38 connected distant airports

3.1.7. Transport model PuT line routes and services

3.1.7.1 Maritime operators of the study area, fleet and services overview

During the summer period of 2013, a total number of 15 maritime operators were providing regular passenger services in the study area, excluding the strait connections and the connections of the Argo-Saronic Gulf islands. It is noted that in the evolution of the fleet in the study area, there is a significant trend to faster ships. The following table presents an overview of the regular PAX and Ro-PAX service vessel types that are in service.

Table A2. Vessel types, capacities and commercial speeds of the study area

index	Name	Type	Avg. Seat Cap.	Avg. Travel Speed (operational)
1	Ferry Sealine	Conventional-Pax / Car Ferry	1,500	17 knot (32km/h)
2	Flying Dolphin	Flying-Pax	140	29 knot (53km/h)
3	Highspeed	Catamaran-Pax / Car Ferry	1,500	28 knot (51km/h)
4	Flying Cat	Catamaran-Pax	400	31 knot (57km/h)

The above-mentioned operators are working individually and privately in a well-established market serving 0.8 million daily passenger trips in the study area during the high season. The fleet of each operator and the main routes have been developed empirically and established over the years, to adapt to the demand of a strongly peaking touristic summer period. These companies are accommodating altogether a remarkable transport workload despite the fact that they are not coordinated and operate on their own maximum ticket revenue basis. The following table presents an overview of the maritime operators in the study area and their corresponding transport workload.

Table A3. Seaborne operator services overview in the study area (summer 2013)

index	Operator name	No. of Lines/ Vessels	No. of Departures (weekly)	Service km (weekly)	Avg. Passenger Capacity per Vessel (summer)
1	Aegean Speed Sealines	1	26	4,881	800
2	Agoudimos Sealines	1	14	1,972	1,300
3	ANEK Sealines	5	52	17,616	1,750
4	Blue Star Ferries	8	86	31,065	1,750
5	Cyclades Fast Ferries	2	31	4,582	1,150
6	Dodekanisos Seaways	3	37	6,319	450
7	Hellenic Seaways	9	126	28,944	1,100
8	Lane Sealines	1	8	2,154	1,000
9	Minoan Sealines	2	22	7,029	2,500
10	NEL Sealines	7	55	18,360	1,250
11	SAOS Sealines	1	28	1,859	700
12	Sea Jets Sealines	4	59	19,534	600
13	Skyros Shipping	1	30	1,598	600
14	Small Cyclades Sealines	1	9	1,008	350
15	Ventouris Sealines	2	17	5,465	1,300
	Sum	*48*	*600*	*152,386*	*1,170**

**weighted average*

3.1.7.2 Airborne operators of study area, fleet and services overview

During the summer period of 2013, a total of 7 airborne operators were providing domestic flight services in the study area and 14 flight operators offered direct regular international connections. In addition to the regular international aviation connections, there are a number of charter flights by various operators on a non-regular basis. The following tables present an overview of the regular internal flight services connecting the islands of the Aegean Sea to the Greek mainland and to international destinations. More detailed information on the lines and destinations for each operator is included in Annex A.

Table A4. Airborne domestic operator services overview in the study area (summer 2013)

index	Operator name	No. of Lines/ routes	No. of Departures (weekly)	Service km (weekly)	Avg. Passenger Capacity per aircraft (summer)	Passengers (weekly)
1	Olympic Airlines	26	677	151,206	70	35,329
2	Aegean Airlines	15	385	123,168	170	54,838
3	Astra Airlines	8	58	24,602	120	4,465
4	Cyprus Airlines	3	22	12,264	160	2,652
5	Sky Airlines	12	74	19,109	30	1,732
6	Minoan Air	6	41	9,222	50	1,148
7	Ryanair Airlines	1	12	6,759	190	2,052
	Sum	***71***	***1,269***	***346,330***	**-**	***102,216***

Table A5. Airborne operators with regular direct international services to the islands of the Aegean Sea (summer 2013)

index	Operator name
1	Olympic Airlines
2	Aegean Airlines
3	Astra Airlines
4	Cyprus Airlines
5	Sky Airlines
6	Minoan Air
7	Austrian Airlines
8	EasyJet Airlines
9	Alitalia Airlines

10	European Air Transport Airlines
11	Iberia Airlines
12	TUIfly Airlines
13	Lufthansa Airlines
14	Ryanair Airlines

From the detailed data collected on the aviation services in the study area, it was possible through data processing to analyse further some characteristics of the capacity supply of the air transport system. In the following table an overview of this analysis is presented.

Table A6. Capacity analysis overview of the aviation system

Row Labels	Number of flights (peak week 2013)	Sum of Capacity-Seats	Sum of Passengers	Average of Capacity-Seats	V/C
domestic_aviation	1,262	133,275	113,335	105	0.85
international_aviation	4,288	767,890	689,301	180	0.90
Grand Total	5,550	901,165	802,636	*162**	*0.89**

**(weighted average)*

From the above table it is evident that the air passenger transport system with destination the Greek islands of the Aegean Sea operates at capacity during the high season. With volume to capacity (V/C) ratios of 85% for domestic aviation to the islands and 90% for the direct international connections to the region, the system is under pressure. There is congestion at the airports and inevitable shifts to the sea modes that still have some excess capacity. Under these conditions the elasticity or the impact of the fares to the mode choice is limited as the most important parameter of the system is related to the capacities and the restrictions they impose.

3.1.8. Popular origins of international tourists by direct airplane connection

Most of the tourists travelling to the islands of the Aegean Sea via direct flight connections originate from the United Kingdom, Russia, Germany and Italy. A detailed table of passenger flows from abroad for the peak week of 2013 is presented next.

Table A7. Popular trip origins for direct international flights to the islands

	Origin Country	Sum of passengers (week) in both directions
1	United Kingdom	96,020
2	Russia	83,229
3	Germany	77,660
4	Italy	65,597
5	France	40,721
6	Netherlands	37,511
7	Norway	36,164
8	Israel	33,135
9	Sweden	30,042
10	Denmark	27,319
11	Belgium	23,151
12	Poland	21,750
13	Austria	19,912
14	Czech Republic	19,903
15	Switzerland	17,872
16	Finland	13,694
17	Ukraine	9,831
18	Romania	4,495
19	Cyprus	4,424
20	Slovakia	3,547
21	Spain	3,338
22	Lithuania	2,823
23	Serbia	2,707
24	Luxembourg	2,544
25	Hungary	2,331
26	Slovenia	2,164
27	Turkey	1,500
28	Lebanon	1,497
29	Belarus	999
30	Ireland	930
31	Albania	590
32	Latvia	560
33	Iceland	368
34	Estonia	355
35	Portugal	260
36	Kazakhstan	221
37	United Arab Emirates	89
38	Malta	48
	Grand Total	***689,301***

The most popular destinations are Heraklion, Rhodes, Kos and Chania. In the following table the matrix of OD pairs with their passenger volumes via direct international flight connections to the islands of the Aegean Archipelagos for the peak week 2013 are presented in detail.

Table A8. Passenger OD matrix via direct international flights

Country	Heraklion	Rhodes	Kos	Chania	Santorini	Mykonos	Skiathos	Samos	Karpathos	Mytilini	Limnos	Chios
U.K.	15,426	13,435	7,351	3,469	2,304	1,827	3,070	265	-	448	418	-
Russia	22,532	13,000	3,937	1,467	679	-	-	-	-	-	-	-
Germany	17,645	9,403	7,116	1,998	386	596	125	992	234	337	-	-
Italy	6,150	6,701	4,148	2,034	4,604	6,226	1,522	415	1,001	-	-	-
France	13,505	3,261	1,120	685	1,057	735	-	-	-	-	-	-
Netherlands	7,146	2,907	5,224	807	241	40	122	952	321	816	-	182
Norway	1,013	5,403	1,562	7,506	1,156	-	615	341	264	118	-	105
Israel	8,511	5,683	1,825	-	-	418	-	-	132	-	-	-
Sweden	1,053	5,370	1,070	5,134	872	-	418	692	414	-	-	-
Denmark	683	3,603	1,219	5,827	939	-	348	553	140	349	-	-
Belgium	4,024	2,996	2,476	1,460	234	166	-	55	-	121	-	46
Poland	3,487	2,864	2,193	2,332	-	-	-	-	-	-	-	-
Austria	2,300	2,095	1,456	941	1,045	517	405	411	504	224	-	61
Czech Rep.	3,363	3,468	2,219	360	128	-	128	-	177	-	77	34
Switzerland	3,889	1,925	2,045	-	302	615	-	162	-	-	-	-
Finland	380	1,850	686	3,174	199	-	151	409	-	-	-	-
Ukraine	3,586	1,072	258	-	-	-	-	-	-	-	-	-
Romania	998	532	241	-	200	86	192	-	-	-	-	-
Cyprus	415	273	-	996	116	111	303	-	-	-	-	-
Slovakia	353	1,244	178	-	-	-	-	-	-	-	-	-
Spain	487	217	119	-	445	402	-	-	-	-	-	-
Lithuania	314	470	451	178	-	-	-	-	-	-	-	-
Serbia	202	685	128	132	-	-	118	-	-	91	-	-
Luxembourg	581	366	326	-	-	-	-	-	-	-	-	-
Hungary	673	493	-	-	-	-	-	-	-	-	-	-
Slovenia	172	170	270	-	59	-	36	75	171	130	-	-
Turkey	125	-	-	-	-	625	-	-	-	-	-	-
Lebanon	-	227	-	-	63	459	-	-	-	-	-	-
Belarus	143	275	83	-	-	-	-	-	-	-	-	-
Ireland	465	-	-	-	-	-	-	-	-	-	-	-
Albania	199	96	-	-	-	-	-	-	-	-	-	-
Latvia	280	-	-	-	-	-	-	-	-	-	-	-
Iceland	-	-	-	184	-	-	-	-	-	-	-	-
Estonia	178	-	-	-	-	-	-	-	-	-	-	-
Portugal	130	-	-	-	-	-	-	-	-	-	-	-
Kazakhstan	-	111	-	-	-	-	-	-	-	-	-	-
U.A.Emirates	-	-	-	45	-	-	-	-	-	-	-	-
Malta	24	-	-	-	-	-	-	-	-	-	-	-
Grand Total	120,424	90,189	47,695	38,723	15,024	12,819	7,551	5,319	3,356	2,631	495	427

Out of the 26 airports in the islands of the Aegean Sea, 12 are servicing international direct flights. The most popular destinations with direct flights to the islands of the Aegean Sea are Heraklion (35% of the total international passengers via direct flights), Rhodes (26%), Kos (14%), Chania (11%), Santorini and Mykonos (4% each).

The majority of the international passengers via direct flights come from: the United Kingdom (14% of the total international passengers via direct flights), Russia (12%), Germany (11%), Italy (10% each), France (6%), Norway and Israel (5% each), Sweden and Denmark (4% each). These 10 countries account for 77% of the total international tourists travelling with direct flights to the islands of the Aegean Archipelagos.

The most popular OD pairs with more than 7,000 tourists arriving at the islands of the Aegean Sea during the peak summer week of 2013 via direct international flights, corresponding to a share of 2%- 7% of the total demand are: Russia-Heraklion, Germany-Heraklion, United Kingdom-Heraklion, France-Heraklion, United Kingdom-Rhodes, Russia-Rhodes, Germany-Rhodes, United Kingdom-Kos and Germany-Kos. These 9 pairs are gathering 35% of the total international volume of tourists travelling with direct flights to the islands of the Aegean Archipelagos.

Some air transport interconnections between the islands (island hopping) in our network were recorded. The airport of Heraklion can be considered as a small hub with connections to Ikaria, Kos, Kythira, Mytilini, Rhodes and Santorini. In addition, in the summer of 2013 the Rhodes airport acted as a smaller hub offering connections to Karpathos, Kastellorizo, Kos, Limnos, Mytilini, Samos and Santorini. In the following table and figure we present these air transport interconnections between the islands.

Table A9. Airborne interconnections within the islands

s/n	Small hub	Connected airports
1	Heraklion	Ikaria
2		Kos
3		Kythira
4		Mytilini
5		Rhodes
6		Santorini
7	Mykonos	Santorini
8	Rhodes	Karpathos
9		Kastelorizo
10		Kos
11		Limnos
12		Mytilini
13		Samos
14		Santorini

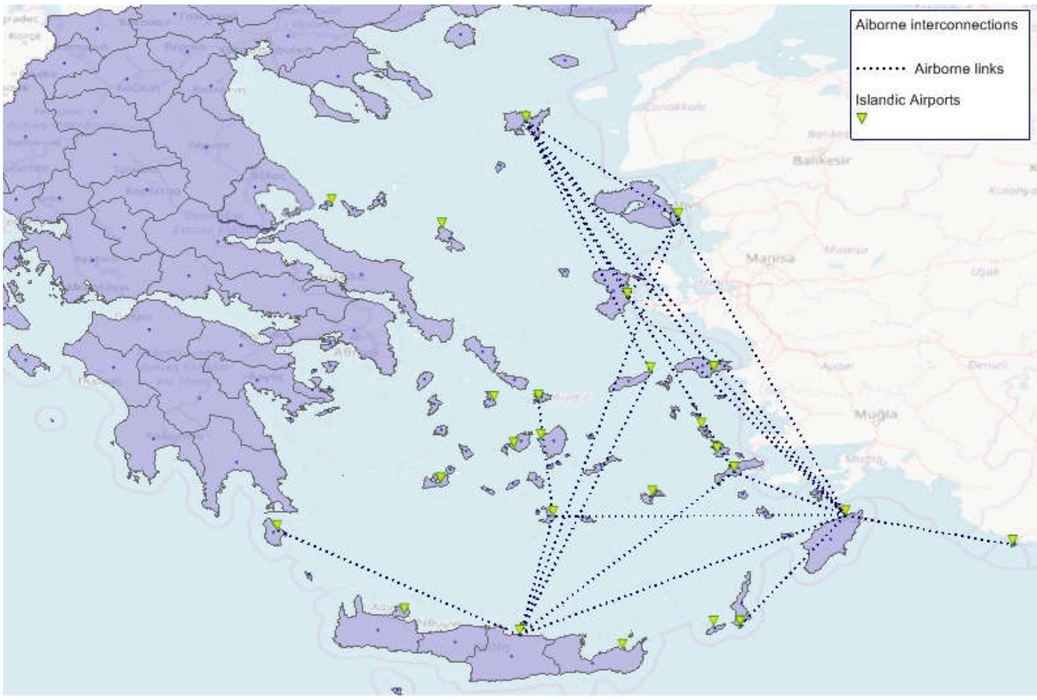


Figure A7. Interconnected islandic airports (summer 2013)

4. NETWORK PERFORMANCE AND SERVICE ASSESSMENT

4.1. Network overview and performance

The detailed transport model developed provides information on the overall network performance. In the following table the general network statistics from the Public Transport Model of the Aegean Sea islands are presented.

Table A10. General Network statistics

Network element	Quantity	Comments
Zones	152	44 external zones: Greek inland regions in NUTS 3 level ("Νομός") as external zones and 38 distant zones Country level
OD pairs	23,104	Including ODs between the external zones
Stop areas	154	(26 airports, 90 ports, 38 distant zones/airports)
Lines/vessels	300	(250 airlines, 150 sealines/vessels)
Line routes/time profiles	650	(476 airlines, 174 sealines)
Vehicle journeys	5,739	(5,148 airlines, 591 sealines)

The domestic flight trips to the islands of the Aegean Sea have almost the same journey times of approx. 40min and the detailed mean journey values are meaningful only for the sea connections. Due to this fact, some additional statistics covering only maritime passenger transport are presented below. Based on these statistics, the mean in-vehicle(vessel)-time is 4.5 hours per passenger and the mean ride distance is 100 nautical miles. Although the travel speeds are relatively satisfactory, the travel distances are quite long resulting in long duration travel times. The following table contains network statistics that were extracted from the maritime transport model.

Table A11. Maritime Network statistics with journey mean values

Network element	Quantity or Value	Comments
Zones	114	44 external zones: Greek inland regions in NUTS 3 level ("Νομός") as external zones 70 internal zones: Aegean Islands as internal zones
Origin-Destination pairs	11,060	Excluding ODs between the external zones
Stop areas	90	90 ports
Lines/vessels	48	Excluding vessels of strait connections and Argo-Saronic Gulf region connections
Line routes/time profiles	178	per week
Vehicle journeys	603	per week
MeanJourneyTimePuT	9.5h	Mean journey time (any path leg with or without PuT service) of all PuT trips
MeanInVehTimePuT	4.5h	Mean in-vehicle time (only path legs using PuT service) of all PuT trips
MeanJourneyDistPuT	582km	Mean journey distance (any path leg with or without PuT service) of all PuT trips
MeanRideDistPuT	100 nm (186km)	Mean ride distance (total length of path legs using PuT service) of all PuT trips
MeanJourneySpeedPuT	62km/h	Mean journey speed (journey distance divided by journey time of all path legs with or without PuT service) of all PuT trips
MeanInVehSpeedPuT	22knot (41km/h)	Mean in-vehicle speed of all PuT trips

In order to simulate a realistic passenger capacity restrained model for one week, which will distribute the passenger flows reasonably to all the available itineraries and simulation days, considering that the model runs over a period of 7 sequential days, representative aircraft and sea vessel capacities are specified. Each PuT line route in the model is assigned to a vehicle unit (aircraft or sea vessel) with specific characteristics in terms of the number of seats and total passenger capacity. Each vehicle unit is allocated to one transport system (Sea or Air). The vehicle unit model for the fleet of the study area is based on statistical processing of the aircraft and vessel data intending to determine the most representative aircraft and sea vessel capacities of the fleets operating in the study area. The results of this analysis are presented in the following table.

Table A12. Vehicle units used for the capacity restrained model for representative aircraft/sea vessel capacities

VehUnit:No	CODE	NAME	TSYSSET	SEATCAP
1	Airplane_L	Airplane_Large	AIR	168
2	Airplane_M	Airplane_Medium	AIR	78
3	Airplane_S	Airplane_Small	AIR	37
4	Ferry Sealine	Ferry Sealine	SEA	300
5	Flying Dolphin	Flying Dolphin	SEA	100
6	Highspeed	Highspeed	SEA	200

4.2. Seaborne network system assessment and weaknesses

4.2.1. Connections only possible via Piraeus

Out of 4285 OD pairs representing connections between islands, only 891 are connected in the peak season via Piraeus primarily and secondarily via other peninsula ports. This amounts to a relatively high percentage exceeding 20%. The equivalent virtual speed of direct connection ("as the crow flies") is less than or 5.4 knots (10km/h). This has also been tested graphically via routing queries for the Public transport shortest path connection between the selected OD pairs.

It is roughly estimated that this market segment represents almost 10% of the total demand between islands (4285 OD pairs) in the existing situation. This percentage sums up to 2% of the total demand for travelling in the study area, excluding any generated passenger flows demand in case of possible new services deviating Piraeus. This particular part of the demand estimation is beyond the scope of this research and therefore, it is only mentioned to justify the minimum speed threshold of the connectivity between islands.

This means that there is a segment of the market not serviced at all. Further analysis can determine whether it is also of critical value. While this approach is considered user optimum and does not necessarily imply more potential revenues, it could improve significantly the cohesion and accessibility of the core study area. Potential system performance improvements exist in regards to new services and connections replacing missing links, which are specified in the following chapter.

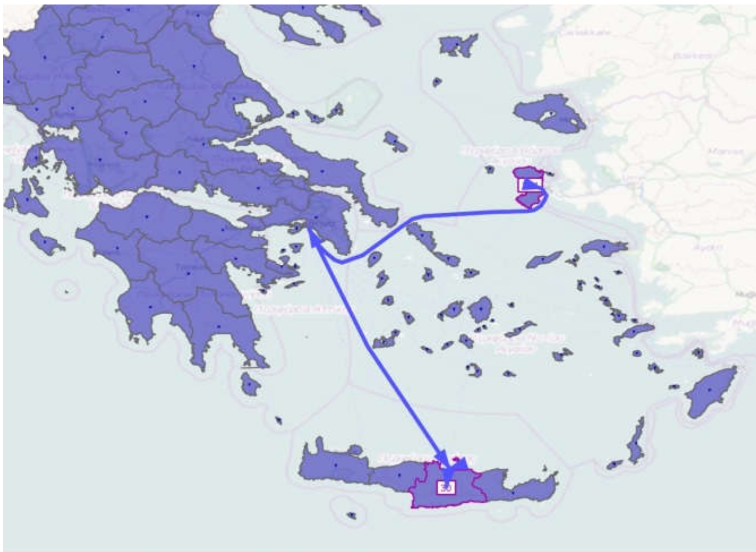


Figure A8. Connection of Chios and Heraklion only possible via Pireus

The figure above graphically displays an indicative connection between islands only possible with a long detour via Piraeus in summer 2013. A specific example of the connection of Chios and Heraklion is presented.

If the table of the 891 Origin-Destination pairs that appear to be connected only via Piraeus (primarily and secondarily via other peninsula ports) is categorized, then the following list emerges in more than 50 instances and therefore, it is presented as cases of problematic connectivity: Agathonisi, Anafi, Fournoi, Nisyros, Lipsi, Tilos, Psara, Patmos, Irakleia, Schinoussa, Leros. Although many criteria need to be taken into account in such a selection process, the above-mentioned islands are generally considered as "more difficult to reach" destinations for the summer period of 2013.

4.2.2. Missing maritime links

After testing different approaches in the preparatory context of the current analysis, the issue of missing links and problematic connections has been addressed through Cluster analysis.

Clustering is the task of grouping a set of objects in such a way that objects in the same cluster are more similar to each other than to those in other clusters groups. It is a common task of exploratory data mining, as well as a common technique for statistical data analysis, used in several scientific fields. The clustering procedure applied in our case is focused on transportation and it is based on combining parameters of administrational divisions, proximity and main connections in the existing situation. The study area is divided into clusters and in the following table and figure, the Clustering of the core study area is presented.

Table A13. List of clusters in the core study área

Clusters 1-3	Clusters 4-6	Cluster 7	Clusters 8-9
1	**4**	**7**	**8**
Agios Efstratios	Chalki	Amorgos	Andros
Chios	Karpathos	Anafi	Mykonos
Lesvos	Kasos	Antiparos	Syros
Limnos	Kastelorizo	Astypalaia	Tinos
Psara	Rhodes	Donoussa	**9**
Samothraki	Tilos	Folegandros	Alonnisos
2	**5**	Ios	Skiathos
Fournoi	Antikythira	Irakleia	Skopelos
Ikaria	Gavdos	Koufonisi	Skyros
Samos	Crete	Naxos	
3	Kythira	Paros	
Agathonisi	**6**	Santorini	
Ano Symi	Kea	Schinoussa	
Kalymnos	Kimolos	Sifnos	
Kos	Kythnos	Sikinos	
Leros	Milos	Thirasia	
Lipsi	Serifos		
Nisyros			
Patmos			

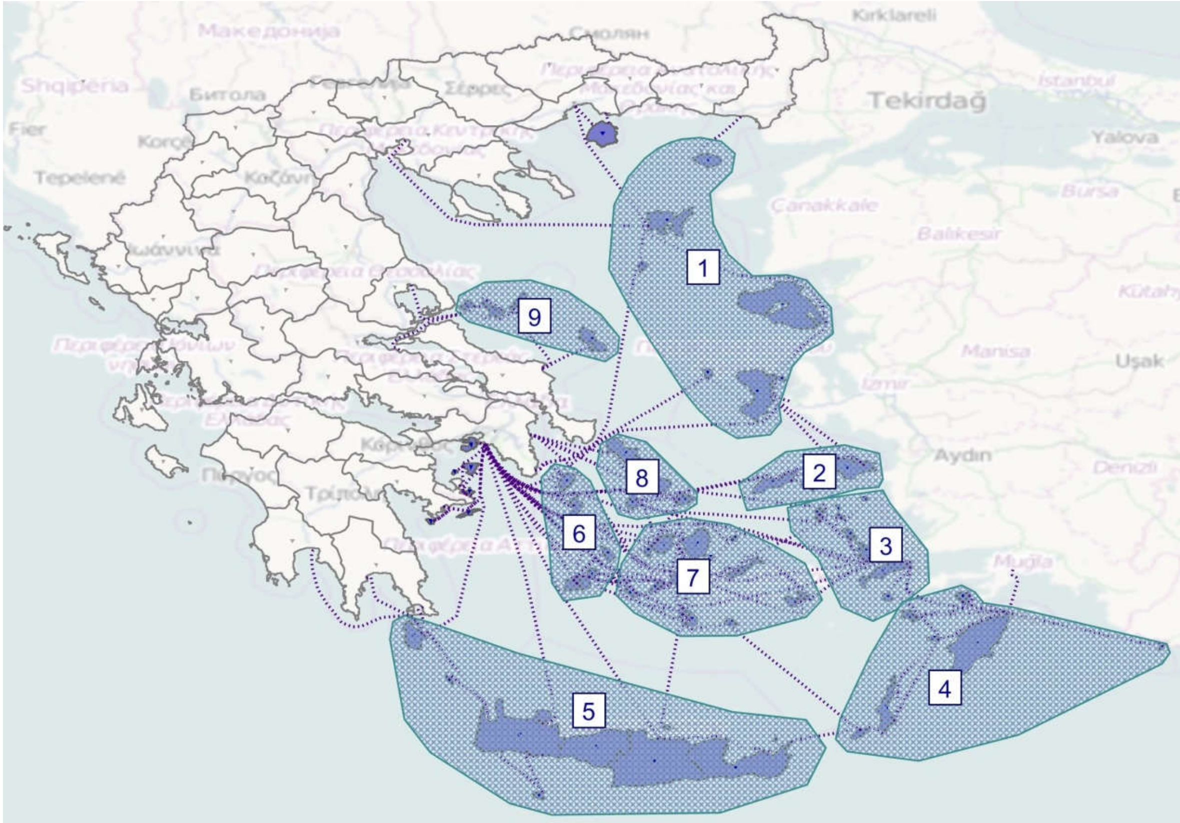


Figure A9. Clustering of the core study area and maritime connections

With the objective of establishing better connections within and between clusters, a set of missing maritime links was identified. More specifically, within Cluster 1 a missing link between Limnos-Samothraki was identified. The same applies to connecting Cluster 2 and Cluster 3 with a missing link between Samos-Patmos. For Cluster 6 a timetable rescheduling is proposed in order to create a connection between Kea-Milos. For Cluster 7 a new connection is suggested between Anafi- Astypalaia. In addition, a need was identified to establish a connection between Cluster 1 and Cluster 8 via the missing link Chios-Andros and therefore it is proposed that the itinerary Chios – Piraeus should make a stop at Gavrio. To achieve better connection between clusters 6 and 7, a link connecting Serifos and Paros is proposed. Finally, to improve the connection between clusters 6 and 8, a link between Serifos and Syros is suggested. These proposals apply for the summer period of 2013 and it is possible that in the meantime some of them have already been added in recent years (by 2018). In the following table the above-mentioned missing links and proposed connection improvements are summarized.

Table A14. Missing links and proposed maritime connection improvements

Clusters involved/affected	Missing link	Consider connection	Problematic connection needs timetable optim.
cluster 1	Limnos – Samothraki		
cluster 6			Kea – Milos
cluster 7		Anafi – Astypalaia	
cluster 2 and cluster 3	Samos (Vathi) – Patmos		
cluster 1 and cluster 8	Chios – Andros (Gavrio) *itinerary Chios – Piraeus should make a stop at Gavrio		
cluster 6 and cluster 7		Serifos – Paros	
cluster 6 and cluster 8		Serifos – Syros	

The maritime passenger network in the islands of the Aegean Sea could be further improved by adopting alliance concepts and practices used by the air transport sector operators. Ferry companies could ally themselves with other ferry companies in constructing a two-ferry company alliance as means of achieving greater service coverage, that will operate more efficiently under coordinated schedules.

4.3. Air Transport network system assessment

4.3.1. Connections only possible at major islands and capacity issues

There is a sufficient number of airports in the islands of the Aegean archipelagos. The network of 26 airports in the islands of the study area is considered a very dense one.

In general, there are no major aviation hubs in the islands of the Aegean Sea that could serve as connection points to smaller islands that have airports. The airport of Heraklion can be considered as a small hub providing connections to the islands of Ikaria, Kos, Kythira, Mytilini, Rhodes and Santorini. Also, Rhodes airport plays the role of a smaller hub with connections on offer to the islands of Karpathos, Kastellorizo, Kos, Limnos, Mytilini, Samos and Santorini, which were provided in the summer of 2013. This is further discussed and justified in Part C of the thesis. Also the airport of Mykonos could serve as a third minor hub for interconnections between sea and air modes. Only few operators, equipped with limited capacity aircrafts, provided island-hopping air transport services in the summer season of 2013. The issue of more efficient inter islandic connections via air is addressed in the following paragraph concerning missing air transport links.

By processing the aviation passenger data, it is concluded that the air transport system in the study area operates on capacity during the summer season and there is excess demand possibly transferred to the maritime network. Very high occupancy rates of V/C between 0.8 and 0.9 for both domestic aviation and international aviation are observed. For this reason it is proposed that the aviation services could be improved with the provision of more frequent flights.

There is an accessibility issue concerning the last mile connection from the road side to the airports of the islands of the Aegean Archipelagos via public transport means. The distance of the islandic airports to the nearest city or major town varies from 1km up to 27kms. Determinants of Greek islandic airports' accessibility are presented in Annex A. The airports' accessibility in the islands of the Aegean Sea could be improved either by providing bus services from the major towns on each island or by increasing the frequency of the existing bus connections. Another measure could involve the application of privately initiated car sharing options or any other demand-responsive public bus service via smartphone applications, additional to the existing taxi services.

4.3.2. Missing air transport links

The issue of missing links and problematic connections between the islands of the Aegean Archipelagos by air transport, was addressed using Cluster analysis along the same lines of the analysis carried out for the missing maritime connection.

In the following figure the analysis based on clusters for the air transport connections between the islands of the Aegean Sea is presented.

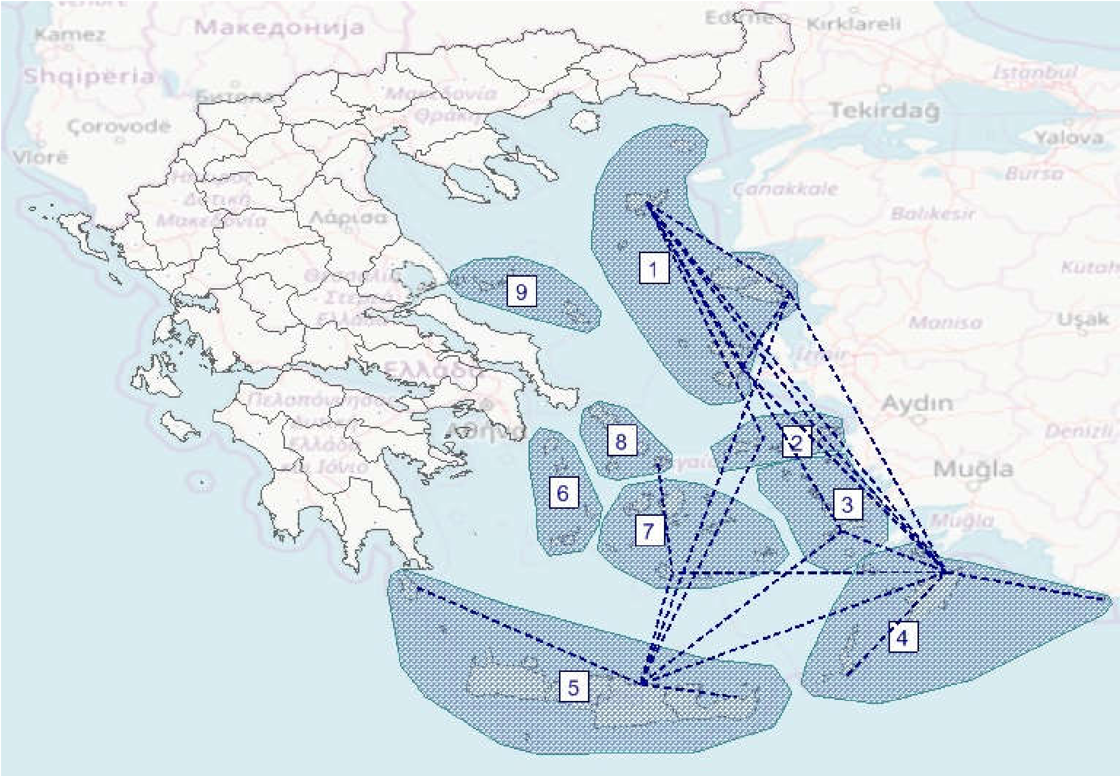


Figure A10. Clustering of the core study area and airborne connections

A lack of interconnections for clusters 6, 8 and 9 is observed. These clusters are situated very close to the Greek mainland and due to this, they are not connected internally. In general terms, there is sufficient connectivity among clusters 1-2-3 and 4, as well as between Crete (cluster 5) and clusters 2, 3, 4 and 7. Four missing airborne links are identified, namely Chios/Lesvos-Skiathos/Skyros, Chios/Lesvos- Mykonos, Rhodes-Mylos, Chania-Mylos and three additional connections to be considered being: Heraklion- Chios/Lesvos, Rhodes-Mykonos and Heraklion-Mykonos. Furthermore, there are two existing (summer 2013) connections with a frequency that could be upgraded from one itinerary per week to two itineraries per week in the summer period. In the following table the assessed missing air transport links and connections are summarized.

Table A15. Missing links and proposed airborne connection improvements

Clusters involved/affected	Missing link	Consider connection	connections with 1 itinerary per week that could be more frequent
cluster 1 - 9	Chios/Lesvos-Skiathos/Skyros		
cluster 1 - 5		Heraklion-Chios/Lesvos	
cluster 1 - 8	Chios/Lesvos-Mykonos		
cluster 4 - 8		Rhodes-Mykonos	
cluster 4 - 6	Rhodes-Mylos		
cluster 5 - 6	Chania-Mylos		
cluster 5 - 8		Heraklion-Mykonos	
cluster 4 - 7			Rhodes-Santorini
cluster 4 - 1			Rhodes-Lesvos

4.4. Combined Maritime and Air Transport multimodality assessment

Restrictions exist as multimodality in large distance passenger trips requires coordinated scheduling and punctual arrival services, which are not guaranteed by the various private operators, who are uncoordinated. Furthermore, last-mile accessibility connections between ports and airports in the islands of the Aegean Sea constitutes a problematic issue. In most cases, there is no public transport i.e. bus service, for transfers between ports and airports in the islands. Nevertheless, at all islands there a well-operating taxi service is in place, with taxi ranks situated at all ports and airports offering transportation between them at a low price. This issue could better be addressed in the near future with demand responsive transport services based on smartphone apps and car-sharing solutions on a commercial basis.

Despite the lack of coordination in the trip schedules, the airports of Heraklion, Rhodes and Santorini, already serving as small interchange hubs between air and sea transport modes, to smaller airportless islands.

A concept of alliances between ferry and airline companies could further optimize accessibility to the islands of the Aegean Archipelagos.

4.5. Trip scheduling platform for the Aegean islands

An added value of the transport model developed for the Thesis concerns its potential use as a platform for trip scheduling. It serves as a detailed information system offering directions on best routes on specific dates and specific time intervals. It also contains real times for the landside part of the journey when connecting major Greek cities of the peninsula to the Aegean Island. Such an application does not exist via the servers that provide pre-trip information on the internet at the moment (2015). An indicative application of this useful tool is presented in the following tables selecting examples of difficult OD pairs that do not necessarily lie on main maritime PAX lines as well as an example of combined air and sea transport.

Table A16. Trip scheduling example for Mykonos-Chania connection by sea

PUT PATH INDEX	ORIG ZONE\ NAME	DEST ZONE\ NAME	FROM STOP AREA NO	TO STOP AREA NO	TSYS CODE	TIME PROFILE KEYSTRING	DEP	ARR	TIME	LENGTH
1	Mykonos		Mykonos Port	Heraklion Port	SEA	MEGA JET to Heraklion < SEA JETS	Thu 1/8/13 13:50	Thu 1/8/13 18:30	4h 40min	296km
2			Heraklion Port	Heraklion Port		Transfer	Thu 1/8/13 18:30	Thu 1/8/13 18:30	0h	0km
3		Chania			P+R	Road segment	Thu 1/8/13 18:30	Thu 1/8/13 20:30	2h	140km

Table A17. Trip scheduling example for Chios-Rhodes connection by sea

PUT PATH INDEX	ORIG ZONE\ NAME	DEST ZONE\ NAME	FROM STOP AREA NO	TO STOP AREA NO	TSYS CODE	TIME PROFILE KEYSTRING	DEP	ARR	TIME	LENGTH
1	Chios		Chios Port	Piraeus Port	SEA	NISSOS CHIOS to Piraeus< HELLENIC SEAWAYS	Thu 1/8/13 23:10	Fri 2/8/13 06:25	7h 15min	288km
2			Piraeus Port	Piraeus Port		Transfer	Fri 2/8/13 06:25	Fri 2/8/13 06:25	* 12h 35min	0km
3		Rhodes	Piraeus Port	Rhodes Port	SEA	BLUE STAR 2/ from Piraeus > BLUE STAR FERRIES	Fri 2/8/13 19:00	Sat 3/8/13 08:10	13h 10min	502km

*transfer waiting time

Table A18. Trip scheduling example for Attiki-Gavdos connection by sea & air combined

PUT PATH INDEX	ORIG ZONE\NAME	DEST ZONE\NAME	FROM STOP AREA NO	TO STOP AREA NO	TSYS CODE	TIME PROFILE KEYSTRING	DEP	ARR	TIME	LENGTH
1	Attiki		Athens Airport	Chania Airport	AIR	AEGEAN Airlines	Wed 31/7/13 05:05	Wed 31/7/13 05:55	50min	267km
2			Chania Airport	Chania Airport		Transfer	Wed 31/7/13 05:55	Wed 31/7/13 06:30	* 35min	0km
3			Chania Airport	Palaiochora Port	P+R	Road segment	Wed 31/7/13 06:30	Wed 31/7/13 08:10	1h 40min	90km
4			Palaiochora Port	Palaiochora Port		Transfer	Wed 31/7/13 08:10	Wed 31/7/13 08:30	* 20min	0km
5		Gavdos	Palaiochora Port	Gavdos Port	SEA	ANENDYK Gavdos Sealines	Wed 31/7/13 08:30	Wed 31/7/13 11:55	3h 25min	72km

*transfer time

5. CONCLUSIONS OF PART A

Part A of this thesis examines the existing transport system for passenger trips in the Aegean archipelagos with the use of advanced transport network simulation tools and more specifically by introducing techniques used in Public transport modelling. This approach allows calculations of the overall network performance and identification of system weaknesses, such as missing links or problematic connection, capacity and interconnection restrictions.

The missing link analysis for the maritime connections is addressed via the clustering of the core study area. A set of new connections is proposed (with the existing situation being the simulated period of summer 2013) such as Limnos- Samothraki, Anafi- Astypalaia, Samos-Patmos, Chios-Andros, Serifos- Paros and Serifos- Syros. Although there are several criteria involved in such a selection, the islands Agathonisi, Anafi, Fournoi, Nisiros, Lipsi, Tilos, Psara, Patmos, Irakleia, Schinoussa, and Leros were identified, generally speaking, as destinations more difficult to reach during the summer of 2013.

According to the overall network performance the mean in-vehicle(vessel)-time is 4.5 hours per passenger and the mean ride distance is 100 nautical miles. Although travel speeds are relatively satisfactory, the travel distances are quite long resulting in long duration travel times. 15 operators are providing maritime transport services in the study area, excluding the strait connections and Argo-Saronic Gulf lines. The fleets of the various operators and the main routes have been developed empirically and established over the years to adapt to the demand of a strongly peaking touristic summer period. These companies offer altogether the remarkable transport workload of 150,000 service kms weekly.

The maritime passenger network in the islands of the Aegean Sea could be further improved through the utilization of alliance concepts and practices applied by airline companies. Ferry companies could ally among themselves within the industry, i.e. establishing a two-ferry company alliance, as means to form more complete networks and operate more efficiently under coordinated schedules.

There is a sufficient number of airports in the islands of the Aegean archipelagos. The network of 26 airports in the islands of the study area is considered a very dense one.

In general, there are no major aviation hubs in the islands of the Aegean Sea that could serve as connection points to smaller islands with airports. The airport of Heraklion can be considered as a small hub offering connections to the islands of Ikaria, Kos, Kythira, Mytilini, Rhodes and

Santorini. Rhodes airport also operates as a smaller hub providing connections to the islands of Karpathos, Kastellorizo, Kos, Limnos, Mytilini, Samos and Santorini, as of the summer of 2013. The airport of Mykonos could potentially serve as a third minor hub for air transport interconnections.

By processing the aviation passenger data, it can be concluded that the air transport system in the study area operates at the capacity level during the summer season. Very high occupancy rates of volume to capacity ratios between 0.85 and 0.9 for domestic aviation and the international aviation respectively, are observed. Charter flights have their share also in the high V/C levels of international aviation with direct flights at the islands. In any case the high volumes at the airports and high V/C ratios, cause congestion at the airports of the study area in the summer season. The findings discussed here provide evidence of excessive demand for air trips that is constrained by the capacity of the transport system. It could have as a result either shifts to sea modes that are less congested which is the good scenario, or shifts to other holiday destinations especially for foreign tourists which is the worse scenario for Greece, as the country has the interest to increase its tourism market share. Capacity constraints of the air mode strongly affect the mode choice for holiday trips and its elasticity. Therefore, the fare cost as the main determinant of the model choice becomes less important as the system works at capacity levels. Offering faster sea modes to compete with the domestic air connections would be an option as proposing increase in flight frequencies is not always feasible due to airport congestion restrictions. The expansion of the holiday period would ease the congestion issues and regulate the strongly peaking demand for trips to the Aegean Archipelagos of July and August.

There is an accessibility issue concerning the last mile connection from the road side to the airports of the islands of the Aegean Archipelagos via public transport means. The airports' accessibility could be improved either by bus services provided from the major towns on each island or by the greater service frequency of existing bus connections. Another measure could be privately initiated car sharing options or any other demand-responsive public bus service via smartphone applications additional to the existing taxi services.

Out of the 26 airports in the islands of the Aegean Sea, 12 are servicing international direct flights. The most popular destinations with direct flights to the islands of the Aegean Sea are Heraklion (35% of the total international passengers via direct flights), Rhodes (26%), Kos (14%), Chania (11%), Santorini and Mykonos (4% each).

The majority of the international passengers via direct flights come from: the United Kingdom (14% of the total international passengers via direct flights), Russia (12%), Germany (11%), Italy (10% each), France (6%), Norway and Israel (5% each), Sweden and Denmark (4% each). These 10 countries account for 77% of the total international tourists travelling with direct flights to the islands of the Aegean Archipelagos.

The most popular OD pairs with more than 7,000 tourists arriving at the islands of the Aegean Sea during the peak summer week of 2013 via direct international flights, corresponding to a share of 2%- 7% of the total demand are: Russia-Heraklion, Germany-Heraklion, United Kingdom-Heraklion, France-Heraklion, United Kingdom-Rhodes, Russia-Rhodes, Germany-Rhodes, United Kingdom-Kos and Germany-Kos. These 9 pairs are gathering 35% of the total international volume of tourists travelling with direct flights to the islands of the Aegean Archipelagos.

Restrictions exist in the combined sea and air transport in the study area. Multimodality in large distance passenger trips requires coordinated scheduling and punctual arrival services, which are not guaranteed by the various private operators, who are uncoordinated. Also, last-mile accessibility connections between ports and airports in the islands of the Aegean Sea is a problematic issue. This issue could better be addressed in the near future by demand responsive transport services, privately initiated car-sharing solutions or shuttle services. In spite of the lack of coordination in the trip schedules, the airports of Heraklion, Rhodes and Santorini, already operate as small interchange hubs connecting air and sea modes, to smaller airportless islands. A development concept involving ferry companies and airline companies' alliances could further optimize accessibility to the islands of the Aegean Archipelagos. This concept indicates directions for future research.

In the existing situation (2015) there is no integrated information system for trip scheduling with intermodal options in the study area. An additional value of the transport model developed is its potential use for trip scheduling purposes in the area of the Aegean islands. An official website serving as a trip scheduling platform for the Aegean islands would assist and improve mobility both for tourists/ visitors and locals.

The most popular OD pairs with more than 7,000 tourists arriving at the islands of the Aegean Sea during the peak summer week of 2013 via direct international flights, corresponding to a share of 2%- 7% of the total demand are: Russia-Heraklion, Germany-Heraklion, United Kingdom-Heraklion, France-Heraklion, United Kingdom-Rhodes, Russia-Rhodes, Germany-

Rhodes, United Kingdom-Kos and Germany-Kos. These 9 pairs are gathering 35% of the total international volume of tourists travelling with direct flights to the islands of the Aegean Archipelagos.

PART B: THE DEMAND SIDE

PASSENGER DEMAND AND PATTERNS
OF TOURISTS' MOBILITY
IN THE AEGEAN ARCHIPELAGO
WITH COMBINED USE OF BIG DATASETS
FROM MOBILE PHONES AND STATISTICAL DATA
FROM PORTS AND AIRPORTS

INITIAL DEMAND MODEL AND REVISION USING DATA FROM HOTEL RECORDS

6. INTRODUCTION AND BACKGROUND OF PART B

The passenger transport system in the Aegean Archipelagos represents a complex network of maritime and air connections servicing the demand of approx. 0.5 million tourist trips per week in the high season. Its complexity lies in the large number of users, the significant number of 66 islands offering tourist attractions and the overall 78 serviced ports, 25 airports and 30 private operators of the islandic study area. The overall objective is to analyze and visualize trips in the study area in order obtain detailed understanding of the system and enable the identification of possible weaknesses at a next research level. The analysis was made at the extended level of one week during the peak summer period, as the typical maritime travel times in the study area range from 3 to13 hours for maritime connections and for the air transport connections the majority of trips have a duration of around 40 mins namely for inland flights.

6.1. Problematic and Scope of this Approach in the Specific Study Area

This Part of the Thesis aims to investigate the existing transport system for passenger flows in the Aegean archipelagos travelling by sea and air during the peak period of the summer of 2013. Due to the special conditions of the study area and its polynesian complex, on-site surveys for the passenger demand assessment are becoming complicated and inefficient. Alternatively, it was opted to set up in a typical gravity model based on aggregated statistical data available for both maritime and air transport modes operating in the Aegean region. Nevertheless, there are limitations and uncertainties involved in developing an OD matrix from aggregated statistical data. The main disadvantages lie in the estimation of the trip distribution per OD pair. Also, there is a number of trip patterns that are not identified and therefore not described properly under this approach.

For this reason, exploiting mobile phone tower technologies as alternative methods for providing some level of travel behavior information was considered. These large data sets can be mined or translated into mobility patterns. Yet, there are still limitations in this approach for the deployment of OD matrices in the given study area. Overall results and flows cannot possibly be derived because the samples are not statistically justified. There are biases whose effect cannot be estimated. The main concerns are that firstly, only one mobile network operator provided data for this research, secondly, the mobility of persons not active through mobile calls cannot be captured and thirdly, there is a possibility that mobility of foreign tourists using roaming could be underestimated due to minimum call activity or device switching off during holidays. Several assumptions need to be determined for the exploitation of the large data sets and big data mining steps followed during this process. Another disadvantage derives from the scattered location of the mobile phone antennas in the Aegean region, leaving big sections of trips made by sea without network coverage. Tracking deployment signaling in many cases "jumps" instead of a route in a sequential path formulation is also considered.

For this reason in this research the possibility to complete and correct the gravity model with data from mobile phone tracking was examined. More specifically it was aimed to compare the modeled flows and paths based on the aggregated data with mobility patterns derived from processing big data from mobile phone tracking. In order to compare and combine these two above, statistical methods and distributions were used. Complementary, graphical patterns and visualizations resulted from the model and the representation of the big data from mobile phones in open-source maps and other applications were also used.

6.2. Overview of Literature Review

Mobile data positioning records and other tracking technologies such as GPS, smartphones location settings etc. can provide a depth of insight into travel behavior and activity patterns that could complement traditional modeling approaches based on aggregated data. Wanga, Zhanga, Liua and Quana (2013) proposed an urban mobility classification (walk/ bicycle, bus/ car) method based on cell phones and estimates of travel speeds. Their method uses k-clustering and linear classification.

Demissie, Correia and Bento (2013) analyzed cell handover activity to capture urban dynamics. They validated their methods with modelled traffic flows. Additionally, they applied statistics and visualisation methods for traffic pattern mobility mapping. Widhalm, Yang, Ulm, Athavale and González (2010) discovered methods to reveal activity patterns that emerge from cell phone data in urban areas. They presented a method detecting stays and extracted a set of geolocated time stamps that represent trip chains. They cluster activities by combining the detected trip chains with land use data by modeling the dependencies between activity type, trip scheduling, and land use types via a Relational Markov Network.

A few years later, in a similar approach, Nitsche, Widhalm, Breuss, Brändle and Maurer (2013) exploited emerging technologies of smartphones. Individual trips of the person carrying the phone are automatically reconstructed and trip legs are classified into one of eight different modes of transport. This task is performed by probabilistic classifiers combined with a Discrete Hidden Markov Model. The method required the collaboration of volunteers. In 2009, analysis of data from cellular phone systems in order to study long-distance travel patterns was applied in Israel. The approach of Bekhor, Cohen and Solomon allowed passive data collection on many travellers over a long period of time at low costs. The method was specifically designed to capture long distance trips, as part of the development of a national demand model [23].

Iqbal, Choudhury, Wang, González (2014) also developed OD matrices using mobile phone records and limited traffic counts. The records consisting of time stamped tower locations with caller IDs, are analyzed and trips within certain time windows are used to generate tower-to-tower transient OD matrices. These are converted to node-to-node transient matrices that need scaling up. An optimization based approach, in conjunction with a microscopic traffic simulation platform, is used to determine the scaling factors.

Kang, Gao, Lin, Xiao, Yuany, Liu and Maz (2010) in their study introduced statistical and spatiotemporal analysis methods to identify individual human mobility patterns from mobile phone records. With examples of data mining and patterns in urban areas under the time geography framework, they called their technique “geo-visualizing” and presented daily and week-long individual travel-activity paths in 3D and 2D. Moreover, they provided distributions of the typical distance covered by individuals per gender and age.

Wolf, Bachman, Oliveira, Auld, Mohammadian, Vovsha (2014) in their report for NCHRP provided guidance on using GPS data for evaluating travel behaviour. They summarised the existing techniques and set up standards for this analysis. Among other useful information, they proposed GPS data cleaning and processing in three steps: noise filtering, trip identification and mode transition identification.

Csáji, Browetc, Traag, Delvenne, Huensc, Doorenc, Smoredae and Blondel (2012) analyzed mobility with mobile phone records by defining a set of features for each user. These features represent aspects of users’ behaviour e.g. number of incoming calls, number of people dialed, position of the user etc. They also investigated frequently visited locations by determining type of location such as “home” and “office” based on temporal calling dynamics. They presented the distribution of commuting distances revealed by the analysis of mobile phone data. Lv, L.Chen, Shen and G.Chen (2015) explored the cell-id trajectory similarity measure. They applied a clustering algorithm to discover potential route patterns from cell-id trajectories, and a nearest-neighbor classification algorithm to match current trajectories to route patterns.

M. Zilske and K. Nagel (2015) investigated replacing travel diaries with sets of call detail records (CDRs) used as inputs for an agent-oriented trace simulation. They proposed constructing an agent population directly from a CDR dataset and fusing it with link volume counts to reduce spatio-temporal uncertainty and correct for underrepresented traffic segments. They demonstrated their approach by illustrative scenarios with synthetic data. Their approach is based on the MATSim transport micro-simulation and the Cadyts calibration scheme. [6-26]

The positioning adopted in this part of the thesis in regards to the aforementioned existing literature is between Kang, Gao, Lin, Xiao, Yuany, Liu and Maz (2010), Demissie, Correia and Bento (2013) and Lv, Chen, Shen and Then (2015).

7. METHODOLOGY AND APPROACH OF PART B

7.1. Approach and Methodology Overview

For the elaboration of the research a large set of data from different sources was collected, processed, cross-examined and visualized. The data consists of conventional statistics from ports and airports on node level as well as from sealine and airline timetables and statistics on the link and/or itinerary level. This data was processed to provide trip attractions, travel times between OD pairs, gravity model exponentials and model validation. The conventional data types and methods are complemented with a set of big data (approx. 44 million records) from mobile phones that were provided in respect with privacy regulations by one out of the three mobile network operators in Greece, servicing one third of all users in the country. This dataset is useful after assumptions and corrections in extracting and mapping travelers' mobility patterns in the Aegean Sea. The main tools used are global positioning systems GIS, transport modelling and simulation tools, SPSS, Access database tools, OpenStreetMaps and GoogleMaps applications among others.

Expected results are the calculation and validation of demand matrices per mode in the study area with the combined use of conventional data from port and airport statistics, from sealine and airline statistics. Furthermore, the identification and visualization of mobility patterns of tourists during the high season from dig data sets from mobile phones completes the analysis with added value tools, estimations of the average travel distance via sea and air per tourist, identification of cases with more than one destination visited such as chain trips, identification and validation of transfer points, when there is a change of mode or line. The schematic overview of the approach followed is presented in the following figure:

3 Part B: The demand side

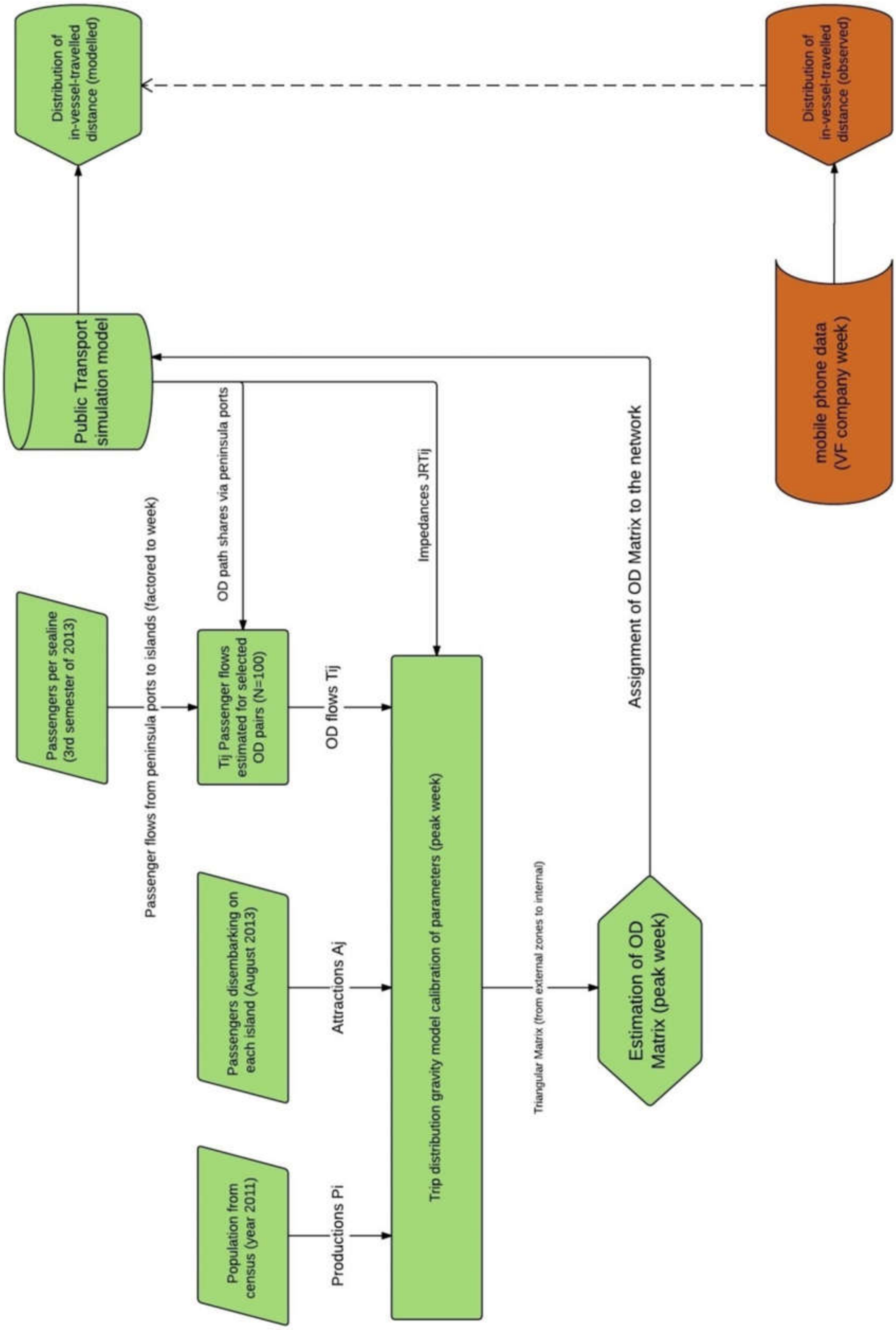


Figure B1. Overview of modelling and cross-examination process

7.2. Study Area, Zoning System and Transport nodes

The study area consists of the large Aegean archipelago complexes and islands of Greece, which are: Eastern Aegean islands, Cyclades, East Cyclades, Western Cyclades, Small Cyclades, Dodecanese, Crete and Argo-Saronic Gulf islands. In the following figure the core study area is presented. [4]

Figure B2. Study area

<u>Transport Zone system</u>

The transport model zoning system consists of 152 zones in total.

- 38 distant zones: 38 foreign countries which are connected via direct flights with the Aegean Islands
- 44 external zones: Greek inland regions in NUTS 3 level (“Νομός”) as external zones
- 70 internal zones: Aegean Islands at island level and Crete, which is the largest island in NUTS3 level, as internal zones

The distant zones consist of European countries, Balkan counties, Turkey, Russia, Kazakhstan, Lebanon, Israel and the United Arab Emirates at NUTS0 level. In all of these cases, direct flights to the Aegean islands were identified and modelled.

Nodes/ ports/ airports

The network was modelled on the basis of nodes and links. For the maritime network, nodes represent ports and links represent existing (summer 2013) maritime connections from port to port, served by the itineraries of the various operators. For the air transport network, nodes represent airports and links represent connections by air from airport to airport.

A total of 90 ports were included in the transport model of the study area. They comprise the major inland ports of the Greek peninsula offering access to the Aegean Sea. Furthermore, they include a large number of island ports of the Aegean Archipelago. The network is completed with the inclusion of 26 domestic airports and 38 distant airports from abroad, which in the simulated period, are connected with direct flights to the core study area of Aegean Sea islands.

All the itineraries, both by sea and air, were modelled in detail with their departure and arrival times as a public transport system. Due to large distances travelled modelling periods exceeding one day had to be considered since many trips in the study area are not completed during the course of a single day. For this reason the itineraries running during a whole week period were simulated. A time schedule-based assignment was used for the simulation.

7.3. Modelling Passenger Demand from Aggregated Statistical Data

For the modelling of the passenger demand a simple four-step methodology with some adjustments was used. The four-step process is a well-known and widely applied methodology, consisting of the following steps:

- Trip Generation
- Trip Distribution
- Modal Split
- Assignment to the network

For the Trip Generation step summary passenger flows from the statistical authority were used. For the next step, that of Trip Distribution, a gravity equation based on 'Productions' and 'Attractions' of each zone was estimated and calibrated. The Production-Attraction system was based on Population of each zone and Number of arrivals in each island-zone respectively. Based on the above, modal trip distribution matrices were calculated next, as an adjustment to the third step. An independent modal split step was also tested but the results were not satisfactory due not only to the complexity of the system but also due to the significant amount of charter flights-on demand that cannot be easily parametrized and modelled. Furthermore, the modest fit of such an independent step is also attributed to the very wide variety of flight ticket costs when compared to the standard ticket costs of the ferries in the study area. For the last step, the transport system was simulated by employing public transport assignment algorithms using the detailed timetable-based approach that was modelled in the network. The simulation period corresponds to one week from Monday, the 29th of July 2013 to Sunday, the 4th of August 2013.

7.3.1. Trip Distribution and Modal Split

The gravity model is the most common formulation of the spatial interaction method. It is named as such because it uses a similar formulation to Newton's law of gravity [5]. A simple trip distribution equation based on gravity has the following form:

$$T_{ij} = \mathrm{k}\,\frac{Pi^{a}.\ Aj^{\beta}}{dij^{c}}\ (1)$$

Where:

- Tij: flows of passengers between origin zone i and destination zone j.
- Pi and Aj: Productions in origin zone i and Attractions in destination zone j.
- dij: Spatial separation (distance or time or cost) parameter between the origin and the destination.
- k: proportionality constant related to the rate of the event; used also for scaling.
- α: Potential to generate movements (emissiveness).
- β: Potential to attract movements (attractiveness).
- c: A parameter of transport friction related to the efficiency of the transport system between two locations.

A significant challenge related to the usage of spatial interaction models, notably the gravity model, is related to their calibration. Calibration involves finding the value of each parameter of the model (constant and exponents) to ensure that the estimated results are similar to the observed flows. To complete the process of calibration, estimated results have to be compared against empirical evidence.

Trip Distribution and Modal Split consist of two different steps in the conventional 4-step model, applied to transport planning. However, within the present research these two steps are applied together, resulting in matrices of passenger volumes travelling between zones by type of mode which in the examined case corresponds to sea and air.

After testing a set of possible production, attraction and spatial separation parameters, it was found that the equation applies better when using:

- Pi: Population of each origin zone as the production parameter. Data from the census of 2011 was used.

- Aj: Number of arriving passengers to each destination zone as the attraction parameter. Data from statistical authorities was used.

- dij: Minimum journey travel (JRT) time from origin to destination per mode. Data from the simulated public transport model was used.

The last parameter was calculated by the public transport assignment taking into account the modelled itineraries with their departure and arrival times. In cases where no direct connection to an island exists, the public transport assignment considers the calculation of minimum travel times, the connected lines option and transfer waiting times. After applying the trip distribution model, the produced matrices where lower triangular, having calculated the direction from the peninsula to the destination islands and from the origin islands to the destination islands. The triangular matrices were mirrored in order to get the final OD matrices.

7.3.2. Sea Model Trip Distribution Calibration and Validation

The equation was calibrated in MatLab and validated in SPSS. The equation applies where the population parameter for productions is reasonable, while the distant zones (countries abroad) were excluded from the distribution model. The equation for selected OD pairs (with attractions>0 from external zones to internal zones and between internal zones, excluding flows between external zones on the Greek peninsula) was applied. The calibrated equation has the following forms:

$$Tij \ = 0.0035 \ \frac{Pi^{0.5}.\ Aj^{0.8}}{JRTij^{0.4}} \ \ (2)$$

Tij, flows in number of passengers per week in the peak period

Pi, population in number of inhabitants of zone i

Aj, number of arriving passengers in ports of zone j per week in the peak period

JRTij, Journey time from zone i to zone j in minutes for the peak period

The validation of the distribution model for sea passengers was calculated with the Pearson's correlation statistical method. As presented in the table that follows, in this case the Pearson's correlation coefficient was greater than 0.9 and the correlation between observed and modelled flows, was found significant at the 0.01 level. In greater detail, the findings were:

r>0.9 Ports (number of observations 70, *source: Hellenic Statistical Authority*)

r>0.9 OD Pairs-destination to the islands (number of observations 97, *source: Hellenic Statistical Authority and processing*)

Table B1. Validation of the estimated matrix by sea

Correlations_Ports (on transport nodes)		Observed arrivals	Modelled arrivals
Observed _disembarking	Pearson Correlation	1	.991**
	Sig. (2-tailed)		.000
	N	70	70
Modelled _disembarking	Pearson Correlation	.991**	1
	Sig. (2-tailed)	.000	
	N	70	70

Correlations_OD Pairs (on transport lines)		Estimated from aggregated statistics	Modelled
Observed	Pearson Correlation	1	.911**
	Sig. (2-tailed)		.000
	N	97	97
Modelled	Pearson Correlation	.911**	1
	Sig. (2-tailed)	.000	
	N	97	97

The Greek ports and statistical authority constitute the sources of the observed values. This data is considered to be very close to the actual situation but a cross-check that was conducted between observations on ports and sea-lines did not result in absolute consistency. The data is collected in the aggregated level of total tourists without any categorization of Greek residents and non-residents. More assumptions on how the demand for sea transport was calculated are noted in the Appendix.

7.3.3. Air Model Trip Distribution Calibration and Validation

The equation was calibrated in MatLab and validated in SPSS. The calibration was conducted for selected OD pairs that consist of airports and thus, offering the possibility to connect by air to the Greek peninsula and to each other. The equation applies to domestic flights where the population parameter for productions is reasonable while the international direct flights to the islands and the respective distant zones which are countries abroad were excluded from the distribution model. The calibrated equation for selected OD pairs (with attractions>0) is as follows:

$$Tij = 0.0562 \frac{Pi^{0.4}. Aj^{0.6}}{JRTij^{0.1}} \quad (3)$$

Tij, flows in number of passengers per week in the peak period

Pi, population in number of inhabitants of zone i

Aj, number of arriving passengers in airports of zone j per week in the peak period

JRTij, Journey time from zone i to zone j in minutes for the peak period

The validation of the distribution model for air passengers of domestic flights was calculated with the Pearson's correlation statistical method. As presented in the next table, in this case the Pearson's correlation coefficient was greater than 0.9 and the correlation between observed and modelled flows, was found to be significant at the 0.01 level. In more detail it was found:

r>0.9 Airports (number of observations 25, source: Civil Aviation Authority of Greece)

r>0.9 OD Pairs-destination to the islands (number of observations 64, source: Civil Aviation Authority of Greece).

Table B2. Validation of the estimated matrix by air for flights within the country with destination to the islands

Correlations_Airports (on transport nodes)		Observed _arrivals	Modelled _arrivals
Observed _arrivals	Pearson Correlation	1	.992**
	Sig. (2-tailed)		.000
	N	25	25
Modelled _arrivals	Pearson Correlation	.992**	1
	Sig. (2-tailed)	.000	
	N	25	25

**Correlation is significant at the 0.01 level (2-tailed)

Correlations_OD Pairs (on transport links)		Observed	Modelled
Observed	Pearson Correlation	1	.919**
	Sig. (2-tailed)		.000
	N	64	64
Modelled	Pearson Correlation	.919**	1
	Sig. (2-tailed)	.000	
	N	64	64

**Correlation is significant at the 0.01 level (2-tailed)

All the observations, both for airports and airline connections links, are from detailed per flight records that were systematically collected from each individual local airport authority. This data and the statistics deriving from it, in terms of the calibration and validation of the trip distribution model, are considered highly accurate and reliable.

7.4. Using Mobile Phone Activity Data for Tracking Passenger Trips

Understanding the dynamics of the individuals' daily mobility patterns is a crucial factor in a wide range of fields. However, lacking the tools to monitor the time-resolved location of individuals rendered this research both time consuming and costly in the past. Nowadays, the rapidly developing capacity to collect space-time activity (STA) data through new information technologies such as cellular phones, WiFi and GPS methods has improved the quantity and quality of this data and reduced its collection cost [6]. The current Thesis commenced in 2013 and its data refers to the summer period of that same year. Since then, the new technologies of smartphones and location settings have penetrated today (2015) the Greek market to a significant degree. The evolution of the new technologies of smartphones and location settings, has offered a new future perspective in analyzing and visualizing GPS data from mobile handsets with Internet connection for mobility purposes.

In this Part of the thesis, MS Assess databases and SQL queries were used for analyzing a large set of data deriving from mobile phone activity in the study area. This data allows the investigation of individual human mobility patterns, mining and analysis under a given time and geographical framework. The approach introduced supports that this kind of individual human mobility pattern can complement the aggregated statistical data for mobility in the study area. By using millions of raw mobile call records, cell phone usage statistical characteristics were computed, in order to derive aggregated mobility patterns for thousands of mobile phone users and individual mobility patterns for different groups, which are divided into two types of users: domestic users and foreigners travelling to the Greek islands from other countries, in relation to the recorded categorization data availability.

Data from the mobile company was used to extract mobility indicators. We also used it to calibrate and evaluate our demand matrices and extract some additional findings. Some cases were selected and are presented here as examples of spatiotemporal analysis visualizing them in 2D graphic representations of mobility patterns and their evolution through space and time in Google Earth background maps. Analyzing the spatial and temporal patterns of an individual person's travel activities allows better understanding of the mobile phone dataset content and this is taken into account in our statistical computations, the histograms and the logical tests and explanations of the analysis.

7.4.1. Operating Principle of Cell Towers for Serving Telecommunications

In this section general information on the operating principle of the cell towers or antennas for serving phone calls and messages is provided. This explains the way this system permits rough location estimation of the cell phone devices and their users consequently.

The mobile phone transmits "a signal" when connected to the network in order to know any time to which the antenna can send the calls. The cell tower is a cellular-enabled mobile device site where antennae and electronic communications equipment are placed. It is typically installed on a tower or other raised structure that supports antennae, transmitters/ receivers, digital signal processors, control electronics, a GPS receiver for timing, electrical power sources, etc.

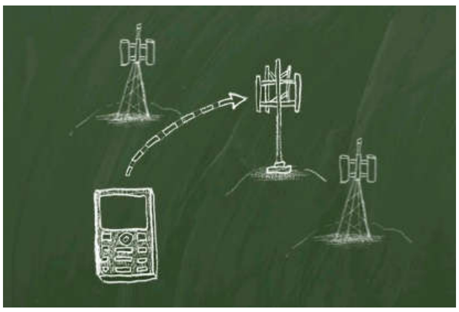


Figure B3. The course of a cell phone call 1

The cell tower concedes a free field to service the call, the sms or the data usage and send it away as digital information that is directed in the wider network.

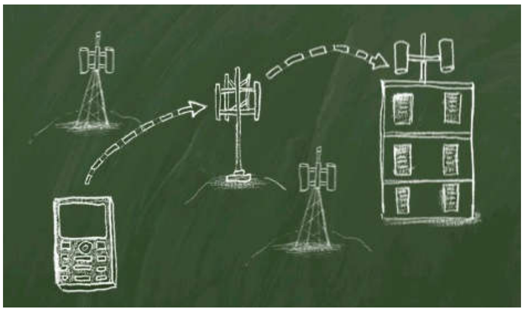


Figure B4. The course of a cell phone call 2

The call, or the sms to another mobile phone device, is directed through the network via the antenna that is closer to the mobile phone of the call or sms recipient.

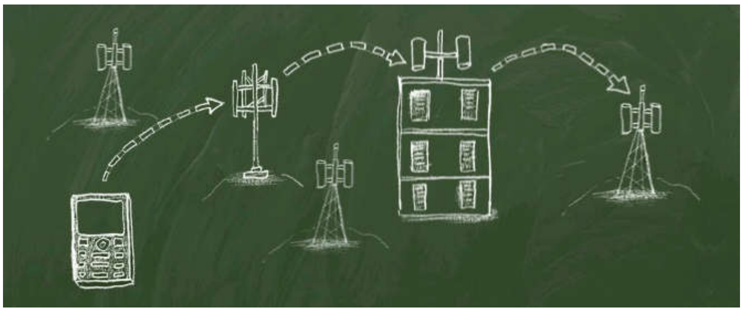


Figure B5. The course of a cell phone call 3

Considering that the mobile phone of the recipient as also "a signal", meaning that it is constantly connected to the network, it recognizes from which Base Transceiver Station to find the incoming calls or sms and it detects the radiofrequency. This process is completed within only a couple of seconds.

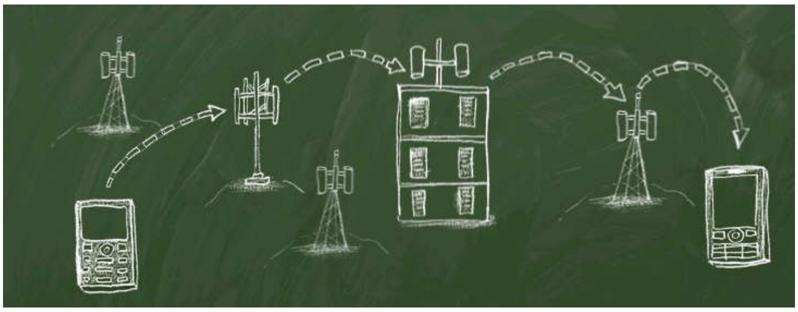


Figure B6. The course of a cell phone call 4

7.4.2. Topology of Cell Antennas in the Study Area

The following map depicts the coverage in the study area of the cell towers or antennas of the operator Vodafone Greece that provided with anonymous call activity data for this research. The network is very dense and it covers also very small islands, such as Gavdos, Antikythira and Kastellorizo.

Figure B7. Coverage of the cell towers in the study area

7.4.3. Raw Mobile Phone Data Source and Utilization

The anonymous encrypted dataset was provided by the Greek provider company Vodafone Greece in ascii format. This company serviced, in the reference year 2013, one third of the wireless mobile broadband subscriptions in the entire country and possessed a very dense network of coverage at all the inhabited Greek islands of the Aegean Archipelago. In the telecommunication sector of Greece there are three mobile network operators providing mobile phone connection services. Their exact market share in terms of users for the reference year 2013 is presented in the following table.

Table B3. Mobile phone network operators in Greece and their market shares

company	Active connections-users in Greece 2013 (end of the year) in thousands	% of Total
Vodafone	3,874	30%
Cosmote	5,889	45%
Wind	3,237	25%
Total	13,000	100%

Source: Hellenic telecommunications and post commission yearly reports [9]

The mobile records that the operator provided, respecting the personal data anonymity principle, contain call activity per handset. More specifically, the raw mobile phone data contains outgoing calls and relevant records such as handset dummy id, routing tower-cell id, coordinates (latitude / longitude) of the phone tower routing the communication for each phone call dialed by users, date, time and final user type (VF / Visitor). The specific user types, in accordance with the data availability, are domestic users and foreigners (mostly tourists) divided into clients of the Greek mobile network operator described in the datasets as 'VF' users and roaming clients serviced by the same provider described in the datasets as "Visitors'.

In summary seven such datasets with records were provided, one for each day of the simulated peak week of the summer 2013 and more specifically from Monday, 29 July 2013 to Sunday, 4 August 2013. According to the datasets provided, the average daily mobile phone activity reaches the big data amount of 6.3 million outgoing calls and respective records. The 24hour ascii file per day was provided in the following format:

HANDSET_ID|CELL_ID|LATITUDE|LONGITUDE|DATE|TIME|TYPE

987975997040670|09391|36-12-49N|28-5-39E|29/07/2013|00:49:03|VF

646202956221870|47977|35-17-8N|25-28-7E|29/07/2013|00:48:57|Visitor

…

It is noted that only the coordinates of the tower routing the communication are known, while the exact location of users within a tower's service area is not known.

7.4.4. Time-spatial Representations of Mobility Patterns

In order to represent the mobility patterns in a more quantitative and meaningful manner, a 2D trajectory modeling approach was used in Google earth. In this method, each dot corresponds to a mobile phone tower, and each time a user makes a call, the closest tower routing the call is recorded, pinpointing the user's approximate location. The red colored lines represent the recorded movement of the user between the towers. The following Figure shows the trace of a 'VF' handset travelling by sea from Lasithi, Crete to Athens/ Piraeus. It is estimated that this user is a passenger of a regular sea line itinerary depicted here in white. This estimation is based on matching the passengers' trace in time and space with the itinerary's timetable and route.

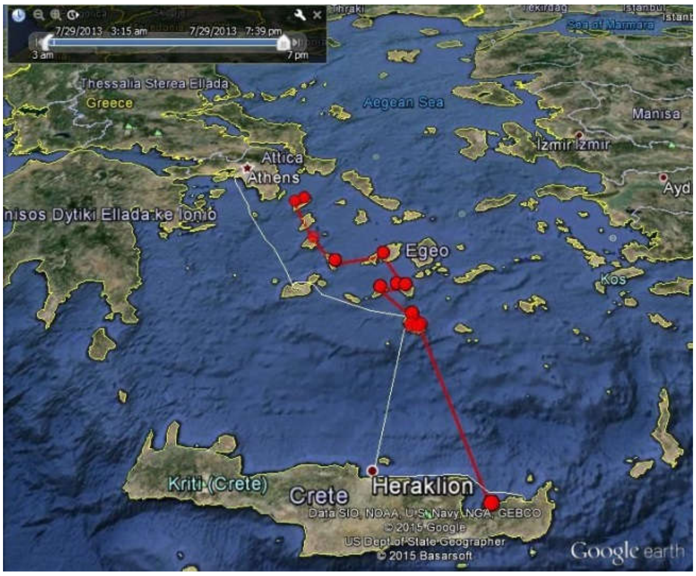


Figure B8. Mobile VF user route in red that has been identified in time and space as passenger of a regular itinerary in white

In the next Figure, the trace of a 'VF' handset travelling by sea from Amorgos to Athens/Piraeus is presented, colored red. Depicted in white is presented in the same figure, the matching sealine route, assuming that the specific user is a travelling passenger of a regular sea line itinerary.

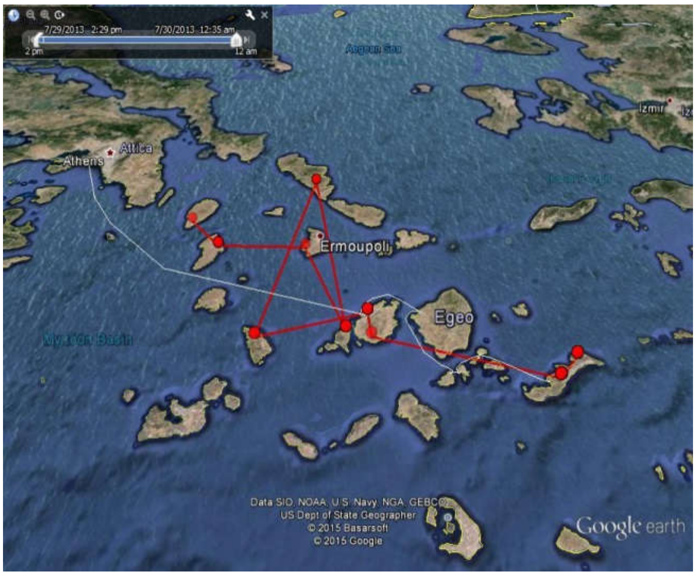


Figure B9. Mobile VF user route in red identified in time and space as passenger of the regular itinerary in white (from Amorgos to Piraeus)

In this last Figure for passenger tracing with red color the trace of a 'Visitor' travelling by sea from Kos to Thessaloniki or Kavala or Istanbul is presented. This case has not been identified as a passenger of a regular sea line itinerary.

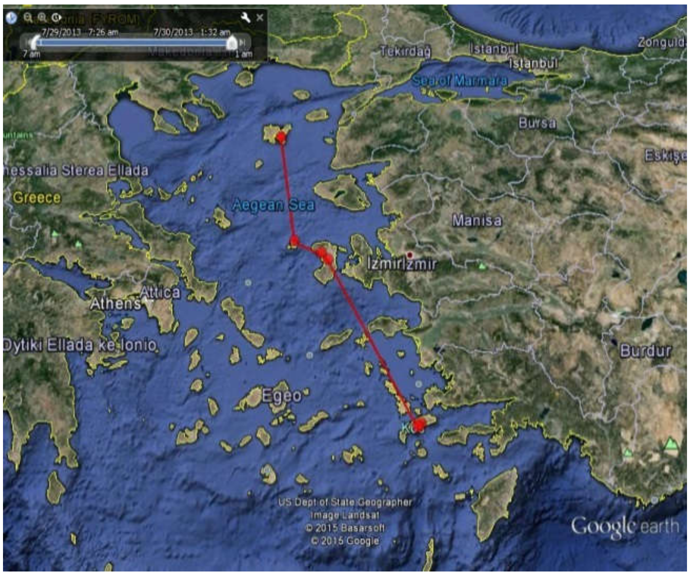


Figure B10. Mobile Visitor user route in red, not been identified in time and space as passenger of a regular itinerary

7.4.5. Analysis of the Mobile Phone Records

The analysis of the big data from mobile phone activity has been conducted using a number of tools such as MS Excel, MS Access and SPSS (Statistical Package for the Social Sciences). The datasets from all 7 day records were analyzed and it was found in SPPS that the percentage of the "Visitors" or foreigners, mostly tourists is 30%. The relative percentage of "VF" domestic users which may be tourists, local inhabitants and seasonal workers is up to 70%. These results are presented in the following Table. The share of roaming users serviced by the specific telecommunication operator is not known, therefore the relative (rough) estimates for the category of "Visitors" are presented next

Table B4. Types and shares of mobile users in the core study area. Daily averages for the peak week of summer 2013

User type	Thousands of handsets-users core study area operator Vodafone (daily average)	Thousands of users estimated core study area for all mobile network operator companies (daily average)*	% of Total
Visitors	156	~ 520	~ 30%
VF	363	1,210	70%
Total	519	1,731	100%

*for the estimations the shares noted on Table 3- "Mobile network operators in Greece and their market shares" were used, (~ the share of "Visitors" is roughly estimated)

During the peak tourist period a significant number of tourists arrive while others depart from the Greek islands. This vivid activity was observed in the datasets from handsets suddenly (by air) or slowly (by sea) "appearing" in the study coverage area of the Aegean Sea and others "disappearing". The weekly profile of handsets recorded in the study area is presented in the next Figure.

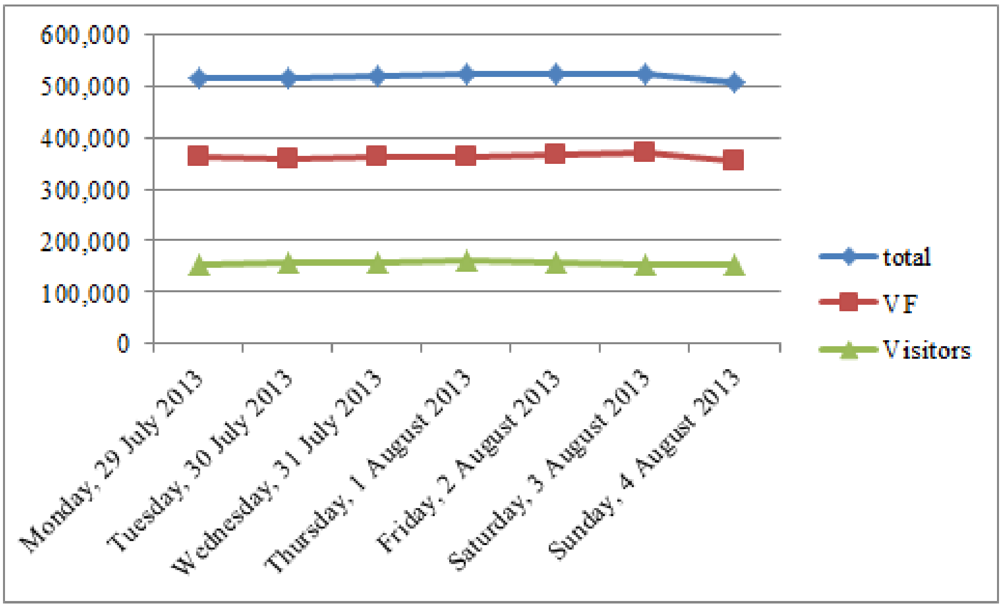


Figure B11. Week profile of users in the study area

The figure shows a moderately stable balance between arrivals and departures of Visitors, who are mostly foreign tourists during the peak week of summer 2013. The same applies for 'VF' domestic tourists but a small increase is observed on Friday and Saturday when typically holiday trips for Greek inhabitants start.

The weekly profile of mobile activity for the simulated summer tourist peak period shows a significant activity that decreases during the weekend. This profile is presented in the following Figure with the number of calls and respective records in the dataset being recorded in millions for all user types.

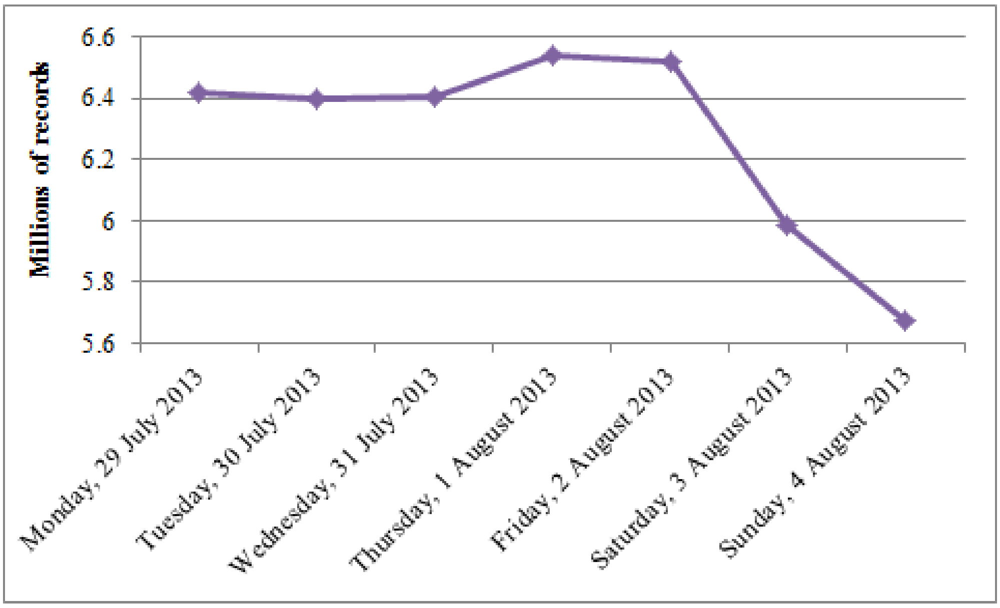


Figure B12. Mobile phone activity weekly profile for all types of users

Further analysis was conducted in SPSS in order to calculate the number of calls per mobile phone holder in the study area at the specific time of the year. The two step cluster analysis indicates that 95% of all the user types make seven calls per day and thus, seven times per day their approximate position is recorded. The daily number of calls per handset is very encouraging to cater for the survey's needs, showing a vivid action of phone calls resulting in many records and respective positions per user.

7.5. Estimating Mobility from Mobile Phone Data Statistics

At this point the mobile phone data analysis progressed with the categorization of the mobile set holders in the study area into moving travelers and non-moving local inhabitants, seasonal workers and longer than one week staying tourists. A mobile phone user is identified as a moving traveler only when the handset is located in at least two different islands of the Aegean Archipelagos during the day, whereas the ones who stay on the same island during the whole day are considered as non-moving users.

Passengers by air transport use direct flights from abroad or from Athens and Thessaloniki. Therefore they cannot be traced in the phone data records and cannot be clearly distinguished from non-moving users. On the other hand, people travelling by sea can be traced and identified as moving travelers. In the provided records by the mobile phone operator the cases of passengers of regular ship lines cannot be distinguished from the cases of yacht travelers, cruise passengers, fishermen, coastguard, navy and merchant ships personnel. All of these categories travel in the study area but it can be assumed, with some certainty, that they constitute only a small minority compared to the large flows of tourists travelling by sea in the area during the peak summer season. For this reason, it is assumed that moving travelers from the mobile phone data records are passengers of regular ship lines.

The number of moving users was calculated using MS Access, where each outgoing call and relative record was allocated to an island grouped by handset_id and by island location. In a second step, all the handsets that appeared only in one island without changing during the course of one day, that is 24 hours, were extracted using an SQL query in Access. The trips within Crete, which is the largest island in the study area, were also excluded so that only passengers changing islands during their course are calculated in the mobile phone statistics. All the extracted records are considered intra-zonal trips within the island and are not useful in the current analysis. Running the query and selecting only moving users by sea (in both ways, from the peninsula to the islands and vice versa, as well as between islands) has resulted in the next table, where 'Visitors' account for 25% of the total moving users while 'VF' users for 75%. Although it is known that the mobile network operator that provided the mobile data services 30% of the local market, the exact share of roaming users serviced by the specific telecommunication company is not known. Therefore, the relative (rough) estimates for all mobile phone users for the category of "Visitors" are presented next.

Table B5. Travelling mobile users, types and shares per day during the peak week of summer 2013

User type	Thousands of moving users per day by sea company Vodafone	Thousands of moving users per day by sea estimated for all mobile phone users	% of Total
Visitors	12	~ 41	~ 25%
VF	36	120	75%
Total	48	160	100%

*for the estimations the shares of Table B3 were used, (~ the share of "Visitors" to all mobile phone users is roughly estimated)

7.6. Cross-Check between Mobile Phone Data and Statistical Port and Airport Data

7.6.1. Transport System Statistics in the Core Study Area

The counted aviation passengers travelling in both ways during the peak week of summer 2013 (average daily in thousands of passengers) are presented in the following table:

Table B6. Passengers by airplane both directions daily during the peak week (counted)

Cluster	Thousands of passengers by air daily average	% of Total
domestic_aviation	15	15%
international_aviation	85	85%
Total	100	100%

*Source: Civil Aviation Authority (detailed data from each airport)

The average daily number of passengers travelling with regular sea-lines (excluding cruise passengers) in both ways during the peak week of summer 2013 in the core study area are presented based on the tables "D1_02_disembarking passengers 2013" and "D1_03_embarking passengers 2013" from the National Statistical Authority of Greece (ELSTAT). These tables provide monthly statistics (using statistics from July and August 2013). In order to calculate the average daily number of passengers, a factor was used taking into account the summer peak during the first week of August. The results are presented in the following table together with the comparable results of the table "Travelling mobile users, types and shares per day during the peak week of summer 2013".

Table B7. Passengers by sealines both directions daily during the peak week

Cluster	Thousands of passengers by sea daily average arriving and departing at ports of the Aegean islands	Thousands of moving users per day by sea estimated for all mobile phone users
domestic_sealines	164*	160

*Source: National Statistical Authority-ELSTAT

It was found that these two summary results, originating from completely different sources of data are consistent. This is evidence that this method, for calculating moving passengers by sea in the study area using data from mobile phones, is efficient. In the following table the numbers of passengers are summarized and the modal split of the transport system is also presented. The share of passengers travelling by air is approximately 40%, while the share of passengers moving by sea is approximately 60%. If the analysis is restricted to the domestic transportation services, the dominance of maritime means is clearly evident. The regular sealines are servicing more than 90%, while domestic aviation services less than 10% of the passenger flows to and from the islands of the Aegean Sea.

Table B8. Passengers by transport mode, daily averages in both directions and shares during the peak season (counted)

Modal split	Mode of travel	Thousands of passengers daily average peak season	% of Total	% of Total
domestic sealines	Sea	164	62%	62%
domestic_aviation	Air	15	6%	38%
international_aviation	Air	85	32%	
Total		264	100%	100%

Source: National Statistical Authority-ELSTAT and Hellenic Civil Aviation Authority

7.6.2. Applying Data Fusion Techniques to Extrapolate Mobility Patterns from the Mobile Phone Records

To extract some results from the mobile phone activity datasets a data simplification procedure was applied. This procedure enabled to reduce the records and concentrate the information following a simple data fusion technique in steps. The target set was to produce "Weekly mobility profiles in time intervals per hour"

- Step 1: Data fusion of location pinpoints

  As an initial step a new column was added for "location pinpoint" in the database where a transport zone number (TAZ) was allocated to each record based on the antenna location that serviced the call. MS Access and Sql queries were used for this step. All non-moving users that do not change TAZ over one day were excluded from the datasets.

- Step 2: Data fusion of time pinpoints

  As a next step another column was added for "time pinpoint" in hours where to each time record that was in hh:mm:ss format, an hour sequentially starting from day 1 Monday 29/07/2013 0h to Sunday 04/08/2013 24h was assigned. MS Access was used for this step and more specifically the Sql query syntax for the Hour function: Expr1:Hour ([Time]).

- Step 3: Combination of previous steps and data grouping

  At this level steps 1 and 2 are combined with grouping of the location and time pinpoints for each mobile phone user. One Pinpoint islandic location per hour for each user results in major data compression. In case of multiple locations within one hour, for simplification reasons the records were grouped by assigning the location of the min zone number.

  At the end of these three steps, the dataset was significantly reduced. From 6,2 million of records per day on average it was limited down to 2.0 million per day on average. This equals to a reduction of data records by 68% and allows to start processing in MS Excel with reasonable computation times. Moreover, this sort of data fusion eliminates the effect of the pinpoint "jumps" that can falsely be interpreted as moving phone users from island to island, whereas in reality they represent changing of servicing antennas in distant areas with a weak signal. In some cases jumps like that were observed in the mobile phone activity datasets several times within one hour.

- Step 4: Pivoting of the tables

With this step, the tabular or panel data format was transformed into a time interval matrix format, reducing the records further and provided a new perspective of the information contained in the initial databases. As an outcome of this step a matrix of daily mobility profiles in 1 hour intervals for each user was produced. At the end of this step, the datasets dropped down to 0.2 million of records, that being 97% less than the initial ones. The newly constructed array[0,1,..167] has a length of 168 columns for each handset_id. It contains information on the location of every handset in each time interval and has the following configuration:

day 1	day 2	day 3	day 4	day 5	day 6	day 7
0h-23h	24h-47h	48h-71h	72h-95h	96h-119h	120h-143h	144h-167h

- Step 5: Handling of blanks and record filling in

The weekly mobility profile matrix has a lot of blanks. When there was no phone activity and in time intervals there were no calls, these blanks were observed, especially during the night. The matrix was only 26% full of moving locals during one day and 20% full of moving Visitors from abroad. For the handling of blanks a simple algorithm was used, which updated the empty cells by setting a new value for location based on the previous time interval location record. The algorithm is presented next for each time interval i=0,1,…..167

```
for i=1,2,…167
        if location[i] = null
        location[i] ←location[i-1]
        end if
end for
```

7.6.3. Distance Traveled Distributions

For the calculation of the travelled distances per user from the mobile phone records, one single average latitude and longitude of towers to each island zone was allocated so that internal zone trip distance calculation is excluded. The latitudes and longitudes were transformed in x,y coordinates of the Greek Grid GGRS'87 (ΕΓΣΑ'87) and calculated on-the crow-distances from one position to another as time advances during the day. Some examples of such paths visualization were presented in previous figures (7,8 and 9). Our calculation shows that the mean travelled distance per passenger from mobile data during one week in the core study area is 212km for all user types 'VF' and 'Visitors'.

The traffic assignment simulation is based on the trip distribution model for passengers travelling by sea presented in the previous chapter. If straight connections and trips from the Argosaronikos islands to Athens-Piraeus are excluded, in order to make the indicator comparable to the mobile data coverage region, then the mean in-vessel travel distance per passenger rises up to 224km per passenger. This cross examination was found to be consistent.

Mean values are only indicative and they cannot offer a lot of information on the transport system and mobility patterns in the transport system under analysis. For this reason, the histograms of travelled distances by sea were calculated and they are presented in the two next Figures.

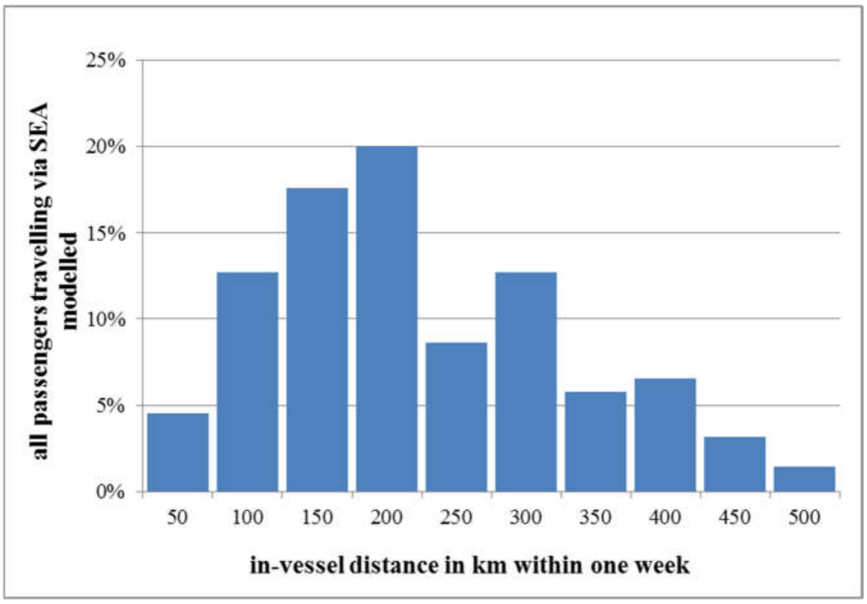


Figure B13. All travellers via SEA from the transport assignment based on trip distribution model (mean travelled in-vessel distance 225 km per week)

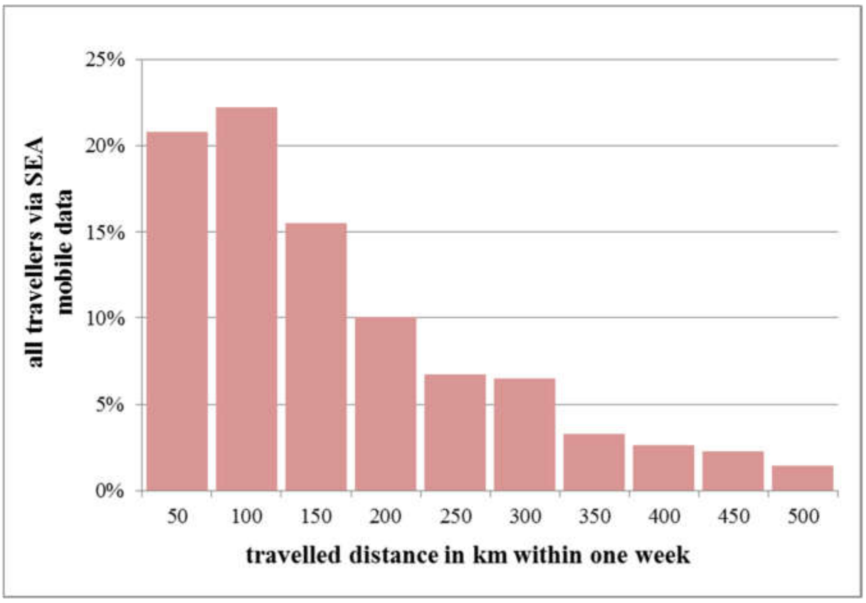


Figure B14. All travellers via SEA from mobile data (mean travelled distance 212 km per week)

If the two above figures are compared, considerable differences in the distributions can be observed. The histogram from the mobile data record seems to be underestimated for the longer distances. As an explanation of this gap, the impact of Crete on the transport system could be considered. Crete with its major ports Chania and Heraklio, lies within a distance of approximately 300 km from Athens-Piraeus which is the main inland port. These major lines of Crete provide direct daily services in both directions. During their course in the open sea, there is no mobile phone network coverage. Also the majority of its itineraries are running through the night, at a time period when the mobile phone activity drops. According to the statistics from ELSTAT (Greek Statistical Authority), the direct lines to Crete during the peak period of summer 2013, are servicing 13% of the total trips (except for strait connections) in the study area. This amount of trips is insufficiently captured by the mobile data records as ships travel directly to Crete with no intermediate stops and with no mobile network coverage along their course. In the next Figure these major lines to Crete are presented. This figure is a snapshot from the modelled network.

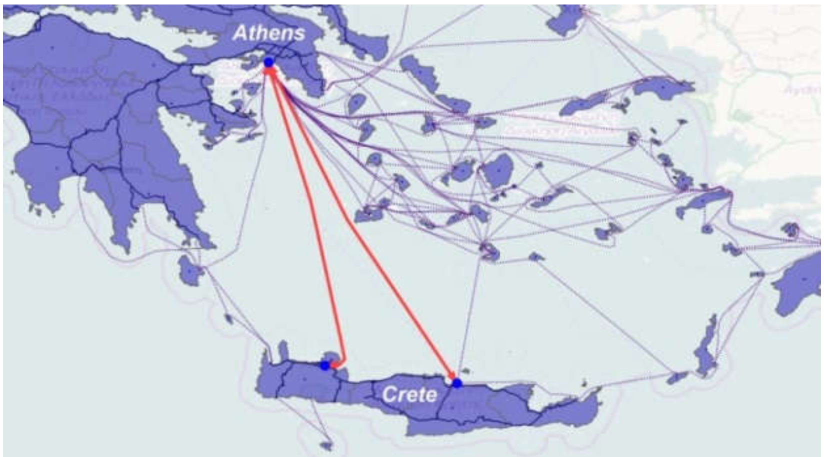


Figure B15. Ship lines from Athens-Piraeus to Crete (direct sealines with no mobile network coverage along the way)

On the other hand, the modelled flows seem to underestimate smaller distance trips of 50 and 100 km. It needs mentioning, that the mobile data includes aggregated data for all types of mobility in the Aegean Sea such as yacht tourists, cruise tourists, fishermen, navy personnel and merchant ships' personnel besides passengers of regular sea lines. Nevertheless, the analysis was based on the assumption that these special categories form only a small minority within the large category of ferry passenger mobility. There is also some impact from smaller ships connecting neighboring islands. These ships are not registered as regular sealines and therefore, are not sufficiently modeled in the network. In addition, in the mobile phone paths some position "jumps" from island to island are noticed, similar to the example of the Mobile VF user route visualisation from Amorgos to Piraeus and in other cases straight lines that do not follow closely the pattern of a regular passenger ship route. The impact of this phenomenon cannot be estimated in the distribution of distances from the mobile phone records and as such, it could be wrong to compare directly the histograms from the different sources, simulation model and mobile network operator.

Progressing the research a step forward and attempting to understand the reason for the difference between modelled in-vessel-distances and mobile phone paths, the distributions from the same source (mobile company) were compared for the two user types 'VF' and 'Visitors' in the following two figures.

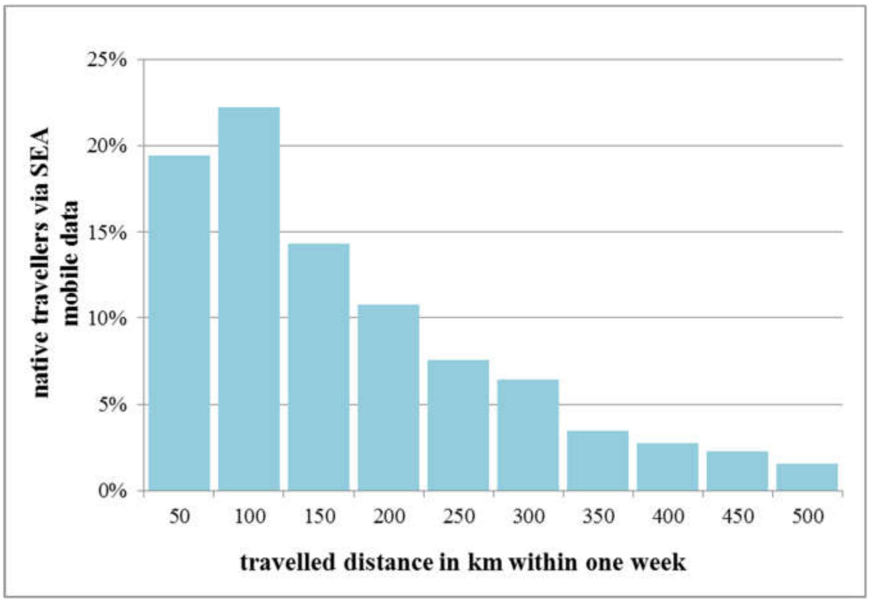


Figure B16. Domestic travellers via SEA from mobile data (mean travelled distance 225 km per week)

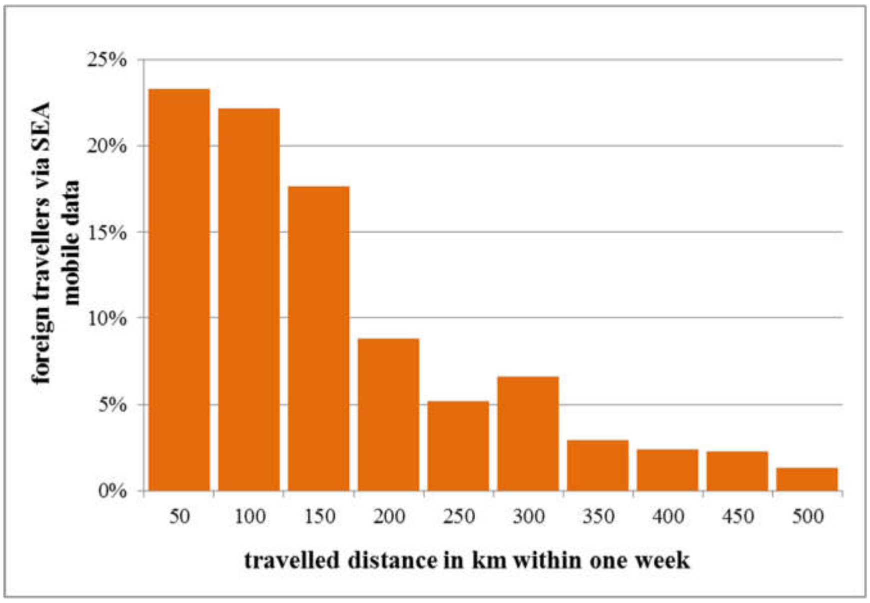


Figure B17. Foreigner travellers via SEA from mobile data (mean travelled distance 188 km per week)

The two figures are now directly comparable and some differences between them can be identified. It is observed that the mobility pattern of 'Visitors' displays a greater number of short-distance trips. A statistical analysis was conducted for the Distance variable and its overview is presented in the following table.

Table B9. Overview of descriptive statistics for the variable “Travelled Distance”

Statistics Travelled Distance (km)		mob. phones VF	mob. phones Visitors	mob. phones All	Modelled Sea
Mean		225	188	212	225
95% Confidence Interval for Mean	Lower Bound	224	186	211	224
	Upper Bound	227	189	213	225
5% Trimmed Mean		174	154	167	214
Median		129	117	124	183
Variance		134,554	90,876	119,210	20,941
Std. Deviation		367	301	345	145
Minimum		12	12	12	4
Maximum		20,958	27,416	27,416	1,076
Range		20,946	27,404	27,404	1,072
Interquartile Range		192	174	190	167
Std. Error Mean		0.677	0.744	0.510	0.167

According to the descriptive statistics presented in this Table, the lower and upper bound of the 95% Confidence Interval for Mean for the cases of domestic tourists is very close to the modelled one. Another interesting observation is that the spread of travelled distances as defined by the Interquartile Range appears close to one another for all four cases. The Box plots visualizations of this table are presented in the following figure, where extremes and outliers, which were very high for the mobile phone records, were excluded. Again some discrepancies are observed among the median values of travelled distances but overall, the Box plots display noticeable similarities both in the boxes and their whisker cups of the various datasets. This is regarded as a positive indication that the processed mobile phone records, for the identification of mobility and the modelled passengers via sea based on aggregated statistics, are consistent with each other.

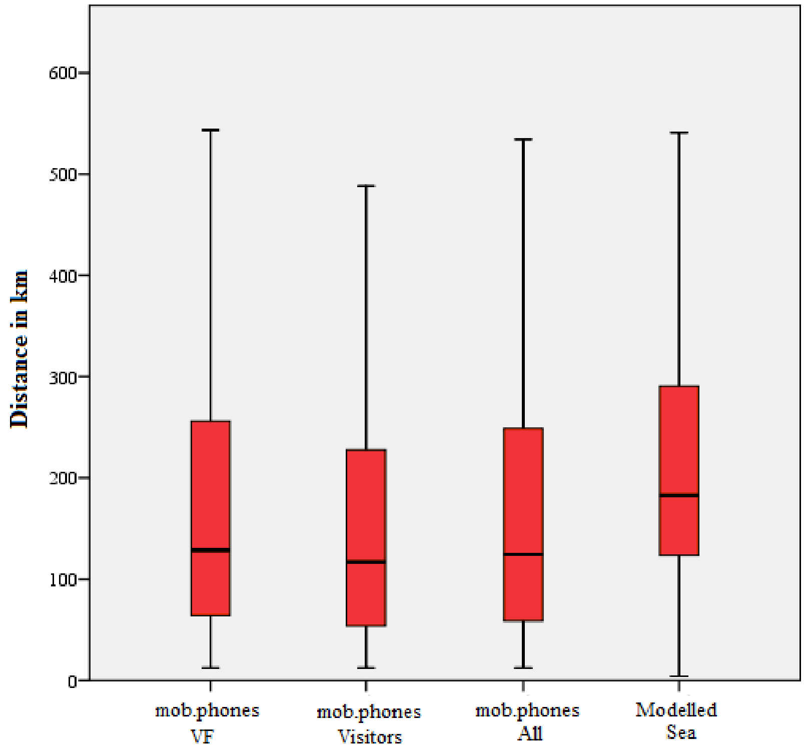


Figure B18. Boxplots of the travelled distance from the various datasets

A statistical test was conducted for the difference between mean travelled distances of the various categories using Student's t-test. This test does not require the same number of observations in the two datasets. It is assumed that the two sample populations are independent and have theoretical average values of μ1 and μ2. The Null hypothesis H0: μ1 - μ2 = 0, assumes that the two mean values are the same. The significance p indicates the probability of obtaining the observed t-value if the null hypothesis is correct. If $p< 0.05$, then the null hypothesis is rejected and the difference between the two sets is statistically significant. In this case significant difference is proved in the mean length of travelled distance by sea between domestic and foreign tourists in the Aegean Archipelagos, while the travelled distance is statistically significant equal on the level of 95% confidence interval with $p = 0.548$ (Sig. 2 tailed, equal variances not assumed) between domestic tourists and modelled flows.

The mobility pattern of domestic users 'VF' in figure "domestic travelers via sea from mobile data" is closer to the histogram of the simulation model presented in the figure model". Noticeable similarities between modelled and domestic travelling phone users are also observed in table B9 (Overview of descriptive statistics for the variable Travelled Distance) and figure B18 (Boxplots of the travelled distance from the various datasets). This leads to the conclusion that the trip distribution model based on domestic activity with zone population as the parameter of trip Production, has to be revised. The impact of foreign tourists travelling by sea, who were found to account approximately for 25%, may distort the OD matrix. The distant yet popular destinations of Crete, Kos and Rhodes (300, 400 and 500 km respectively from Athens) are serviced by direct international flights. Foreign tourists arriving by airplane to Athens continue their trip by sea via Piraeus but choose destinations closer to Athens. While the majority of domestic tourists are traveling with ferries to the islands of the Aegean Sea, they are willing to travel by sea to more distant destinations. Based on the estimations from the mobile phone records, the domestic tourists are travelling 20% longer distances (average 225 km) by sea compared to tourists from abroad (average 188 km). An indication of this trend for domestic tourists to prefer travelling by sea is presented in the next table although both domestic sealines and domestic aviation statistics do include some shares of foreign tourists.

Table B10. Passengers by domestic means of transport mode, daily averages in both directions and shares during the peak season (counted)

Modal split	Mode of travel	Thousands of passengers daily average peak season	% of Total
Domestic sealines	sea	164	92%
Domestic aviation	air	15	8%
Total		179	100%

Direct results for domestic tourists in each island from the mobile datasets for “VF” users cannot be derived, as this category of users includes also the locals (inhabitants of islands) using the same telecommunications provider. It was intended to test separate trip distribution models for tourists, who are Greek residents and tourists, who are non-residents coming from abroad. Seeking other sources of the necessary information to develop these two distinct models it was found that statistical data on domestic and foreign tourists’ arrivals per island exists but it is confidential (only published in aggregated territorial level i.e. groups of islands) and thus, was not made available to us.

7.6.4. Travelling Days Calculations

With further analysis of the weekly mobility profile matrices, which were derived from the mobile phone activity, it was observed that the majority of trips are completed within one day. Yet, in many cases passengers complete their trip within two days. This finding is consistent with the model and with the itineraries and timetables of the sealines. Domestic tourists travel more days than visitors from abroad. The frequencies of travelling days per passenger are presented in the following table:

Table B11. Travelling days per passenger

travelling days	ALL		VF		Visitors	
1 day per week	61%		56%		69%	
2 days per week	19%	80%	20%	76%	18%	87%
3 days per week	9%		10%		7%	
4 days per week	5%		6%		3%	
5 days per week	3%		4%		2%	
6 days per week	2%		2%		1%	
7 days per week	1%		2%		0%	

In the same matrices it is also observed that 70% of the users moving during two or more days of the peak week, from Monday to Sunday, travel in sequential days. This finding reduces significantly the impact of round or return trips within one week from Monday to Sunday and respectively any overestimations that might have occurred in the trip travelled distance per user, which is by default calculated as a one way trip. Smaller percentages between 1-3% of persons with almost daily mobility is not necessarily an outlier as the mobile phone database includes the crew of ship lines, fishermen, naval personnel, cruise passengers etc. who are constantly on board.

7.6.5. Maps Link Count Analysis and Path Analysis

A link based volume map was developed based on the week mobility profile matrix, which was created from the mobile phone records in time intervals of 1 hour. It was observed that these calculated volumes were balanced per direction. When the volumes in each direction are compared, there is correlation with a Pearson coefficient r=0.965, while in the modelled network. the sea links had similar volumes per direction with a Pearson fit of r=0.941.

This constitutes an indication of reliability for the week profile matrix developed. These link volumes are compared with the modelled network. These maps are presented in the next two Figures.

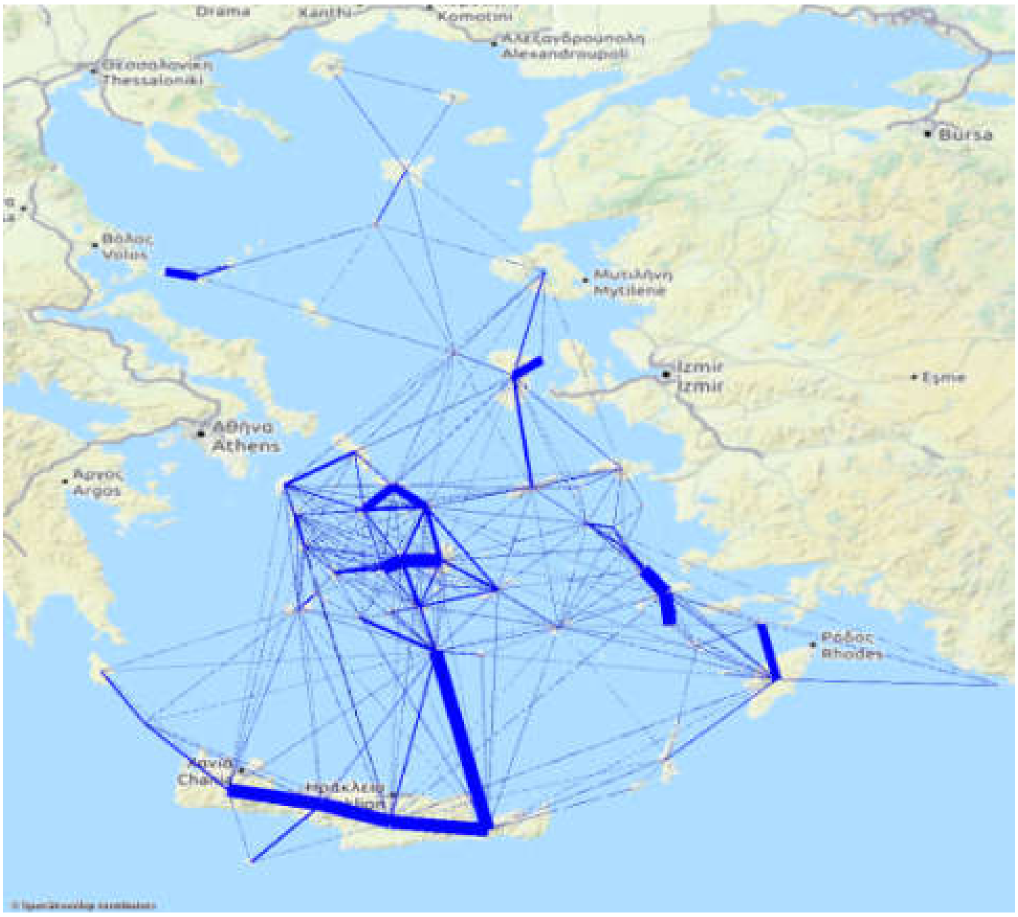


Figure B19. Link volumes for one week from mobile phone records

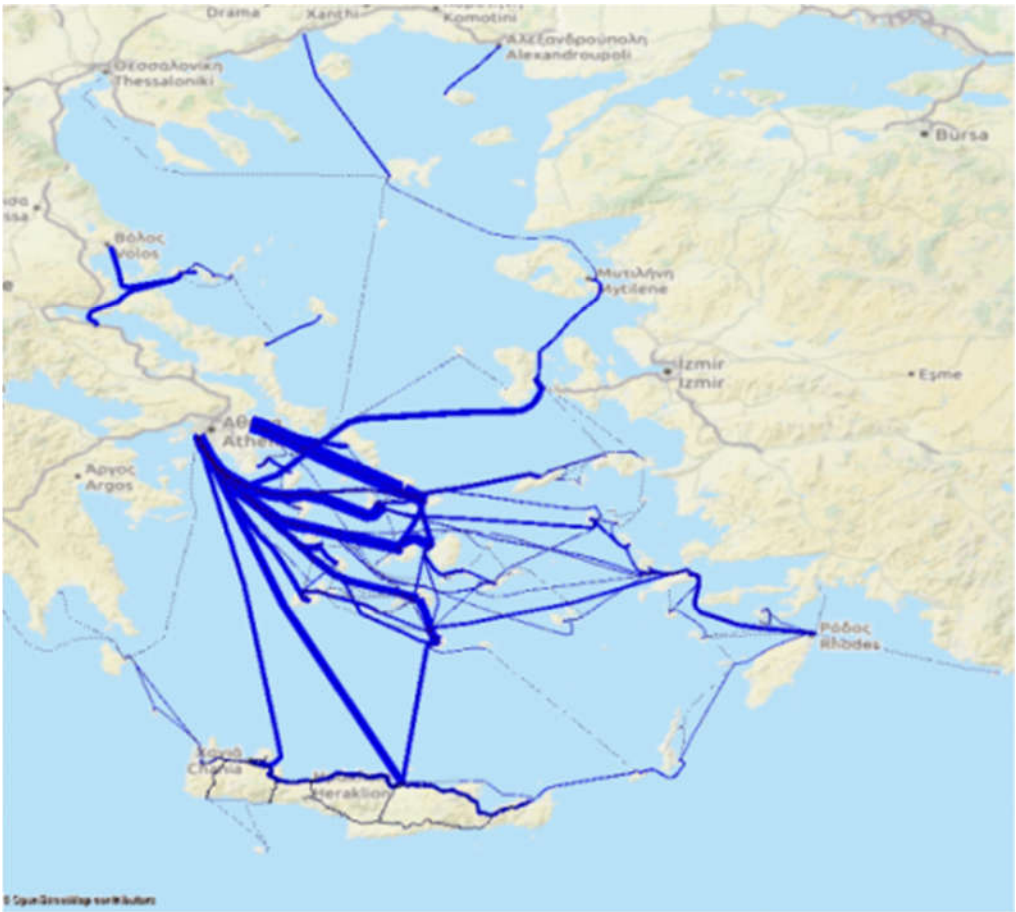


Figure B20. Link volumes for one week modelled flows

The two maps display some resemblance if the trips from Piraeus to Crete are excluded. Both maps have volumes balanced per direction. They have identical volumes within Crete zones. An indicative link volume correlation was performed and a poor fit of Pearson =0.322 was found, which was expected if the significant impact of “jumps” of the mobile phone pinpoints are taken into account.

Path analysis from the processed mobile phone data shows some groupings of data i.e. 80% of the daily trails are followed by more than 20 passengers. Still 7% of the paths were found to be unique. Additional analysis of the paths showed that 35% of the daily trips to be circular and 65% of them linear. The percentage of circular trips is slightly overestimated by means of expected false indications from antenna changing, not reflecting real trips.

8. CONCLUSIONS AND FUTURE WORKS OF PART B

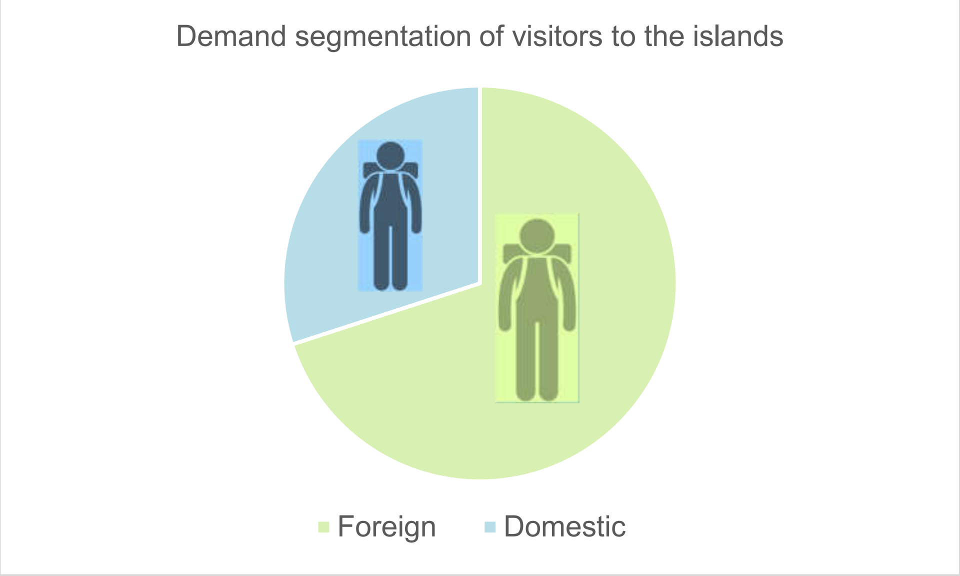
This research showed that there is clear potential in exploiting the mobile probe geolocation data from cellular phones concerning the mobility of tourists in the Aegean Sea during the peak summer season. The approach allowed big data collection at no cost for a great number of travellers over a large time period; 24 hours per day continuously for one week. Data was cross-examined and trials were conducted to combine the data from mobile phones with aggregated statistical data and model simulation outputs.

Processing the mobile phone records using data fusion steps, led to a massive reduction in records, while still maintaining levels of useful mobility information. Through table pivoting techniques the tabular or panel data format was transformed into a time interval matrix format, reducing the records further and offering a new perspective for the information contained in the initial databases. As an output from this process, a weekly mobility profile matrix in time intervals of one hour was developed. This matrix comprised only 3% of the initial records in the study area. Data fusion and table pivoting permitted the reduction from the initial 6.2 million of records per day average down to 0.2 million per day average.

The two comparable approaches, modelled and estimated mobility by mobile phone records, proved consistent in the total numbers of traveling passengers, in mean travelled distances per passenger and their statistical range. Nevertheless, some discrepancy was observed in the histograms of in-vessel-distance between the modelled flows and data from mobile phones. When compared to each other, the distance histograms show differences in the mobility patterns between locals and foreigners when travelling by sea. This could have led to some distortion to the calculated Origin-Destination matrices despite the fact, that the gravity models of trip distribution have a very good fit. The mobile datasets include “jumps” and straight lines. These effects cannot be quantified in the calculation of the in-vessel-distance distribution per passenger. Given that there is no evidence from the aggregated statistical data of the Origin-Destination matrices and the traveled distance per passenger, it could be considered to calibrate the transport simulation model based on the indications from the mobile phone datasets. These are indications of significant difference in the mobility of Greek resident tourists visiting the islands of the Aegean Sea and tourists coming from abroad. It was not possible to extract information for cases of combined air and maritime transport from the phone datasets. As further research steps, the analysis could be continued and completed by conducting questionnaire surveys of revealed preferences and stated preferences for the two major categories, domestic visitors or tourists and foreigners. It is anticipated that by applying the theory of discrete choice modelling and analysis in the study area interesting results would be delivered, in conjunction with the methods used for analyzing tourists' mobility, which were described in this part.

9. EXTENDED WORK ON TOURISTS' SEGMENTATION FOR CORRECTING THE DEMAND MODEL

The analysis conducted in the previous chapters shows the need to segment the demand for transport in the islands of the Aegean Sea during the peak summer season in two major categories: Domestic tourists/ visitors and Foreign tourists/ visitors.

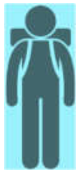


These two distinct categories have differences in the mobility patterns and travel related decisions, which was proved by the analysis from the mobile phone traces and mobility patterns paths in the study area.

Another reason for the revision of the demand model is to simulate more accurately the combined trips. There is a number of trips that are completed with the combined use of land modes, air mode and sea modes. In the initial model only the combinations of land mode + sea or land mode + air were considered. There was no demand choice model and no provisions for the trip chains of foreign tourists that were using the airport hubs of Attika and Thessaloniki, as an intermediate stop for transfers and continuation of their trip to their final destination in the islands of the Aegean Archipelagos. In the analysis of the mobile phone records for the roaming users that indicate foreign visitors, a significant share of foreigners are observed at specific sea-routes such as Piraeus – Crete and Cyclades. Also in the records of the domestic arrivals and departures at the insular airports of the study area, in some cases, a column exists for the TEAA tax that is relevant to the final destination of the travelers. This column indicates a number of foreigners outside the Schengen Area.

There is no specific information for the share of foreign travelers that use direct flights to the islands of the Aegean Sea compared to others that use the mainland transport hubs of Greece for the completion of their trip.

To complete these gaps in the current analysis, an approach for a solution is proposed based on combined sources of information, the analytics and capabilities of the transport simulation model developed for this research, the mathematical tools and expression of demand segmentation and route choices, also of aggregated data for validation of the results.

Visitors / tourists	
from another country*	from Greece
	
Direct long-distance flight	road** + air
Flight to Athens (or Thessaloniki) + air	road** + sea
Flight to Athens (or Thessaloniki) + sea	road** + air + sea

*Limited use of road only when necessary for interconnection eg. Athens airport-Pireus etc.,

some categories of tourists may also arrive by road, eg. Bulgaria, Turkey etc.

** road or rail

The share of foreign visitors that arrive at the destination island of the Aegean Archipelagos compared to the total arrivals of foreigners to the region is estimated at approximately 50%.

9.1. Problematic and Scope

The aim of this chapter is to correct the demand model by introducing two major categories of visitors to the islands of the Aegean Sea during the peak summer season. Such a correction is useful to represent the travel patterns in a more realistic and accurate way as these two demand segments have significant differences in their travel choices. In the lack of detailed data to analyse the demand in segments, the current approach on the problem is based on aggregated statistical data, mobile phone records, assumptions and working hypotheses. The validation of the results is based on the passenger flows for each sea and air route.

9.2. Improvements of the 4-step demand model

9.2.1. Demand segmentation to groups

In part B of the Thesis, from the statistical analysis of the mobile phone activity, it was concluded that there are significant differences between the mobility patterns of domestic tourists and foreigners. More specifically it was found that domestic tourists are travelling 20% longer distances by sea modes in the study area, compared to tourists from other counties. To improve the initial draft demand model for the summertime peak week in the region of the Aegean Archipelagos, where all domestic trips were considered in a single demand segment, distinguishing into two groups of travellers is suggested. One for Greek or domestic tourists and one for foreign tourists. This simple segmentation is in reality very challenging, as there are no statistical data on the number of foreigners travelling by sea modes or with domestic airline connections from Athens to the islands of the Aegean Sea. Although the big majority of foreign tourists are arriving at their final destination with direct flights to the islands, there is still a good proportion of them that are travelling with domestic connections either by sea or air and this remains to be further analysed and estimated.

For this segmentation, the following sources of information are exploited and combined in terms of the current analysis.

Air passenger statistics	
Airports	
	Airport statistics for passengers of direct scheduled and non-scheduled flights arriving/departing from each international airport of the study area, monthly reports and summer peak week raw data (sources: Hellenic Statistical Authority, Civil Aviation Authority of Greece)
	Airport statistics for passengers of domestic flights arriving/departing from each airport of the study area, monthly reports and summer peak week raw data (sources: Hellenic Statistical Authority, Civil Aviation Authority of Greece)
Airlines	
	Passenger flows of direct scheduled and non-scheduled flights to the islands of the study area, monthly reports and summer peak week raw data (sources: Hellenic Statistical Authority, Civil Aviation Authority of Greece)
	Passenger flows of domestic flights to the islands of the study area, monthly reports and summer peak week raw data (sources: Hellenic Statistical Authority, Civil Aviation Authority of Greece)

Sea passenger statistics
Ports
Port statistics for passengers with sea modes to the islands of the study area, monthly reports (sources: Hellenic Statistical Authority, Ministry of Maritime Affairs and Insular Policy)
Sealines
Passenger flows of major sealines to the islands of the study area, monthly reports (sources: Hellenic Statistical Authority, Ministry of Maritime Affairs and Insular Policy)

Hotel and rental accommodation statistics
Hotel capacities
Number of hotel beds at each island of the study area (source: Hellenic Chamber of Hotels)
Tourists' arrivals at hotels
Arrivals of foreign visitors at rented accommodation year summary per island or region of the Aegean Archipelagos (source: INSETE Greek Tourism Confederation)
Arrivals of domestic visitors at rented accommodation year summary per island or region of the Aegean Archipelagos (source: INSETE Greek Tourism Confederation)

The hotel records from the Greek Tourism Confederation INSETE are the only source of information for the distinction of visitors to domestic and foreigners at the island level. Therefore, this database was further analysed and used for the estimation of shares between Greek and foreign tourists on each island. Gaps and shortcomings of the recordings as well as other sources of distortions like sampling methods in minor islands, the impact of organised and free camping, don't allow the extraction of exact volumes of visitors per demand segment. The numbers from the arrivals at hotels and rented accommodations are lower and different from the summary volumes of visitors arriving at each island from the transport statistics. This is depicted in the table below. The figure presents the reference grouping of islands.

Figure B21. Island groups

(map source https://www.fivestargreece.com/island-groups/)

Table B12. Hotel and transport arrivals in the study area for the year 2013

YEAR 2013	Crete	South Aegean		North Aegean	Sporades*
		Dodecanese	Cyclades		
Hotel arrivals					
Foreign tourists	2,741,231	2,073,310	379,197	191,247	74,157
Domestic tourists	324,856	155,346	159,853	108,885	36,507
sum	**3,066,087**	**2,228,656**	**539,050**	**300,132**	**110,664**
Transport arrivals					
Direct international flights	3,323,978	2,771,476	422,740	175,906	141,609
Domestic flights (via Athens or Thessaloniki)	611,513	451,720	348,523	331,776	15,575
Sea passengers at ports	401,428	1,152,373	3,695,768	674,599	756,617
sum	**4,336,919**	**4,375,569**	**4,467,031**	**1,182,281**	**913,801**
ratio hotel arrivals/ passengers	0.707	0.509	0.121	0.254	0.121
population 2011 census	683,086	242,270	124,525	198,894	13,798

* year 2014 numbers and shares

There is a strong correlation between the arrivals with direct international flights and hotel arrivals of foreign tourists (Pearson correlation 0.997).

There is a strong correlation between the arrivals with domestic flights and hotel arrivals of domestic tourists (Pearson correlation 0.938).

The big difference between the total hotel arrivals and total passenger arrivals that is noted in the case of Cyclades, could be explained as the impact of island hopping or ferry hopping within this area. The distances between the islands of Cyclades are relatively small. More specifically, the average sea link length between the islands of this group is approximately 44km or 23 nautical miles and the estimated weighted average travelled length is approximately 40km or 21 nautical miles. Ferry trips like this with a duration of 1-1,5 hours on average, are ideal for sea tours and excursions, sometimes daily ones, that increase the number of recorded passengers at the ports. The same explanation applies to the case of Sporades where the ratio of reported hotel arrivals to the number of arriving passengers is approximately 12%.

Combined transport and secondary destinations have also been observed in the survey sample of Part C of the current thesis.

According to the "Qualitative characteristics of resident tourists Vacation Survey 2014" of the Statistics authority of Greece, for the majority of personal trips in 2013, the type of accommodation used was non-rented accommodation (summer house, accommodation provided for free by relatives, friends, other owner-occupied accommodation). More specifically, only 33% of the Greek residents used rented accommodation for their personal trips (including the category rest, pleasure, vacation which represent 71% of personal trips) in 2013. [1]

The abovementioned 33% of Greek residents using rented accommodation for their personal trips is for the whole country and for the whole year 2013. There is no available data for this effect in the study area and for the specific time period of the summer peak season from another official source.

In the next figure the results for the accommodation type from the RP survey conducted in 2017 in terms of the current analysis and presented in detail in Part C of the thesis, are depicted. These values are filtered for residents of Greece with trip purpose "Holidays" and destinations to the islands of the Aegean Sea. They show a high percentage of Greek residents that used

[1] Qualitative characteristics of resident tourists Vacation Survey 2014, Statistics authority of Greece

rented accommodation for their holiday trip to the islands of the Aegean Sea. This percentage is 74% in a sample size that after filtering was 121 questionaries.

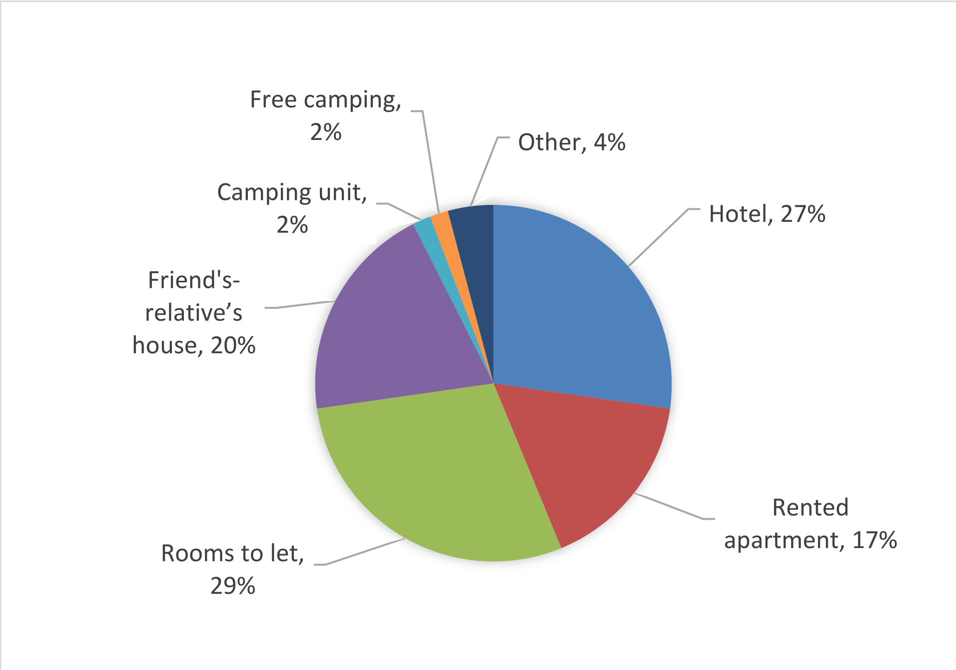


Figure B22. Accommodation type for domestic holidays trips_RP survey 2017

Therefore, a correction due to a suspected under-representation of visitors from Greece to the islands of the Aegean Sea in the table that follows, is not suggested.

Still, these records from the Greek Tourism Confederation INSETE website, are regarded as a good source of information on shares of visitors per demand segment i.e. Domestic tourists and foreigners. The impact of the above-mentioned distortion in the summer peak season is considered not influential in the analysis of shares. In some cases where the reports are on the level of groups of islands, such as for islands of Attica region, then the same share in each island was assumed. The same applies for “satellite” minor islands such as Paros-Antiparos, Chios-Psara. In limited cases where no information existed on the database on the island level, the necessary information was extracted from reference studies from the Regional Operational Programme PEP 2014-2020 reports like in the case of Sporades islands; or from reference academic studies and thesis like in the case of Samofthraki (N.Schwaiger, Exploring Sustainable Tourism on Samothraki 2017).

Table B13. Summary table of estimations of tourists' segmentation for the summer peak week

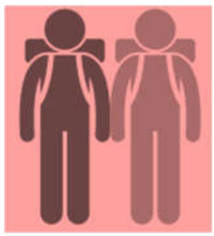
peak week of the year 2013	Crete	South Aegean		North Aegean	Sporades*	source
		Dodeca-nese	Cyclades			
Foreign visitors	89%	93%	71%	64%	67%	ELSTAT **Prefecture level** hotels and camping
Visitors from Greece	11%	7%	29%	36%	33%	ELSTAT **Prefecture level** hotels and camping
	100%	100%	100%	100%	100%	
Foreign visitors	217,949	192,800	193,142	34,213	25,813	Own calculations based on hotel arrivals & passenger statistics
Visitors from Greece	26,433	21,487	123,185	29,046	13,284	Own calculations based on hotel arrivals & passenger statistics
	244,382	214,287	316,327	63,259	39,097	
Foreign visitors	89%	90% (93%)	61% (71%)	54% (64%)	66%	INSETE **Island level** hotels
Visitors from Greece	11%	10%	39%	46%	34%	INSETE **Island level** hotels
	100%	100%	100%	100%	100%	INSETE **Island level** hotels
International aviation passengers	172,763	150,393	29,341	10,393	7,914	Aviation Authority passenger statistics
Inland aviation passengers	15,718	13,993	15,705	10,156	628	Aviation Authority passenger statistics
Sealine passengers	55,901	49,901	271,281	42,710	30,555	Ministry of Shipping passenger statistics
	244,382	214,287	316,327	63,259	39,097	
International aviation passengers	71%	70%	9%	16%	20%	Own calculations based on statistics
Inland aviation passengers	6%	7%	5%	16%	2%	Own calculations based on statistics
Sealine passengers	23%	23%	86%	68%	78%	Own calculations based on statistics
	100%	100%	100%	100%	100%	

* year 2014 numbers and shares

Additional details on the abovementioned estimations and references exist in Annex B2. In the figure below there is a graphical representation of the number of arrivals in hotel establishments for native and foreign tourists in the main insular complexes of the study area.

Figure B23. Number of arrivals in rented establishments 2013

From our analysis combining the three sources of information and recording of touristic attributes, it is concluded that in the Aegean Archipelagos study area, the weighted share between native tourists and foreign tourists is 27% vs 73% during the summer peak season for the reference year 2013. This indicator has never been estimated on the level of each island of the Aegean Archipelagos and this is a contribution of the current research.

Foreign visitors	**Visitors from Greece**	**All visitors**
		
736,866	272,096	1,008,962
73%	27%	100%

**Logos developed by the Statistical Authority, modified by the author*

9.2.2. Trip distribution step revision

The gravity model that was initially developed and presented at the beginning of Part B is now revised, as a better level of detail was proved necessary to describe the demand side of the transport system under study. This was made possible by combining findings from disaggregated surveys conducted for this research and described in detail in Part C.

The revised trip distribution equation is using productions and attractions to determine the constraints of the demand matrix per demand segment. The mathematical formula selected for the current analysis, has the general form:

$$F_{ij} = \frac{Q_i \times Z_j \times f\left(U_{ij}\right)}{\sum_{i=1}^{n}\left(Q_i \times f\left(U_{ij}\right)\right)}$$

where:

F_{ij} : Passenger flows from the origin zone i to the destination zone j

Q_i : Origin zone i

Z_j : Destination zone j

U_{ij} : Value for the utility between zones, for example distance or travel time from zone i to zone j

In this formula the direction of the distribution is soft on the Origin side or the Productions and hard on the Destination side or the Attractions. In this formula a balancing multi-procedure method is applied that is doubly constrained with an initial matrix according to the attraction totals. This specific method is selected as the attractions to the insular destinations are known from the aggregated statistical data on arrivals to the ports and airports of each island. These transport statistics were combined with hotel records and assumptions described in the above subchapter that allowed the demand segmentation and estimation of the attraction totals per tourists' category. While for the production side from each origin there is no available de facto data and more uncertainties exist.

9.2.2.1 Foreign visitors: Long-haul destination choice model

For the correction of the trip distribution or else defined as destination choice of the long-haul trips from abroad to the islands of the Aegean Archipelagos, the following structure and process is introduced, based on Productions and Attractions:

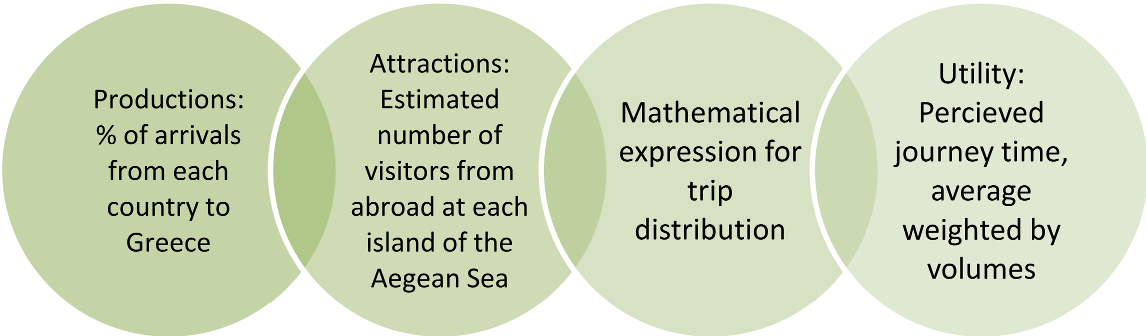


Figure B24. Long-haul destination choice model for foreign visitors

Where "Productions" represent the share of visitors from each country to Greece for the reference year and "Attractions" represent the estimated number of visitors from other countries at each island of the Aegean Sea from aggregated statistical data on ports and airports.

As the utility function, the perceived journey time (PJT) in minutes is selected. This is a customized function that consists of In-vehicle time, PuT-Aux ride time that describes the road part of the trip to the transport hubs of the Greek peninsula and it is mostly relevant for domestic tourism. Also Access and Egress time, walk time and Origin wait time. Transfer time and a penalty time for each time there is a transfer. Here is a list of PJT relevant components with their definition as described in VISUM software manual, which is the software that has been used to model the transport system of the area under study.

Skim	**Definition**
Access time (ACT)	Time required for covering the origin connector
Egress time (EGT)	Time required for covering the destination connector
Origin wait time (OWT)	Wait time at the start stop point (applies to the headway-based assignment only, as for the timetable-based procedure OWT = 0 is assumed)
Transfer wait time (TWT)	Wait time between arrival and departure at a transfer stop point
In-vehicle time (IVT)	Time spent inside PuT vehicles including dwell times at stops.
PuT Aux time (XZ)	Run time with PuT Aux transport systems *(here, private car)*
Walk time (WKT)	Walk time for transfer links between two stop points within a stop area or between different stop areas of a stop and on links in the network
Perceived Journey time (PJT)	Perceived time between the departure from the origin zone and the arrival at the destination zone PJT = ACT + OWT + ∑ IVT + 2 x ∑ TWT + (30 min) x ∑ Number of transfers + ∑ WKT + EGT

An important note is that the skim matrix of the utility as the PJT per OD pair is calculated in the transport simulation software as the average weighted by volumes of passengers for all modes per demand segment. This is only possible via an iteration process that includes also the mode choice and assignment-to-the network steps. There are some benefits to the selected approach. First of all, the range of travel times per mode that may exist between OD pairs is considered. Additionally, PuT frequencies and mode capacity issues as well as traveling day of the week parameters are integrated into the equation. This is regarded as an innovative solution to the destination choice exercise for the study area that offers many advantages.

From the many different tested mathematic formulas for the Utility of the destination choice for this demand segment, the one that had a better fit was the simple Kirchhoff function where,

$$f(U_{ij}) = {U_{ij}}^{c} \text{ with } c = -1$$

9.2.2.2 Visitors from Greece: Short-haul destination choice model

For the correction of the trip distribution or else defined as destination choice of the short-haul trips from Greece to the islands of the Aegean Archipelagos, the following structure and process is introduced, based on Productions and Attractions:

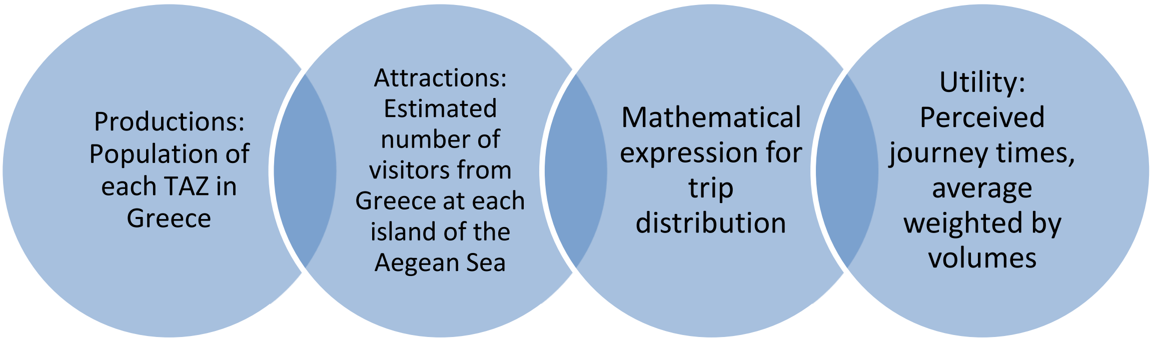


Figure B25. Short-haul destination choice model for visitors from Greece

Where “Productions” represent the population of each zone of Greece according to the more recent data to the reference year and “Attractions” represent the estimated number of visitors from Greece at each island of the Aegean Sea from aggregated statistical data on ports and airports. As the utility function, the perceived journey time (PJT) in minutes is selected, where similarly to the previous demand segment:

$$PJT = ACT + OWT + \sum IVT + 2 \times \sum TWT + (30\ min) \times \sum \text{Number of transfers} + \sum WKT + EGT$$

Explanation: Access time (ACT), Transfer wait time (TWT), In-vessel time (IVT), travel time for the road part (TR), Travel time between ports and airports of the same island (TPA), Egress time (EGT)

According to the bibliography of Mackie P. *et al* (2003) for public transport long-distance journeys in the UK and confirmed for the specific study area by Hatziioannidu F. and

Polydoropoulou A. (2021), the transfer waiting times are valued at twice the IVT and therefore, a factor of 2 is applied at the TWT attribute.

Same as previously, the skim matrix of the utility as the PJT per OD pair is calculated in the transport simulation software as the average weighted by volumes of passengers for all modes per demand segment. This is only possible via an iteration process that includes also the mode choice and assignment-to-the network steps. This is a solution to the destination choice question for the study area that offers many advantages explained in more detail above.

From the many different tested mathematic formulas for the Utility of the destination choice for this demand segment, the one that had a better fit also for the domestic travelers, was the simple Kirchhoff function:

$$f(U_{ij}) = {U_{ij}}^{c} \text{ with } c = -1$$

9.2.2.3 Trip distribution validation

The results of the destination choice models described above, are very good. For the whole set of 70 insular destinations, the validation has rho squares greater than 0.9 for both domestic tourists and foreign tourists. The detailed table with Attractions and modelled destination flows is presented in Annex B2.

The revised trips destination model is for all available modes. This approach offers an improved solution to the holiday destination choice question in the study area compared to the initial approximate solution. It considers tourist segmentation to locals and foreigners and it allows mode choice and path choice procedure at a next stage compared to the initial solution that was fixed for each mode sea and air. This way, there is the possibility of assessing mode interchanges, trip modal shifts and testing of mode complementarity policies.

9.2.3. Mode choice step as a combination of route choice for public transport assignment

During the analysis conducted for Part C of the thesis, it is observed through the revealed preference (RP) part of the survey that there is a small yet significant number of trips to the islands of the Aegean Archipelagos completed with a combination of sea and air modes. This introduces a multimodal dimension in our analysis. It extends beyond the combination of a private mode for the land part of the trips to the Aegean Archipelagos and one public transport mode either sea or air, as it was addressed in the initial solution. It is about the combination and complementarity of the two public transport modes, sea and air in the study area. To model this effectively and improve the initial rough transport model where the passenger flows per PuT mode were fixed, a new approach is explored here. This approach allows the simulation of multimodal trips and interchanges at intermediate stops of the system, not only between land modes and air and sea modes but also between air and sea. The two steps of mode choice and path choice or assignment-to-the network are performed in one step with many iterations until the equilibrium state is reached on the basis of an impedance function. The Public transport assignment is capacity restrained as each itinerary is modeled in detail with its vessel type and number of seats. This was also presented in Part A. Access times between the various stops of ports and airports are also modelled using realistic times from google maps. The impedance function developed for the path formulation is integrating the travel cost parameter via the fare model and ticket costs that are estimated per mode and presented in detail in Part C. More parameters apply in the formulation of the minimum cost function or else defined as impedance function in Visum, in combination with the perceived journey times.

PJT = ACT + OWT + ∑ IVT + 2 x ∑ TWT + (30 min) x ∑ Number of transfers + ∑ WKT + EGT

Additional boarding penalties for PuT modes are applied on the vehicle journeys attribute as follows: 60 min for air routes and 20 min for sea routes.

- Impedance function for the path formulation

The impedance function developed is a combination of journey times, VOT for travelling, Fare in euros from the fare model developed and described in Part C, itineraries and capacity restrictions.

Impedance = VOT x PJT + Fare + vol/cap ratio-dependent

where VOT is estimated at 3/4 of the wage and is assumed at 5.4€/h or 0.09€/min for Greece in the reference year. This value is justified in Part C and it is used extensively in similar studies found in the literature review. For the foreigners a VOT double as much of the domestic tourists is assumed i.e. equal to 0.18€/min.

in the impedance function, the perceived journey time as it is presented above is combined with the value of travel time and travel costs. Capacity restrictions also are considered via the discomfort vol/cap ratio-dependent parameter.

It is also noted that the PJT skim matrix used in the impedance function, is the passenger average weighted for all paths between an OD pair and convergence is possible via an iteration process.

The path choice model is defined by a mathematical equation that uses the impedance function.

Among the many models that were tested, the one with the better results was the Kirchhoff one with c=-1

$$f(U_{ij}) = {U_{ij}}^{c} \text{ with } c = -1$$

The selection of the specific model is also justified in Part C and it is connected with the analysis of the revealed preference survey.

9.2.4. Addressing long-haul trips with chains via Athens

There is a significant number of long-haul trips from foreign visitors that use Athens as an intermediate stop of their holidays to the islands of the Aegean Sea. Evidence on this is provided also from the analysis of the mobile phone records presented at the begging of Part B. In these records a significant share of foreign tourists traveling by sea modes from the ports near Athens (mainly Pireus and secondary Rafina) is observed. Another evidence is that combining the estimations of the destination choice also presented previously in Part B and the detailed Civil Aviation Authority data on direct flights to the islands from the abroad, there is a remaining share of foreign tourists that arrives at their final holiday destination with domestic flights or with ferries from the ports near Athens.

There are many reasons for these trip chains via Athens. Not all countries as origins of holiday trips have direct connections to the Greek islands and also not all islands as holiday destinations have direct flights to abroad. But even for the cases that a direct flight connection exists, as it is already explained in Part A, there are strong capacity restrictions as direct flights operate at the capacity level, implying that any excess demand is shifting to alternative routes via Attica (greater Athens region) which is the main transport hub in Greece. For a category of tourists that they have more days to spend for their holidays, none of the above reasons counts as they actually chose to spend few days in Athens that offers many touristic attractions and sightseeing opportunities, before they continue their trip to the Aegean islands. This category of tourists does not follow the mathematical expression of the generalised cost paths as there are wishes involved in their travel choices that cannot be configured and integrated into the equation.

To address and simulate adequately in the transport model all the abovementioned cases of trip chains via Athens, the trip matrix of foreign tourists is parted in a direct connection matrix and another one that uses Athens as an intermediate stop. From the path analysis of the initial model runs it is possible to extract foreign visitors arriving at the islands with direct flights, so that the remaining passengers it is assumed that they are travelling via Athens.

The partition of the long-haul matrix into direct passenger flows and transport chain flows was selected as the technique that better addresses the raised issue and it was implemented outside the model. The idea was borrowed from CUBE software. The transport chain flows matrix involved the development of a pseudo matrix where each OD pair of interest splits in two trip segments, one from the country of origin to the Attica zone and one from Attica to the insular destination. Then the volumes on the pseudo-OD pairs are aggregated to formulate a new OD matrix.

9.2.5. Public transport assignment validation

The demand transport model developed for this research is a large-scale one, with many distant zones and complex trip chains. Also, not all aggregated statistical values are from the same source nor do they have the same level of recording detail. Therefore, the model validation is a challenging exercise. The chosen method is based on passenger flows at the transport hubs and more specifically at the port level and at the insular airports. XY Scatter plots provide a visualization of the match between the modeled and observed flows. These plots are proposed in most validation guidelines.

The threshold for a strategic 4-step daily model is a Rho square of the errors between modelled and observed flows greater than 0.85 and a fitting slope between 0.9 and 1.1. (ATAP Australian Transport Assessment and Planning Guidelines, T1 Travel Demand Modelling, 2016). In the case of a weekly model like the one developed for the Aegean Archipelagos, there are no specific thresholds in the bibliography.

Both the port and airport validation of the transport model are presented in the following two figures. The Rho squares or the fitting are higher than 0.95. The slope for the passenger flows at the insular airports is 1.10 while the one at the ports is 0.90. Overall, the model a very good fit, considering the complexity of the trip patterns in the area and the combination of modes. Its results are consistent and they are considered valid. Testing of new policies with the help of the model is therefore the most suitable approach. This is further discussed in Part C of the thesis.

► Validation at port level

Number of observations N=72 ports

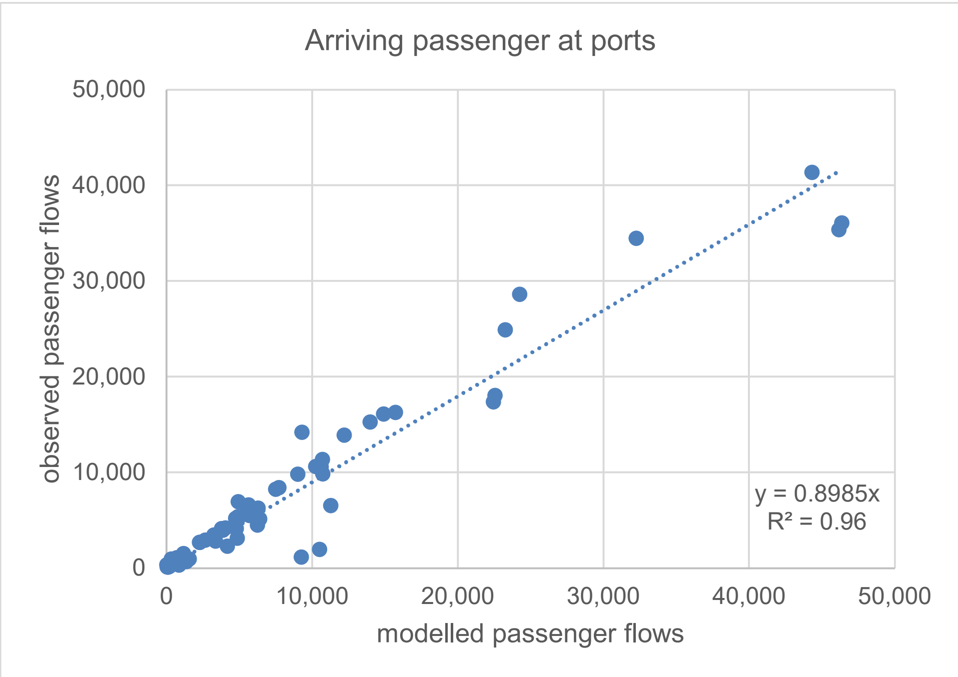


Figure B26. error scatter for model validation at port level

The detailed list of modelled vs observed sea passenger flows at each port of the study area is presented in Annex B.

- Validation at airport level

Number of observations N=24 insular airports

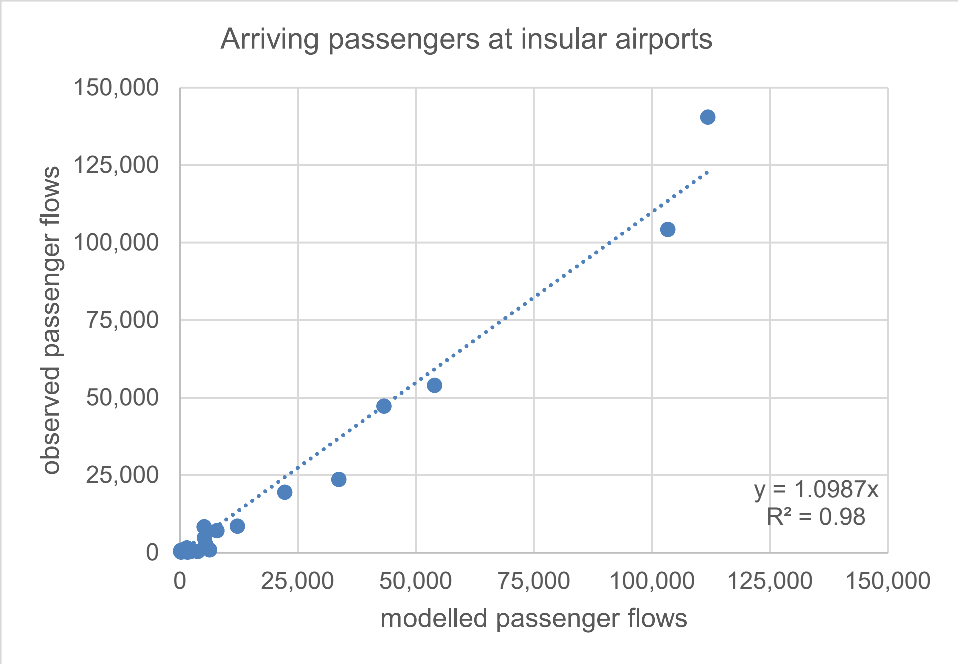


Figure B27. error scatter for model validation at airport level

The detailed list of modelled vs observed air passenger flows at each airport of the study area is presented in Annex B.

PART C: THE BEHAVIORAL SIDE, TRAVEL CHOICES AND POLICY TESTING

A QUESTIONNAIRE SURVEY ON PASSENGER TRIPS IN THE AREA

SOCIOECONOMIC AND BEHAVIORAL CHARACTERISTICS OF THE DEMAND DESTINATION AND MODAL CHOICES

MODEL RESULTS ON POLICY TESTING OF TWO MINOR INSULAR HUBS

10. INTRODUCTION AND BACKGROUND OF PART C

The Aegean Archipelagos in the East Mediterranean region, is consisting of 65 inhabited islands with 77 ports. During the reference year 2015 a total number of 15 operators provided regular passenger services with ferry and highspeed catamaran vessels in the area. A dense ferry network with 48 sealine routes, excluding the strait connections, has been developed empirically over the years to service a strongly peaking tourists' season with 164 thousand long-distance passenger trips per day by sea. The typical sea travel times in the study area are between 3 and 13 hours. The weighted mean in-vessel time is 4.5hours per passenger and the mean ride distance is 100 nautical miles.

This survey aims to analyze the demand side and decisions on the mobility of the passengers travelling to the island of the Aegean Archipelagos. The questionnaire is consisting of 45 Questions and 10 exercises. According to their answers, the respondents are guided to answer questions that fit their profile and skip others. The survey has been developed in Sawtooth SSI and has been conducted electronically. The results of the survey will be processed with various tools including Sawtooth SSI, SPSS, MS Access, MS Excel and Biogeme, in our task to calculate formulas that will combine socioeconomic characteristics of the respondents with their choices.

10.1. Problematic and scope of this approach in the specific study area

Part C aims to complete the former stages with a behavioural analysis of the passengers and their travel choices through a survey. More specifically it is anticipated with this survey to complement our work on the simulation model of the existing situation and the mobile phone activity analysis with behavioral characteristics of the passengers and to explore their decision-making aspects and preferences. The analysis presented in Part A of the Thesis, indicated that the network under study, has very good connection with the mainland ports of Attica and Northern Greece but there are shortcomings in the interconnection among islands that are serviced by different routes. In Part C, we propose some islandic interchange points to improve interconnectivity within the Archipelagos.

- Mobility differences between major tourist groups

Identify differences in the mobility of the two major groups: domestic tourists and foreign tourists. We have some indications of significant differences in the travelled kilometers by sea of these two major groups during the phone activity analysis. We would like to further investigate this trend with this survey. Specific questions like this exist in the RP part of the questionnaire. We aim at quantifying the percentage of foreigners travelling by sea or by air via major greek transport hubs such as Piraeus, Rafina and Thessaloniki ports and the International airports of Greece Then we can correct accordingly our trip distribution gravity model with distinguishing the two major groups.

- Identification of trip patterns and chains

With the revealed preferences part we anticipate to identify the share of trips that can be considered as chains VS return trips that are coupled with the outbound trip. We can include this finding as a new parameter in our transport simulation model. Up to date, we do not know if there is a significant number of trip chains in the study area for the peak season. The impact of secondary destinations in the region of the Aegean sea has never been addressed in the past and there is no relative literature.

- Calibration and improvements of the 4step modelling

We will consider ways to calibrate the trip generation, trip distribution and modal split steps of the 4 step modelling process with the findings of the survey. The combined destination and mode choice survey will allow us to improve our initial approach that has not provided satisfactory results for rips generation and modal split steps of the process.

- Testing of new connection scenarios/ induced demand and accessibility

During the assessment of the supply side of the transport system under study in the existing situation presented in Part A of the Thesis, two important missing links are identified. These two cases are further investigated here analysed here for their efficiency together with more research objectives. More specifically, the objectives of this research are the following:

1. Test the acceptance of a potential new ferry transport system policy using islandic ports as minor hubs in the area of the Aegean Archipelago. The proposed islandic minor hubs are placed at strategic locations for enhanced interconnection between clusters of islands through transfer to a second ferry line. The system applies for islands that in the existing situation are only connected to one another via the mainland ports of Piraeus and Rafina of the Attica region and Thessaloniki, Kavala and Alexandroupolis of the Northern Greece region, formulating extensive detours with high travel times that also include a transfer.

2. Estimate values of time for trips via sea for tourism in the study area; estimate values of waiting time and determine the disutility levels at the transfer points.

3. Model travel behavior wian th the use of disaggregate data and provide calibrated functions for route choice and mode choice improving the transport model of the Aegean Archipelago that was initially developed on the basis of aggregated statistical data.

Enhancement of the interconnection among Greek islands is the 5th Pillar of the National Strategic Transport Masterplan of Greece 2019 for the planning horizon 2018-2037. The National Masterplan has 9 Pillars of measures in total, while relevant with the current analysis and proposed policy is also the 4th Pillar for the Promotion of the Tourism Sector.

This part of the Thesis is composed of five sections. Section 3 describes the questionnaire of the survey. Section 4 is about the statistical analysis of the survey sample. Section 5 is analyzing the preferences of the system users in a ranking exercise. Section 6 tests the acceptance of two minor islandic hubs for a new potential peripheric policy. Section 7 concludes this part.

10.2. Overview of Literature Review

Spilianis I. et.al (2005 and 2012) argues that the accessibility of the islands of the Aegean Archipelago is determined by two components: the destinating or external and the internal transport connections. The former concerns the connections of the islands to the central portals or major hubs of the transport system, while the latter described the interconnections among the islands. The scope of good balance, regularity and completeness of the external and internal insular connections and corresponding flows of passengers, goods and services is called in the bibliography the "double insularity" issue. This term is adopted in the current Thesis as it summarises the main objective for improving the performance of the overall system in this special region of the East Mediterranean Sea.

The use of discrete choice models for modelling travelling behavior was introduced by D.McFadden and T.Domencich with multinomial logit models for mode choice and time of the day choice in the 70s. The fundamentals of discrete choice modelling for transportation were expanded by M.Ben-Akiva, S.Lerman and K.Train in the next decade. In the years that followed, these models have been applied widely for testing pricing policies such as ticket pricing, charging schemes such as toll charges, for demand forecasting such as assessing the market share of new transport infrastructures, for mode choice and for a wide range of willingness to pay surveys.

More recently in a case study from Italy, the method of stated preferences was used to calculate the opportunity value of travel time to recreational sites. The study presents an analysis based on actual driving choices between open access and toll roads and proves that the value of time for recreation trips in Italy is not less than 3/4 of the wage (C.Fezzi, I.Bateman, S.Ferrini, 2013).

The choice of the waiting transfer hub is expected to be an important factor of the total travelling experience, especially for holiday trips. As, Mokhtarian (2005) argues a trip can be an end by itself, thus travelling times and waiting times for transfer are not necessarily wasted time. Furthermore, Tanko et al. (2019) suggests that there is an excess utility for ferry users as they value amenities and scenery comparably to travel time savings.

Therefore, understanding route choice behavior for ferries is very important for planning purposes. Examples in the literature involving short-distance ferry trips include the following. Dehghani et al. (1997) developed a route choice model for the Washington State Ferries transport system on the west coast of the USA. The model tests various policies resulting in demand forecasts at the route level. Multimodal trip chains including ferry routes destinations or ferry terminal choices are introduced, by allocating attractiveness parameters at terminals. A follow-up study by Dehghani et al. (2002) improved the same model through a stated preferences survey for assessing new routes and services. Similarly, Douglas and Jones (2017) investigated the quality of service and passengers' preferences for the ferry system in Sydney of Australia with stated preference surveys and ratings of ferries and wharfs. The results are the value of travelling time and values of service quality that are utilized to calculate the generalised cost function for ferry trips.

For long-distance trips, Polydoropoulou and Litinas (2007) conducted a stated preferences survey for Northern Aegean Sea region in Greece to develop a mode choice model between conventional shipping lines, highspeed sealines and airlines. Estimation results showed that choices depend on travel times, travel costs and socio-economic characteristics such as age, education level and frequency of travelling. For the fjord region, Mathisen (2008) investigated passenger trips and the relationship between travel distance and fares in Norway, where 175 ferries operate in the coastal areas, to serve 131 crossings and 20 million passengers per year in 2005. Using ordinary least squares regression, he concludes in linear generalised cost functions for each mode including ferries, consisting of a distance factor per travelled km and a constant value. With average speed assumptions, he is estimating the travelling cost by ferry.

The above articles focus on ferry transport and methods to study user behavior and estimate values of travel time. Many of these researches involve the utilisation of stated preferences surveys and discrete choice modelling techniques. However, the topic of interchanges at transfer points for ferries is merely addressed as opposed to multiple references regarding public transport urban networks. For example, Douglas and Jones (2013) estimated the pure transfer penalty using different transfer wait times and platform change options through a stated preference survey in Sydney. In Madrid, Cascajo et al., 2017 estimated the pure transfer penalty for commuters of Public Transportation (PT) as a factor for the equivalent increase in in-vehicle minutes. They argue that the transfer penalty is related to habit, crowding, walking, waiting and in-vehicle times, information, as well as intramodality on transfers.

Regarding waiting time, throughout the literature for example Mackie P. et.al 2003 and Transportation Cost and Benefit Analysis II – Travel Time Costs, Victoria Transport Policy 2013, it is valued at 200% or more of the in-vehicle time for land modes.

To bridge this gap, Part C offers an approach similar to the abovementioned ones, but for long-distance trips by sea with interchanges, and tourism as the main trip purpose. The value of transfer times between ferry lines and the disutility of transfers at specific ports are estimated, together with the acceptance of a new policy based on minor islandic hubs in the Aegean Archipelagos.

11. METHODOLOGY AND APPROACH OF PART C

11.1. Reference studies

Diamantis P. et al. (1996) for the Rio-Antirio Bridge connecting N. Peloponnese to W. Greece calculated the value of time, to assess its acceptance as an alternative to the exiting ferry route. He used a method based on revealed preferences, and he estimated a multinomial logit model for the mode choice exercise. The analysis aimed to calculate the values of travel time for two major trip categories i.e. non-business 3.4€/h and business trips 4.9€/h with maximum likelihood procedures.

Polydoropoulou et.al 2004 combines stated preference techniques with revealed preference data and estimates via a multinomial logit, values of time per trip mode. For ship mode this survey concludes in 4.7€/h total VOT or 4.9€/h for professional purposes and 4.3€/h for personal purposes. In that research, there was no detailed distinction of the total journey time, in access to the port or airport time, in-vessel or flight time, waiting time, delays etc. to estimate distinct time values respectively.

Roussi P. 2006 argues that the values of time for travelling vary from country to country while even in surveys conducted for the same country, the results vary due to the different objectives of each survey and the assumptions made in each case. The collection of data also plays an important role in the final outcomes, in terms of questionnaire design, respondents' participation and data processing. For example, the values of the time may differ between urban and rural areas, they depend on the purpose of the trip, etc. In her thesis she continues referring to the Greek literature, where the results of the research of Diamantis P. et al. (1996) and Polydoropoulou A. et al. (2004) who determine the value of travel time cannot be compared because one study calculates an average price regardless of the transport mode, while the latter calculates different prices for each transport mode. She concludes that even in the study of Polydoropoulou A. et al. (2004) which is the most modern and detailed one on this topic, the cumulative travel time from origin to destination is considered without distinction of the trip segments and this is perceived as a generalisation. Roussi concludes that it is necessary to update constantly the values of time, in order to meet the requirements of new transportation projects; and that each new relevant research should address problems and weaknesses identified in the previous ones.

Antoniou et.al 2007 estimates value-of-time using stated-preference surveys and econometric models per trip purpose for land modes in Greece. He is estimating VOT for leisure as 6.3€/h while he proves that VOT of young travellers is lower and also that VOT for leisure trips can be higher than for work trips.

In a similar region of the world, T.Mathisen in 2006 in his paper is referring to The handbook of the Norwegian directorate of Roads for the hourly time cost for each transport mode including ferries. According to this reference, the average time costs 57 NOK/h in 2005 prices. The inflation rate in Norway between 2005 and 2017 was 28.26%, which translates into a total increase of kr16.11. This means that 57 kroner in 2005 are equivalent to 73.11 kroner in 2017. In other words, the purchasing power of kr57 in 2005 equals kr73.11 in 2017. The average annual inflation rate between these periods was 2.1%. This is equivalent to 6.93€ / h in 2017.

11.2. Discrete Choice Theory applied in the study area

According to Ben-Akiva and Lerman (1985) the Utility as a major category of decision rules, is defined as a scalar index of value that is a function of attributes and/or individual characteristics. Its' significance lays in capturing how individuals make trade-offs between the different attributes and maximize their own utility.

The transport system of the study area is modelled in Visum software at a detailed level for all ferry services with their routes and time schedules. The core area of the Aegean Archipelagos is divided into clusters of islands as in the following figure and the connectivity within each cluster and between clusters is assessed for missing links and problematic interconnections. To improve the system, two new connections are tested by conducting a stated preference survey to assess their acceptance. These connections are Chios-Mykonos via Andros port and Chios-Samothraki via Limnos port, affecting primarily clusters 1 and 8. The mainland ports of Attica and of Northern Greece are depicted with blue stars, while the ports of Andros and Limnos with dark red.

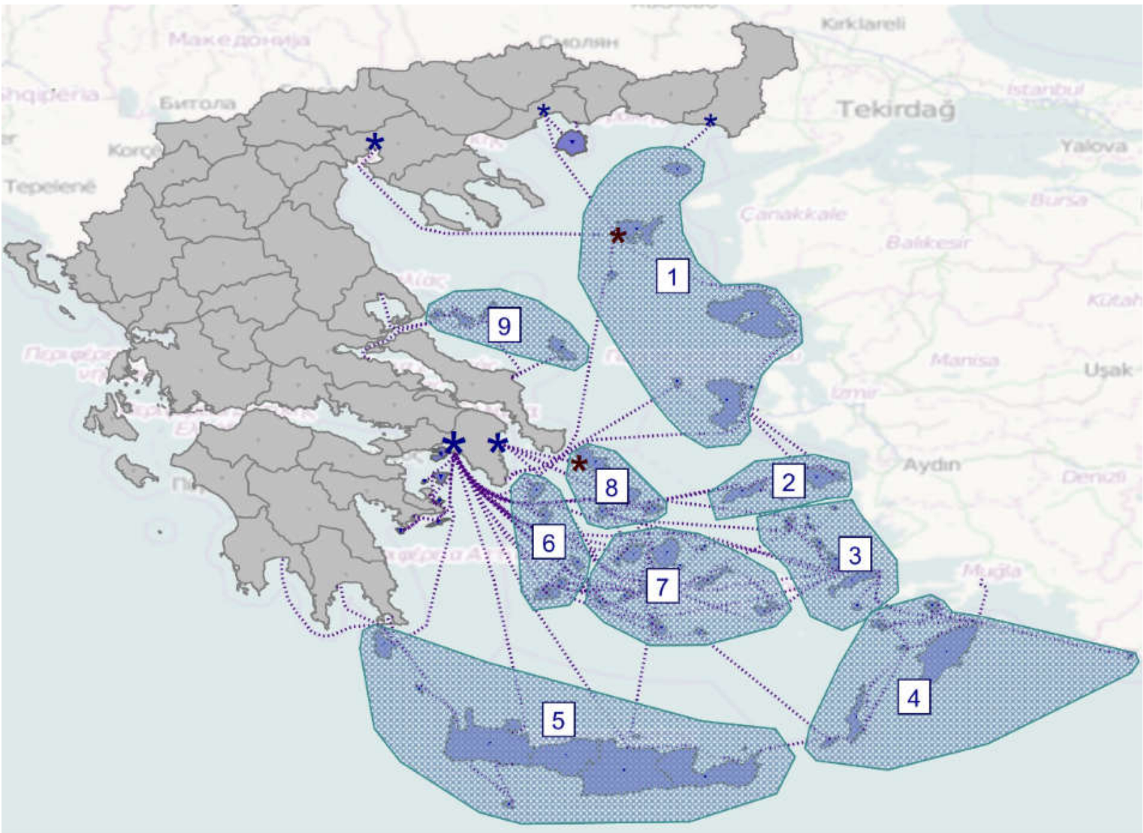


Figure C1. Study area transport model, ports of interest and grouping of islands in clusters

The survey was conducted in 2017 to users of the system who had travelling experience in the islands affected by the tested policy. The questionnaire was electronic and was designed with the Sawtooth software. A discrete choice model was developed using the Biogeme toolbox.

11.3. Use of combined tools

- SAWTOOTH SOFTWARE

Tool for conjoint analysis, discrete choice analysis and other forms of conjoint. Modules of non-conjoint products involving interviewing, perceptual mapping, and cluster analysis.

- BIOGEME TOOLBOX

Bierlaire Optimization toolbox for GEV-generalized extreme value model estimation is a freeware designed for the development of research in the context of discrete choice models in general, and GEV models in particular.

- SPSS Statistics

PSS Statistics is a software package used for interactive, or batched, statistical analysis. The IBM SPSS® software platform offers advanced statistical analysis, a vast library of machine-learning algorithms, text analysis, open-source extensibility, integration with big data and seamless deployment into applications.

- Visum software

Visum is a comprehensive transport modelling software system, for strategic transport planning. It has a lot of functionalities in public transport assignment, multimodality and 4 step modelling. It allows assessing different strategies and multiple “what-if” scenarios for different modes of transport. The traffic planning software supports decisions and plans according to planning targets while delivering reliable results.

12. DESCRIPTION OF THE QUESTIONNAIRE

The questionnaire is consisting of 45 Questions (61 data fields) and 10 exercises. Not all of the questions and exercises are intended to be answered. According to their answers, the respondents are guided to answer questions that fit their profile and skip others with skip functions that we have implemented. Each respondent is answering approximately 30 questions and 1 exercise. The survey has been developed in Sawtooth SSI. It is intended for electronically fill-in. The results of the survey will be processed in SPSS and we will seek formulas that will combine socioeconomic characteristics of the respondents and their choices.

The survey is divided in two major parts. One part is the revealed preferences part and the second part is the stated preferences part. Both the first and the second part are answered by respondents who have travelled to the islands of the Aegean Sea this summer season May-September 2017. Passengers that have only travelled to the islands of the Aegean in the last 3 years but not this last one, they are only participating in the stated preference survey.

Revealed preference data are based on the actual, observed behavior of passengers. By definition, revealed preference data reflect passenger behavior under existing transport system conditions. Socioeconomic factors such as age, gender, financial situation, education status etc. are collected per passenger as well as her/his decisions on destination, mode choice, cost of trip, travel time, accommodation type, duration of stay etc. This part also contains information on the criteria of their choices based on characteristics of the destinations that they are ranked according to the importance and the positive characteristics of each mode (ferry/airplane).

12.1. Design elements of the survey

12.1.1. Survey framework in a schematic diagram

The survey has all the typical characteristics of discrete choice framework and more specifically it includes:

- Personal characteristics
- Trip characteristics, attributes of trip and alternatives
- Attitudes and Perceptions
- Scenario Development

The framework is depicted in a schematic diagram from Yang, Choudhury, Ben-Akiva, Silva and Carvalho as follows:

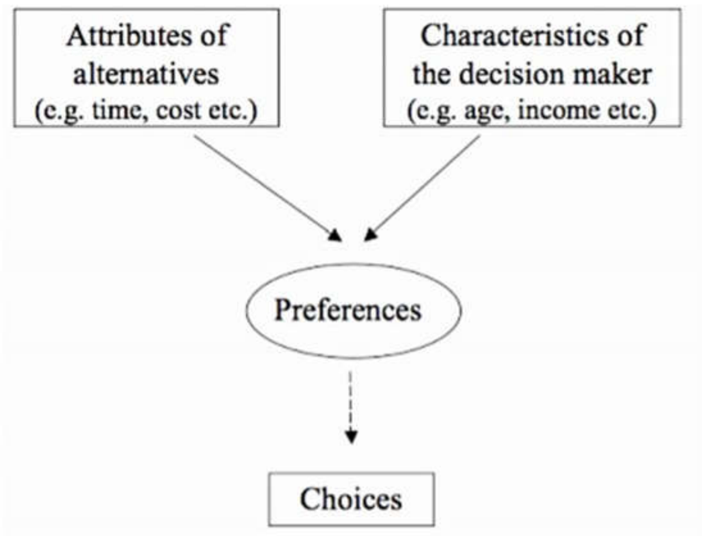


Figure C2. Discrete choice framework *

*Source: Stated Preference Survey for New Smart Transport Modes and Services: Design, Pilot Study and New Revision. L.Yang, C.Choudhury, M.Ben-Akiva, J.Silva, D.Carvalho, 2009

12.1.2. Major passenger categories

The target group of the survey are travelers to and from the Greek islands of the Aegean Sea. They are grouped into categories with the help of the following question which is at the beginning of the questionnaire.

“In which of the following passenger categories do you belong?”

- Visitors from other countries
- Visitors from Greece
- Locals-inhabitants of the Aegean islands travelling to another Aegean island
- Locals-inhabitants of the Aegean islands travelling to the Greek peninsula
- Seasonal employees at the Aegean islands travelling to another island of the Aegean
- Seasonal employees at the Aegean islands travelling to the Greek peninsula

The special categories of locals or seasonal workers in the Aegean region travelling to the Greek peninsula they are instructed to answer for their mainland destination.

12.1.3. Passenger profiles

Who accompanied you on your trip this summer to the Aegean islands? (more than one answers are acceptable)

- No one
- Partner
- Family with one or more children
- Relatives
- Friends
- Business partners, Coworkers
- Travelling with a group
- Other

12.1.4. Trip patterns and chains

The first part of the survey is giving information additionally on secondary destinations if they exist and duration of staying in the secondary destination. This way we gather information on trip chains that we have already identified from the mobile phone data analysis.

In the revealed preferences part, we also identify the share of trips that can be considered as chains VS return trips are that coupled with the outbound trip.

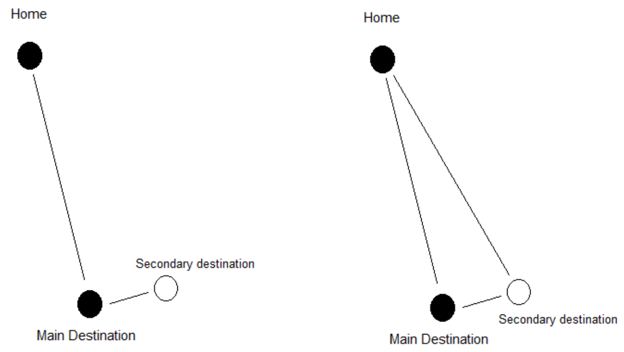


Figure C3. Holiday trip patterns with secondary destination

In a sample of 257 valid responses, a significant number that sums up to 29 % revealed that travellers in their last trip to the islands of the Aegean Sea, had a secondary islandic destination in the study area excluding the trips within Crete. This is the island-hopping effect that is a major trend and it is becoming more and more famous in recent years. Especially for holiday trips, K. Miller in her article in 2019 on Lonely Planet "Plan your perfect Greek island-hopping adventure" writes:

"Scattered like pearls across the shimmering Aegean and Ionian seas, the charms of the Greek islands have lured many. From Jason and his adventuring Argonauts to Frankish Crusaders and Mamma Mia film crews, myth and enchantment enfold the islands much like their ribbons of sugar-soft sand. There's nothing quite like spotting the shoreline from a sun-drenched ferry deck or sailing into a vibrant port. In Greece, getting there is an essential part of the adventure and, thankfully, island hopping is a breeze."

The respondents who had a secondary destination, replied that with a frequency of 40% they returned to their permanent residence/home directly from the secondary destination.

The duration of stay at the main or primary islandic destination of the Aegean Sea for all trip purposes has a weighted average of 6.8 nights per trip. The majority of the respondents stated that they stayed for 5 nights. For the travelers that had a secondary destination in the area under study, the average weighed duration is 3.0 nights while the big majority stay for 1 night. These findings with additional details, are depicted in the two following figures.

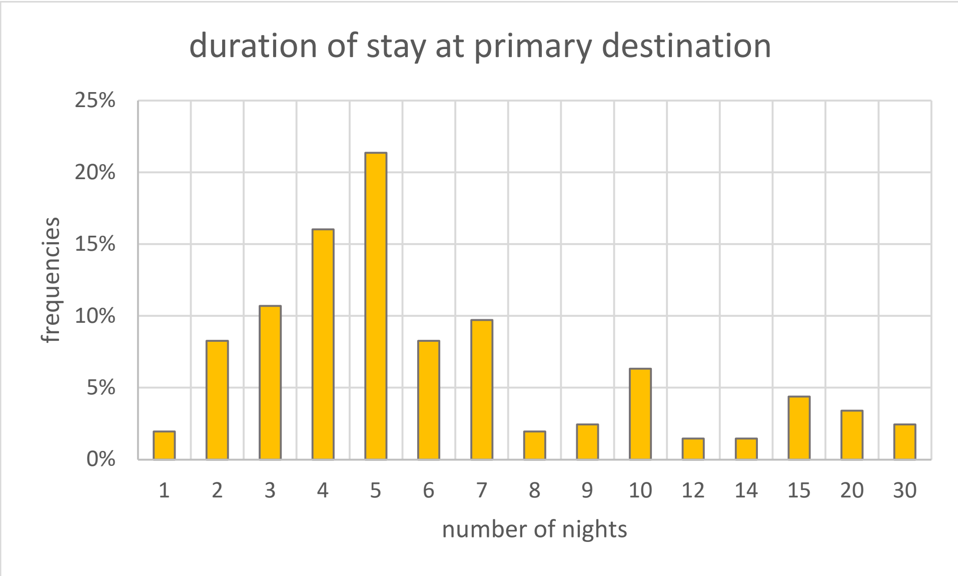


Figure C4. duration of stay at the primary destination

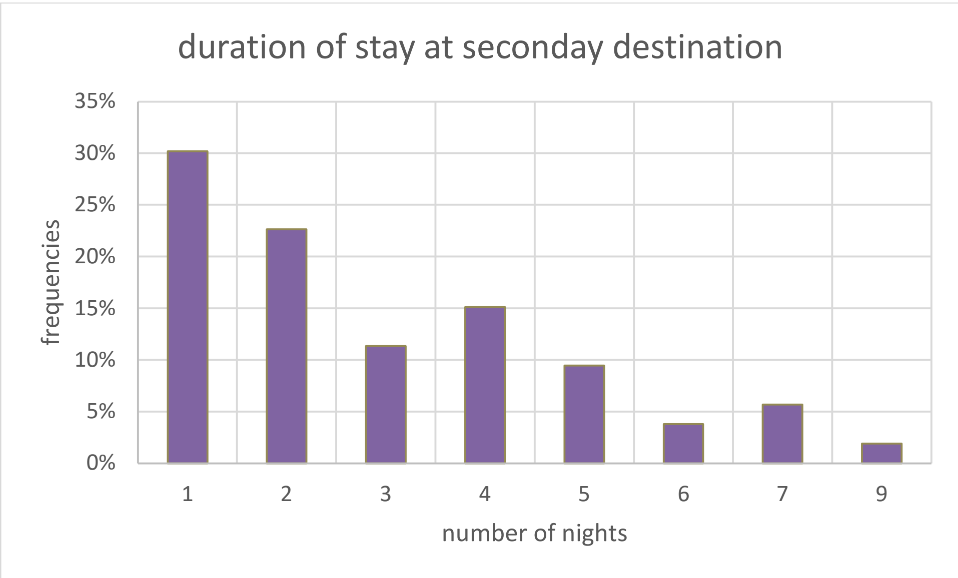


Figure C5. duration of stay at the secondary destination

12.1.5. Elements of rankings on preferences

We have included a question about the importance of attractions in the touristic destinations as follows:

How would you rate the importance of the following aspects of a destination when making a decision about the choice of your next holidays to the Aegean islands? Please, select an answer for each item.	1	2	3	4	5	6	7	8	9
Nice beaches									
Sport Activities, trekking, scuba diving, etc.									
Landscapes and nature									
Hospitality and quality service									
Nice accommodation (hotel, apartments, camping sites etc.)									
Vivid nightlife (bars, clubs etc.)									
Cultural sites and events (museums, theater, music, festivals etc.)									
Nice food (taverns, restaurants, bakeries, pastry shops etc.)									
Silence, tranquility, relaxing opportunities									
Affordable prices									
Good for family holidays									
Local products and shopping									

The scale 1-9 is defined as follows:

1_Extremely Important

2_Very Important

3_Important

4_Somewhat Important

5_Neutrally Important

6_Slighty Indifferent

7_Not Important

8_Not Important at all

9_Totally Indifferent

Similar rankings are made for the mode choice. More details on the ranking exercise exist in the exclusive chapter. The results of this exercise are presented in a separate chapter.

12.2. Dissemination methods of the questionnaire

The questionnaire was internet-based and it was disseminated via social media, a specially designed leaflet distributed in ports and airports as well as targeted letters and emails to the academic society of the University of the Aegean, and references at the websites of the SES Hellenic association of transport engineers and at DAFNI Network of Sustainable Greek Islands.

12.2.1. Social media

Dissemination through social media concerned the design of a Facebook page called "Destination Islands". On this page, there was information on the survey and a link to the questionnaire as well as updates on the survey progress, photos of Greek islands of the Aegean Sea and traditional island music pieces to increase the visibility of the page.

12.2.2. Leaflet

Another way to advertise the survey and attract respondents was a leaflet that was distributed to passengers at ports and airports. A bitly link and a QR code was created for an easy link to the survey. The leaflet is presented here:

www.aegean.gr
UNIVERSITY OF THE AEGEAN

Dear traveller,

We are conducting a survey for the University of the Aegean, Department of Shipping, Trade and Transport. Our research is aimed at travellers to the Aegean islands as we are examining the passenger transport system and accessibility in this area. To participate, you must have taken at least one trip like this in the years 2015, 2016, 2017. This questionnaire takes about 7 minutes. It is electronic and anonymous. Your contribution is very important! Thank you in advance for your valuable help. This link leads to the questionnaire:

http://bit.ly/2taefZG

The link is also available on Facebook:
Destination islands

QR code for the survey link

Figure C6. leaflet printout with link to the questionnaire

13. STATISTICAL ANALYSIS OF THE SAMPLE

13.1. Analysis in of socioeconomic characteristics of the respondents

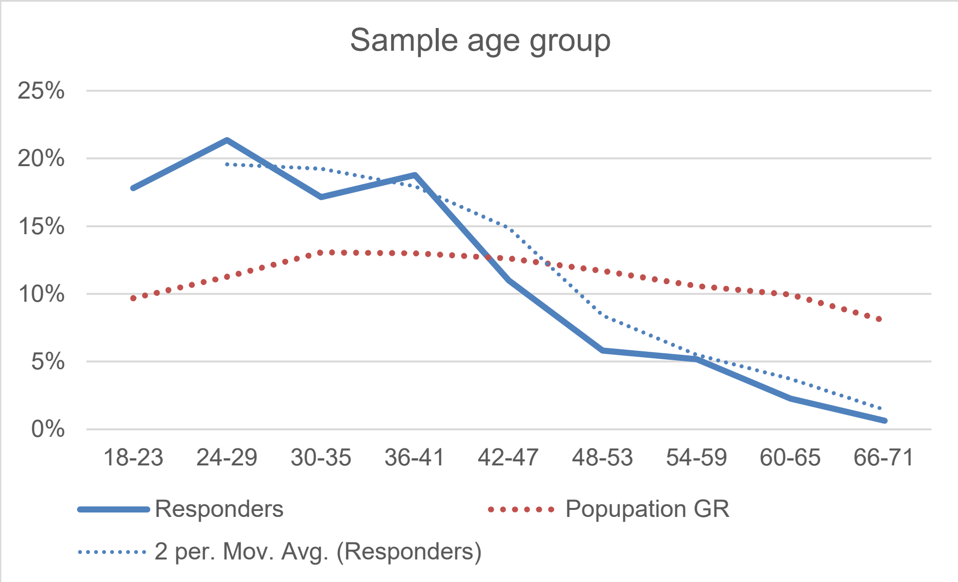


Figure C7. Sample distribution in age groups (source of Population GR statistics census 2011_elstat)

The age distribution of the sample is considered very good and adequately representative. It may differ from the population distribution or age pyramid of Greece but it is highly relevant to the trip rates per age group to the island of the Aegean Sea. The mobility of the domestic tourists as users of the specific transport system, between 20 and 45 years old is higher than the mobility of those between 45 and 70 years. The island of the Aegean Sea is not the closest holiday by the sea destination nor the more economic holiday option and therefore middle age user groups and pensioners are using other holiday alternatives that are closer to the Greek peninsula.

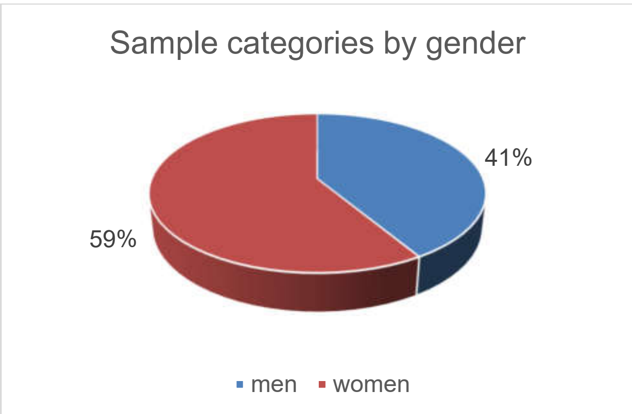


Figure C8. Sample analysis by gender

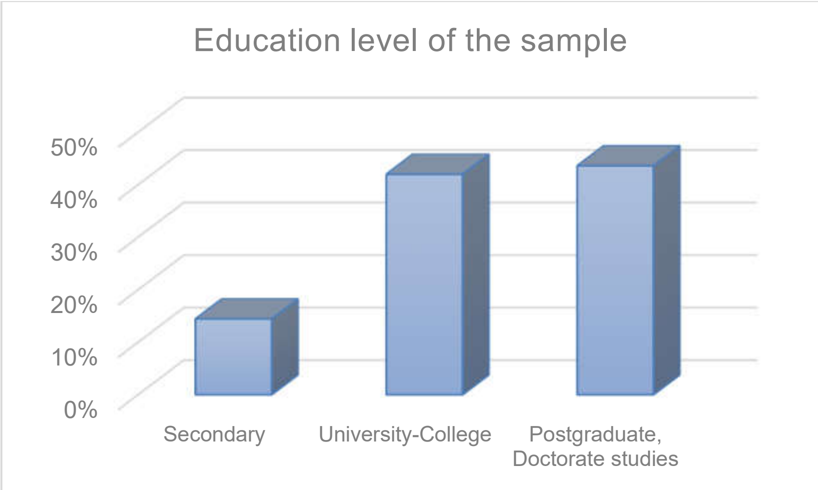


Figure C9. Sample analysis by education level

The high response rate of persons with higher education levels is not representative of the Greek segmentation. The bias observed in the sample regarding the education level is explained by the high response rates within the University community of the Aegean University that hosts the survey and partially by the tendency of response to such surveys by persons that are more sensitised to the research objectives.

Almost 50% of the respondents have an income lower than EUR10,000. And 90% of the sample size has an income between EUR0-30,000.

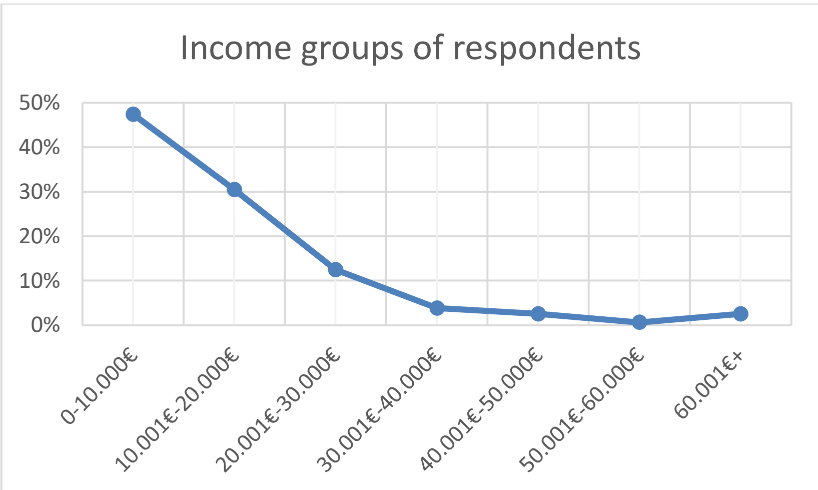


Figure C10. Sample analysis by income level

The majority of the respondents are employees. This is representative of the Greek economy and employment status. Under this category fall all public servants (both civil and military) and private employees who earn a stable salary. Representative in the sample is also the share of self-employed respondents who hold a big part of the economic activity of the country.

Table C1. Employment status sample vs reality

occupation	Survey samples 2017	Real statistics 2017*
Employee	45%	31%
Self-employed	18%	14%
Unemployed	8%	13%
Retired	3%	33%
Student	25%	9%
Other	1%	-
sum	100%	100%

**source: combination of data from various sources and own calculations*

More specifically according to Eurostat data, the share between employees and self-employed in Greece for the year 2017 is 72% vs 28% while in the sample the representation is 69% for employees vs 31% of self-employed, which is very close to the exact shares from the reality.

The representation of students is overestimated as they are with 25% in the sample as the questionnaire was disseminated widely in the academic community. In reality the share of students compared to the total population above 17 years old is approximately 10% according to data from the ADIP report of the Hellenic Quality Assurance and Accreditation Agency and our calculations. The impact of such a distortion in the sample could result in lower values of time for travel as students have more free time to spend outside their studies compared to employed people and also, they have limited money resources to spend for travelling.

The unemployment rate in 2017 was 23% according to the Employment outlook of 2017 by OECD. The representation of unemployed respondents is low in the sample. More specifically in the sample the ratio of unemployed vs employed people is 11% vs 89%. Nevertheless, this is not considered as a shortcoming of the survey as unemployed people travel long distances less than others and eligible for the survey are only people who have travelled to the islands of the Aegean Sea at least once in the last 3 years from the survey.

According to the report from 2018 "Greek Pension System Fiche" of the European Commission, Economic Policy Committee and our calculations, the share of pensioners in 2016 are 33% of the total population above 17 years of age. In the survey they only represent 3% of the responses. This is because the survey was web-based and not all retired persons have skills and tools (ie. smartphones, computers, access to the internet) to complete an internet-based questionnaire. Also, it was difficult to reach this population group as only some of them are using social media. This group of people is not represented adequately in the survey. We cannot assess the impact of this distortion in the sample as we do not have a clear view of the mobility of pensioners for long-distance trips on the island of the Aegean. A general comment is that although we find many foreign pensioners as tourists in the study area, we don't find same as many from Greece. The cost of travelling to the islands including accommodation is not always affordable for Greek pensioners. If this assumption is correct then including only a small number of pensioners from Greece is not necessarily problematic.

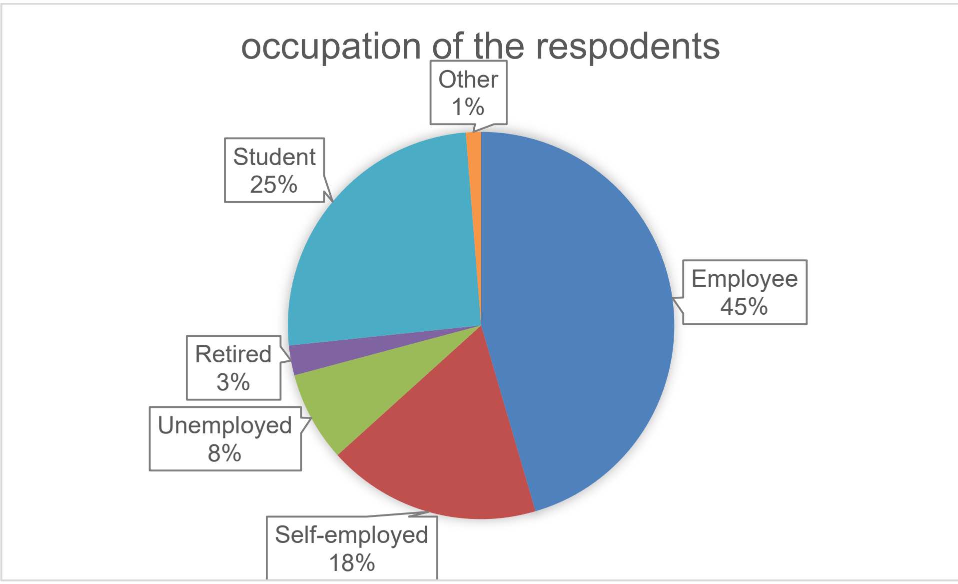


Figure C11. Sample analysis by employment status

13.2. Analysis in frequent users

The analysis of the survey sample shows that more than 50% of the respondents are travelling to or from the islands 1 or 2 times per year. But also, there is a significant number of frequent users that travel more than 2 times per year to the islands of the Aegean Sea or in the opposite direction (islanders who travel to the Greek peninsula).

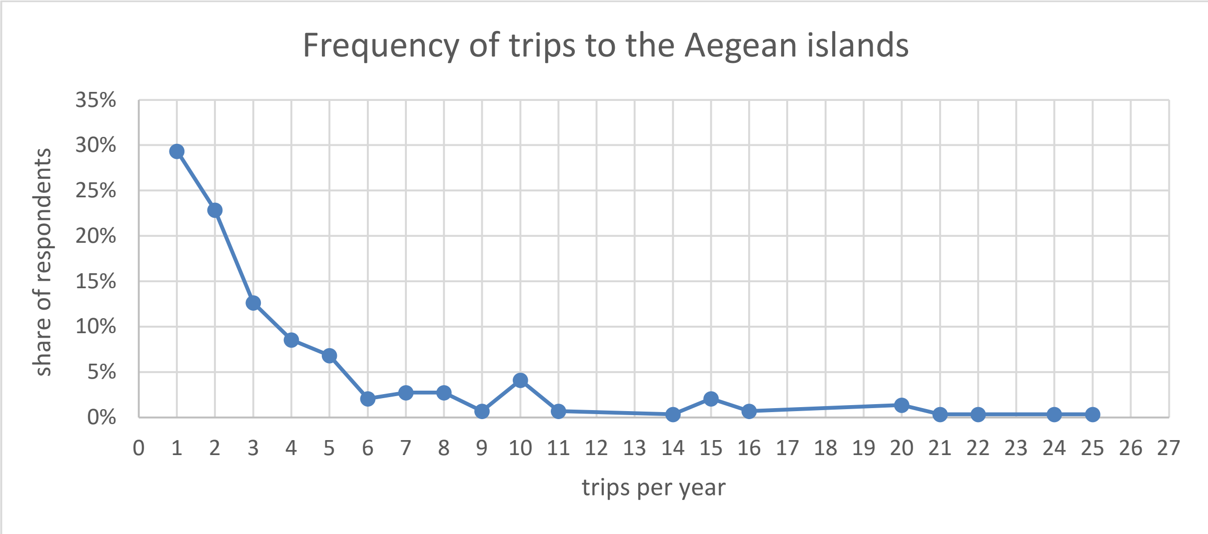


Figure C12. Sample analysis by frequent users

13.3. Analysis per trip purpose

The respondents revealed that the trip purpose of their last trip to or from the islands of the Aegean Sea was Holidays - Tourism by 43%, visiting friends or relatives by 21%, education purposes by 18% and work or business by 14%. The detailed pie for the trip purpose is presented in the following figure.

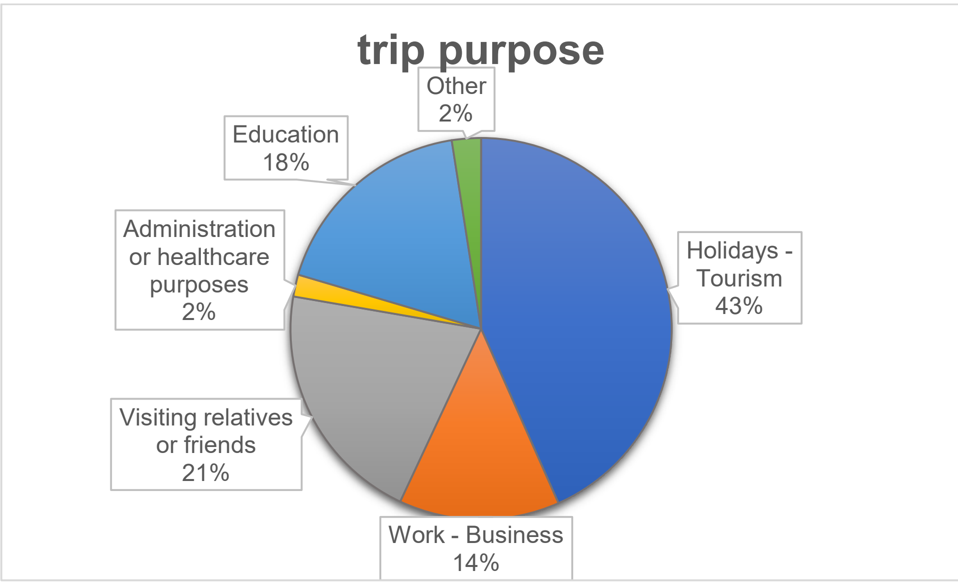


Figure C13. Analysis by trip purpose

13.4. Analysis per accommodation type

The respondents revealed that the accommodation type of their last trip to or from the islands of the Aegean Sea was hotel, rented apartment or room by 60%, while notable is the large share of travelers staying at friends' or relatives'' homes. This trend is also confirmed in the annual reports of the survey on the quality characteristics of domestic tourists in Greece. According to this report, it is observed that in the majority of the trips that took place in 2017 for personal reasons, the accommodation type was non rental referring to private cottages, accommodation provided free of charge by relatives and friends. Specifically, 65.8%[1] of the total trips were in non-rental accommodation for the domestic tourists in Greece for personal reasons. This share is constantly rising for a series of years before 2017 that is also indicative of the economic recession and austerity measures in Greece after 2010 and in order to limit the total costs of holidays.

Camping either organized or free is 3% of the total demand for accommodation in the islands. Holidays - Tourism by 43%, visiting friends or relatives by 21%, education purposes by 18% and work or business by 14%. The detailed pie for the accommodation type chosen by the respondents in their last stay in the year 2017 is presented in the following figure.

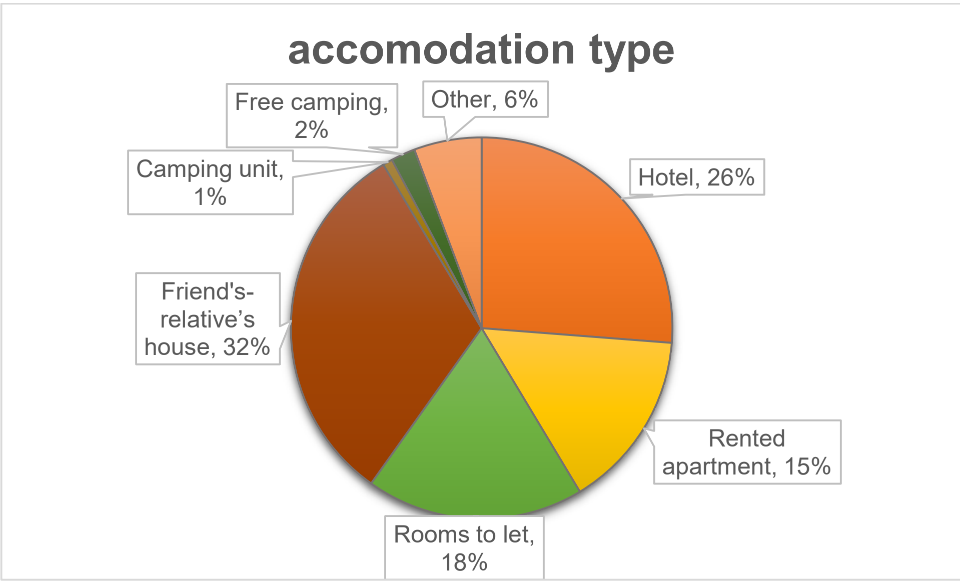


Figure C14. Analysis of accommodation type for trips to and from the Aegean Sea

[1] Source: Survey on quality characteristics of domestic tourists (holiday survey), year 2017

13.5. Analysis per mode preference

The results of the revealed preference survey as well as the ones from the stated preference indicate that the preferred travel mode in the area is by sea with a share of approx. 70%, while domestic airlines to the islands of the Aegean Sea have a share of approx. 30% in the current survey. This is consistent in general to the findings of Part B of the Thesis, nevertheless the magnitude of this trend varies significantly in the estimations from the aggregated statistical data, where the trend for domestic trips by sea vs air is even stronger than in the survey. All the abovementioned are presented in the following table.

Table C2. Mode choice domestic aviation vs sealines cross examination table from various sources

	(1)	(2)	(3)	(4)
Mode	Mode choice revealed for all trip purposes from the questionnaire survey	Mode choice stated for holidays from the questionnaire survey	Mode of travel from statistical data and own calculations for the whole year 2013	Mode of travel from statistical data and own calculations for summer peak period 2013
air (domestic)	35%	25%	20%	10%
sea	65%	75%	80%	90%

The shares in the table above from the various sources are not directly comparable. For example, not all of them refer to the same time of the year. Columns (1) and (3) refer to the whole year while columns (2) and (4) refer to the summer season. Furthermore, columns (3) and (4) include possibly interchanges, island-hopping trips, secondary destinations and other short trips in general that are made exclusively by sea that are not captured in the survey ie. in columns (1) and (2). Additionally, there are uncertainties as the exact shares of foreign tourists using domestic airlines and sealines are not known. Columns (1) and (2) are only for visitors from Greece while columns (3) and (4) are for foreigners. Finally, the stated preference model (1) as it is designed, doesn't include OD cases where there is no air alternative due to proximity to the mainland. More specifically, the destinations in the SP survey are grouped in clusters and many trips close to Attica with exclusively sea mode choice could be underrepresented. Also, the air mode choice is highly restricted by capacity issues and higher price last minute tickets in the summer season while the sea mode fares are flat and there is excess capacity that allows even last minute travelling decisions. These issues are not reflected in the SP survey either. This is not deprecating the reliability of the survey. On the contrary it is an indication of sincerity and commitment of the respondents to the questions as they are phrased.

Table C3. Detailed Mode choice domestic aviation vs sealines cross-examination table from various sources

	Detailed mode	Mode choice revealed for all trip purposes from the questionnaire survey	Mode choice stated for holidays from the questionnaire survey
	air	35%	25%
	Sea_ferry conventional	55%	45%
	Sea_high speed catamaran	10%	30%

Table C4. Mode choice revealed for all trip purposes including combined for all passenger types

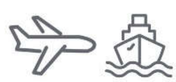
34%	air	
53%	sea	
12%	combined air + sea	

Table C5. Mode choice revealed for all trip purposes including combined for Greek inhabitants with mainland hubs excluded

18%	air	
61%	sea	
22%	combined air + sea	

The results of the analysis presented here, show the estimated shares of combined trips to the islands for up to 12% for all passenger types and 22% for Greek inhabitants. In the absence of a targeted policy for promoting intermodal transport and interoperability in this region, the significant number of combined trips as they are revealed, show that there is need and potential in the area for better cooperation between the two main modes.

In the existing literature and references, the amount and share of combined air+sea trips to the island of the Aegean Archipelago, has never been captured before.

Out of the 70 islands that are possible destinations only 23 or 33% have airports and there is a mode choice of using AIR over SEA. The percentage could become bigger if we exclude the Argosaronikos islands and the island of Thassos that have straits connections to the peninsula. Furthermore, we can include in the list of destinations serviced by air, also the small islands very close to islands with airports; for example, Oinouses and Chios, Antiparos and Paros, Rhodos and Symi/Chalki etc. When we exclude the strait connections the number of destinations is limited to 59 and if we add the smaller islands services by a bigger island with an airport then this percentage is up to 50%. Below there is a detailed list of islands of the study area with and without airports.

Table C6. List of islands of the study area with and without airports

a/a	Zone_id (model)	Zone Name	airport
1	30-33	Krete	✓
2	221	Astypalaia	✓
3	324	Chios	✓
4	343	Ikaria	✓
5	237	Kalymnos	✓
6	345	Karpathos	✓
7	176	Kasos	✓
8	348	Kastelorizo	✓
9	226	Kos	✓
10	64	Kythira	✓
11	242	Leros	✓
12	329	Lesvos	✓
13	334	Limnos	✓
14	114	Milos	✓
15	166	Mykonos	✓
16	155	Naxos	✓
17	153	Paros	✓
18	203	Rhodos	✓
19	344	Samos	✓
20	109	Santorini	✓
21	304	Skiathos	✓
22	284	Skyros	✓
23	167	Syros	✓
24	321	Inousses	via Chios
25	220	Ano Symi	via Rhodos
26	192	Chalki	via Rhodos
27	349	Gavdos	via krete
28	142	Antiparos	via Paros
29	108	Thirasia	via Santorini
30	303	Skopelos	via Skiathos

a/a	Zone_id (model)	Zone Name	airport
1	50	Samothraki	-
2	58	Antikythira	-
3	106	Anafi	-
4	112	Folegandros	-
5	113	Sikinos	-
6	116	Ios	-
7	120	Kimolos	-
8	123	Irakleia	-
9	127	Shinousa	-
10	133	Amorgos	-
11	134	Koufonisi	-
12	141	Sifnos	-
13	150	Donousa	-
14	156	Serifos	-
15	165	Kythnos	-
16	170	Tinos	-
17	171	Kea	-
18	174	Andros	-
19	204	Tilos	-
20	219	Nisyros	-
21	229	Pserimos	-
22	233	Telendos	-
23	250	Lipsi	-
24	257	Patmos	-
25	261	Agathonisi	-
26	307	Alonnisos	-
27	325	Psara	-
28	330	Agios Efstratios	-
29	350	Fournoi	-

13.6. Analysis in passenger types

From the analysis of our sample it appears that 57% are visitors from the mainland of Greece, 30% are local inhabitants of the Aegean islands and 7% are seasonal employees at the islands. Only 5% of the sample are visitors from other countries which is not representative of the tourists' demand. This is a shortcoming of the survey and it happened because it was difficult to disseminate the questionnaire to foreigners without the help of the authorities. For this reason, many of the survey results refer only to Greek residents while visitors from other counties were excluded from the analysis.

Table C7. Analysis of passenger types in the sample

Visitors from other countries	5%	5%
Visitors from Greece (mainland)	57%	57%
Locals-inhabitants of the Aegean islands travelling to another Aegean island	13%	31%
Locals-inhabitants of the Aegean islands travelling to the Greek peninsula	18%	
Seasonal employees at the Aegean islands travelling to another island of the Aegean	3%	7%
Seasonal employees at the Aegean islands travelling to the Greek peninsula	5%	
Total	100%	100%

13.7. Analysis in origin and destination

The frequencies of the origin and destination revealed preference questions, show full coverage of all the transport zone in the study area. More specifically the sample shows a reasonable distribution from the major trip generators of Attica and Thessaloniki regions which are the two most populated cities of Greece. It also shows a full coverage of the islanding transport zones as destinations. The high frequencies of Lesvos and Chios are explained by the fact that the academic community of the University of the Aegean has supported the survey by participating. This can be perceived as a minor bias of the survey but considering the non-existing sources for an organised nationwide survey and sampling for the data collection, this compromise in our survey was inevitable.

Table C8. Origin nisia (sample 312)

Island name	freq	thematic map
Lesvos (Mytilene)	22	
Chios	15	
Rhodos	11	
Samos	10	
Syros	6	
Heraklion	2	
Rethymnon	2	
Samothraki	2	
Limnos	2	
Chania	1	
Lasithi	1	
Ydra	1	
Milos	1	
Naxos	1	
Skyros	1	
Skiathos	1	

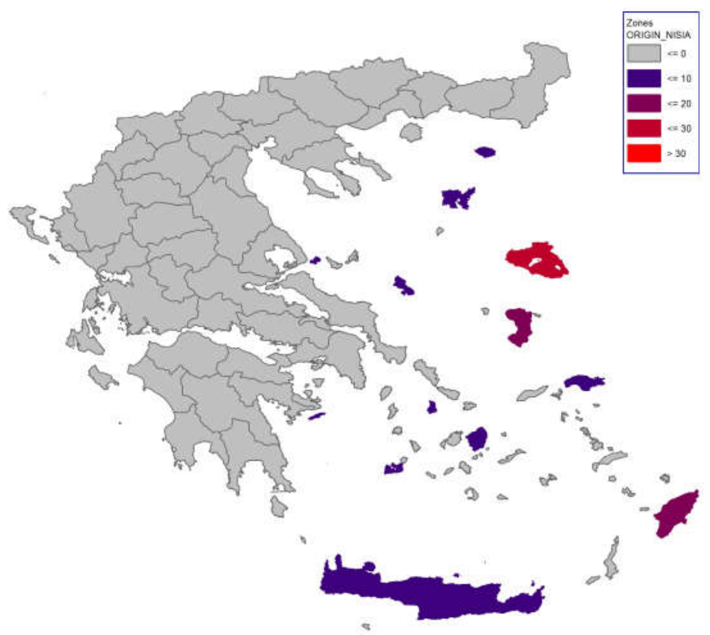


Table C9. Origin_of the sample (312) nomoi

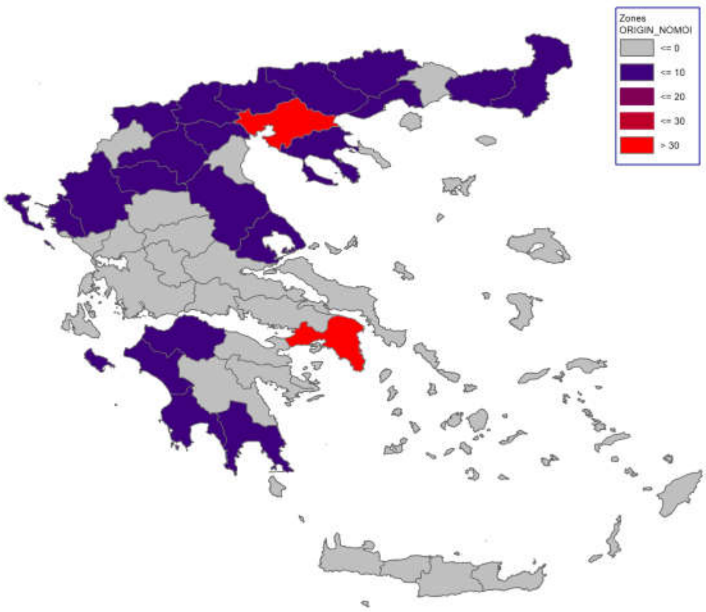
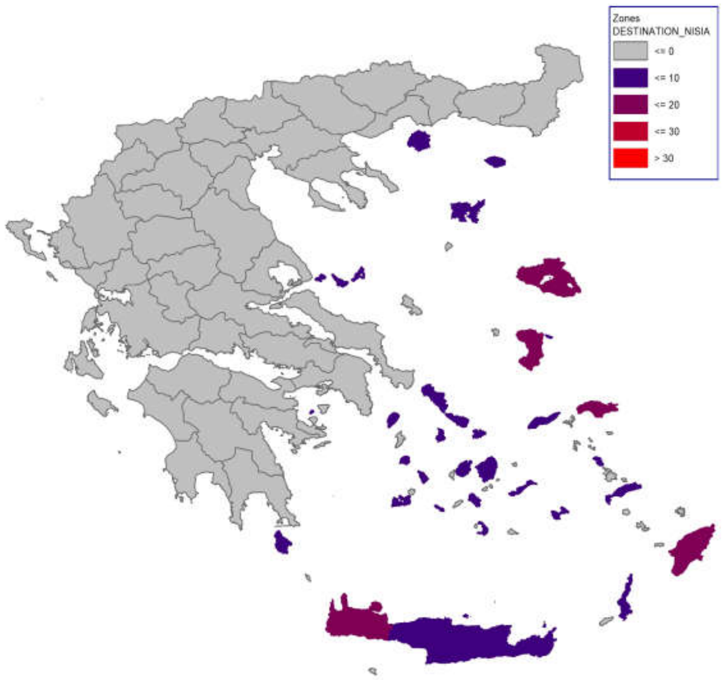
name	freq	thematic map
Attica	50	
Thessaloniki	35	
Larisa	4	
Evros	4	
Kozani	3	
Imathia	3	
Ilia	2	
Grevena	2	
Corfu	2	
Chalkidiki	2	
Pella	2	
Serrai	2	
Laconia	2	
Drama	1	
Rodopi	1	
Achaea	1	
Florina	1	
Zakynthos	1	
Ioannina	1	
Thesprotia	1	
Kilkis	1	
Messinia	1	
Kavala	1	
Magnesia	1	

Table C10. Destination nisia (sample 312) of the revealed preferences

Island name	freq	thematic map
Lesvos (Mytilene)	19	
Rhodos	15	
Chania	13	
Chios	13	
Samos	13	
Limnos	10	
Syros	7	
Thasos	6	
Santorini	6	
Heraklion	5	
Andros	5	
Samothraki	4	
Paros	4	
Naxos	4	
Mykonos	4	
Skiathos	4	
Rethymnon	2	
Kythira	2	
Milos	2	
Ios	2	
Sifnos	2	
Serifos	2	
Tinos	2	
Kea	2	
Skopelos	2	
Ikaria	2	
Lasithi	1	
Folegandros	1	
Amorgos	1	
Symi	1	
Astypalaia	1	
Kos	1	
Alonnisos	1	
Leros	1	
Inousses	1	
Karpathos	1	
Agistri	1	

13.8. Analysis of traveling companions

From the reveal preferences RP part of the survey it is concluded that the majority of the travellers are travelling with their partner or alone when all trip purposes are aggregated, while many respondents are travelling with family or relatives.

The question was placed as follows: “Who accompanied you on your trip this summer to the Aegean islands?” The results are shown in the following graph.

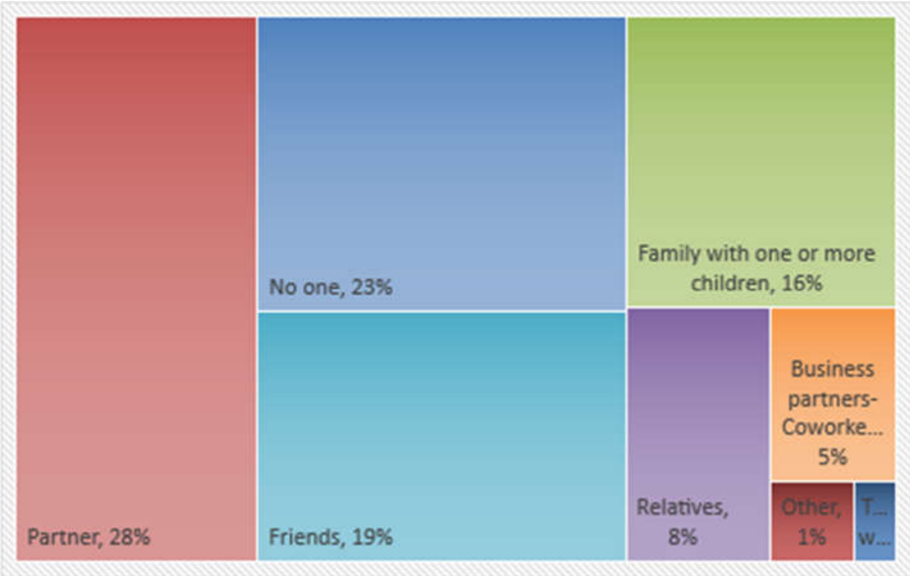


Figure C15. Treemap chart of travelling companions

For further analysis we have calculated the travelling companion per trip purpose, to find that the majority of the respondents are travelling alone when work-business, visiting relatives and education is the trip purpose.

Table C11. Heatmap of travelling companion per trip purpose

0% 100%	*Travelling companion*				
Trip purpose	No one	Partner	Family with child/ren	Relatives	Friends
Holidays - Tourism	10%	39%	27%	3%	20%
Work - Business	41%	26%	0%	0%	7%
Visiting relatives or friends	52%	23%	13%	3%	10%
Education	68%	3%	3%	9%	15%

The above table is also a piece of evidence that the majority of captured trips are from students travelling alone for education reasons as the questionnaire was circulated between the academic community of the University of the Aegean. This is a source of possible bias in the survey that has to be considered.

13.9. Conclusions of the statistical analysis of the sample

Due to lack of resources, there has not been a specific sampling method of interviews collection and sampling via a nationwide mobilization. Nevertheless, the above explained results show diversity with varying respondents' age, income, trip origin and destination. Therefore, the sample is gathered as heterogeneous. An overrepresentation in the sample of students is observed that it is possible to lower the estimated travel VOT.

The average annual income as revealed by the respondents (foreign citizens excluded) is €14,487 for the reference year 2017. The Hellenic Statistical Authority reports for the year 2017 Net national income at market prices per capita €14,033 (source: https://www.statistics.gr/en/statistics/-/publication/SEL33/). Therefore, the sample represents sufficiently the average income of the entire country.

By using the common assumption of 2000 work hours per year (Haab and McConnell, 2002; Hynes et al., 2009), we calculate respondents' average gross hourly wage rate as being about 7,2€/hour in the year 2017 of the survey. This corresponds to a monthly gross income of about €1200. Using the 3/4 of the wage rate in our case would mean a rough estimated VTT of 5,4€/hour.

According to Fezzi, Bateman, Ferrini 2012 (Using revealed preferences to estimate the Value of Travel Time to recreation sites), the opportunity Value of Travel Time (VTT) is one of the most important elements of the total cost of recreation day-trips and arguably the most difficult to estimate. Their results indicate that 3/4 of the wage rate provides a reasonable approximation of the average VTT for recreation trips by car.

14. ELEMENTS OF RP AND SP SURVEY

14.1. Elements of revealed preference survey

The survey revealed a good diversity of destinations and has covered almost all islands even small ones providing information on mode choice, travelling times and costs for all trip purposes. Processing the records of the revealed preference survey and considering the sample size limitations, it was only possible to estimate a fare model that was time-based for each transport mode.

The main elements on the RP survey that are relevant to this exercise are presented below.

- Question on destination

Referring to your trip to the Aegean Sea islands this summer (2017), which island was your primary destination?

- What was the main purpose of your trip?

1. Holidays - Tourism
2. Work - Business
3. Visiting relatives or friends
4. Administration or healthcare purposes
5. Education
6. Other...

- Question on the chosen mode

Which travel mode did you choose for your trip to the primary islandic destination?

7. Air
8. Sea
9. Combination of air and sea transport

- Question on sea travel cost

Cost of sealine ticket (individual ticket, one-way, without car). Please type the price in Euros.

- Question on sea travel time

In-vessel time in hours.

- Question on air travel cost

Cost of airline ticket (individual ticket, one way). Please type the price in Euros.

14.1.1. Fare model based on the RP survey

The fare model was estimated with the use of SPSS software for statistical analysis. The findings of the fare model based on the RP survey are analysed and presented below.

14.1.1.1 Travelling by sea fare model

For the sea modes, flat fares per season and booking class are applied. From the processing of the survey data, it is concluded that sea fares are highly correlated to the travelling distance or else to the travelling time and mode speed. The components of travel time for a direct trip to the islands are discussed below. These travel times are varying a lot and they are estimated with the help of the transport model for each passenger trip.

Table C12. Time categories for direct maritime trips and time estimations

DEPARTURE	**Terminal access time**	5-10min insignificant	Terminal access time (walking or driving)
SAIL	**Maritime side**	Calculated per destination and sea mode in the model	In-vessel time, including boarding time and time to connect between sealines at an intermediate port,
			unexpected departure delay
ARRIVAL	**Terminal egress time**	insignificant	time to exit the port terminal
	Estimated total	Varying, estimated from the model per islandic destination	

In the tables below indicative cost per travel time by sea modes and per trip purpose are presented.

Table C13. Cost of sea modes from the RP survey

All trip purposes	Domestic travellers only		
Row Labels		**Average of SEA_cost/time in €/h**	**Sample size**
1	Conventional ferry	5.74	159
2	High-speed catamaran	9.33	25
3	Flying dolphin	28.13	4
Grand Total		**Average 6.75**	**Total 178**

Table C14. Cost of selected sea mode per purpose from the RP survey

All sea modes	Domestic travellers only		
Row Labels		**Average of SEA_cost/time in €/h**	**Sample size**
1	Holidays - Tourism	8.78	84
2	Work - Business	6.94	16
3	Visiting relatives or friends	5.77	38
4	Administration or healthcare purposes	5.77	2
5	Education	2.63	33
6	Other	7.10	5
Grand Total		**Average 6.75**	**Total 178**

From information derived by the statistical analysis for the sea modes as presented in the above tables and combining it with tariff information from the sealine operators, the following fare travel time-based model is concluded for the maritime passenger transport services in the area

Table C15. Conventional Ferry fare model

Conventional ferry in-vessel-time in hours	interpolate	Fare in €
1.5	X	15.83
2.5	X	20.57
4.5	X	27.82
6	X	32.57
10	X	35.10
>10		36.00

Table C16. High speed ferry fare model

High-speed ferry in-vessel-time in hours	interpolate	Fare in €
2	X	36.80
4.5	X	45.42
6	X	45.57
>6		46.00

14.1.1.2 Traveling by air fare model

Fares of air flights are far more complicated to describe and model than the ones of sea routes. Details and analysis of the travel times by air for domestic connections are presented in Annex C. In the tables below fare costs by air mode per passenger type and per trip purpose are summarised.

Table C17. Cost of air mode per purpose from the RP survey

Domestic passengers and flights only			
Row Labels	**Trip purpose**	**Average cost of an AIR ticket in €**	**Sample size**
1	Holidays - Tourism	79	31
2	Work - Business	87	20
3	Visiting relatives or friends	81	28
4	Administration or healthcare purposes	88	3
5	Education	63	32
6	Other	90	1
Grand Total		**77**	**115**

Similar to the sea modes, a statistical analysis of the fare model estimations and visual representation with the help of SPSS is made for domestic airlines. The distribution of the fares for the domestic flights to the islands is close to the normal distribution. Again, the smaller the confidence interval CI, the more precise the estimated effect. In our data set, 95% of the respondents revealed a fare cost for travelling by air between 70 and 90€ or if the travel time for domestic flights air is assumed as 3h flat (see Annex C) then, 23 and 30€/h. Values on the right reflect more expensive bookings for example business class. Overall, the standard error is small.

These are positive indications of the dataset reliability. The results of the statistical analysis confirm that using the RP data to estimate an approximate fare for air flights in the transport model is a good approach for the needs of this analysis. Considering how complicated and difficult is to model pricing policies that air operators apply, a more detailed approach would be out of scope for the current research.

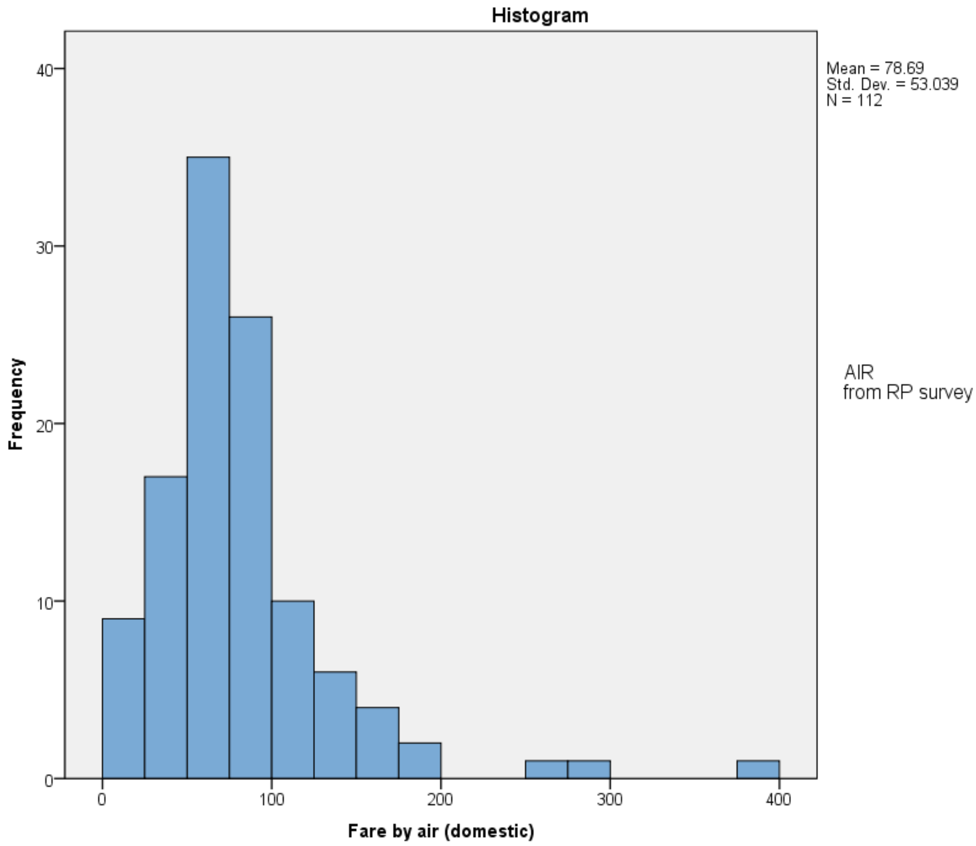


Figure C16. Histogram of aviation fares for domestic trips from the RP survey

From information derived by the statistical analysis for the air routes and their cost, as presented in the above tables and combining it with tariff information from the airline operators, the following fare is proposed for air passenger services in the area.

Domestic aviation: a fare of 80€ is assumed for trips up to 1 hour and a fare of 100€ for longer trips considering that no domestic flight in the area is longer than 70minutes. All fares refer to one-way trips to the islands.

International aviation: a time-based fare model is assumed starting at 80€ for the first hour and increasing by 30€ for every additional flight hour for up to 11 hours of flight as explained in the table below. Again, these fares apply to one-way flight trips.

Table C18. High-speed ferry fare model

Flight duration in hours	interpolate	Fare in €
1		80
2-10	X	110-350
>10		380

If there is are two flight parts for example a long-haul one from the abroad to Athens and a connecting domestic flight part from Athens to the islands, then the cost of the trip is the summary of the international and the domestic flight fare.

14.2. Elements of stated preference survey

14.2.1. Mode choice exercise

This part is a discrete choice exercise that is combining trip destination and mode choice conjoint questions. The Aegean islands are divided into groups. The responders are answering the following question: *"Assume you plan your vacation in the Aegean islands for next summer. Choose among the following list of destinations."*

1. Eastern Aegean Islands 1: Agios Efstratios, Lesvos, Limnos, Oinousses, Samothrace, Chios, Psara
2. Eastern Aegean Islands 2: Ikaria, Fournoi, Samos
3. Dodecanese 1: Kalymnos, Kos, Lipsi, Leros, Nisyros, Patmos, Agathonisi
4. Dodecanese 2: Karpathos, Kasos, Kastelorizo , Rhodes, Symi, Tilos, Chalki
5. Crete and Gavdos
6. Kythira and Antikythira
7. Cyclades1: Kythnos, Serifos, Sifnos, Kimolos, Milos, Kea
8. Cyclades 2 and Astypalea: Santorini, Amorgos, Anafi, Astypalea, Folegandros, Donousa, Irakleia, Ios, Koufonisi, Schinoussa, Sikinos

9. Cyclades 3: Andros, Mykonos, Syros, Tinos, Paros, Antiparos, Naxos
10. Sporades: Alonissos, Skiathos, Skopelos, Skyros

As a conjoint question we have designed a set of three combinations per selected cluster-potential destination for holidays next summer. The responders are answering the following question: "*You have chosen … eg. Eastern Aegean Islands 1: Agios Efstratios, Lesvos, Limnos, Oinousses, Samothrace, Chios, Psara as a potential destination for the next summer. Please choose one of the following combinations of mode, travel time and ticket cost for this trip."* The exercise is a combination of Mode, (Conventional Ferry, Highspeed Ferry, Airplane) Travel time and ticket cost. In the following we present an example of the abovementioned discrete choice fixed exercise:

You have chosen Dodecanese 1: Kalymnos, Kos, Lipsi, Leros, Nisyros, Patmos, Agathonisi. Please choose one of the following combinations of mode, travel time and ticket cost for this trip

	Combination 1	*Combination 2*	*Combination 3*
Mode	Sea ferry	Sea-Highspeed	Airplane
Travel time	14h	12h	1h
Ticket cost	50€	60€	110€

The initial design was to use this part of the survey for mode choice for processing in Biogeme with maximum likelihood estimation procedures. Despite the exhaustive testing of various utility functions, all the estimated models had a poor Rho-square fit. This can be explained due to the scattering deficiency of the ride time by airplane and the small sample size,

The next best approach was to use the elements of SP survey on mode choice, for estimating impedance functions and selecting a mathematical choice equation that better fit the SP mode exercise survey result. Based on this, the following Impedance functions for each mode were assumed:

$$R_{SEA} = \left(wage\_h_i \times {}^{3}/_{4}\right) \times Time_{SEA} + Cost_{SEA}$$

$$R_{CAT} = \left(wage\_h_i \times {}^{3}/_{4}\right) \times Time_{CAT} + Cost_{CAT} + 11$$

$$R_{AIR} = \left(wage\_h_i \times {}^{3}/_{4}\right) \times Time_{AIR} + Cost_{AIR}$$

Where

R_{SEA}	is the impedance function for the conventional ferry mode
R_{CAT}	is the impedance function for the catamaran and similar high-speed ships
R_{AIR}	is the impedance function for the catamaran and similar high-speed ships
$wage\_h_i$	is the estimated wage per hour per respondent using the stated gross year income from the survey
$Time_{SEA}$	is the fixed travel ride time* with conventional ferry in hours from the SP survey which is distinct in each one of the 10 categories of destinations and referring to the selected islandic destination for each respondent
$Time_{CAT}$	is the fixed travel ride time* with a catamaran or similar high-speed ship in hours from the SP survey which is distinct in each one of the 10 categories of destinations and referring to the selected islandic destination for each respondent
$Time_{AIR}$	is the fixed travel ride time* with a domestic airplane connection in hours from the SP survey which is distinct in each one of the 10 categories of destinations and referring to the selected islandic destination for each respondent
$Cost_{SEA}$	is the fixed ticket cost with conventional ferry in Euros from the SP survey which is distinct in each one of the 10 categories of destinations and referring to the selected islandic destination for each respondent
$Cost_{CAT}$	is the fixed ticket cost with catamaran or similar high-speed ship in Euros from the SP survey which is distinct in each one of the 10 categories of destinations and referring to the selected islandic destination for each respondent
$Cost_{AIR}$	is the fixed ticket cost with a domestic airplane connection in Euros from the SP survey which is distinct in each one of the 10 categories of destinations and refers to the selected islandic destination for each respondent

*Ride time (RIT) is the time between the departure from the origin port or airport stop point and the arrival at the destination port or airport stop point.

The selected impedance functions are expressed as cost functions in Euros as units. The factor ¾ was used from the reference studies that they estimate a value of time for travelling for recreation purposes in ¾ of the wage analogous to the time consumption. Using the 3/4 of the wage rate for Greece would mean a rough estimated value of 5,4€/hour as explained in a previous subchapter).

A variety of mode choice models have been tested for their fit to the SP survey results as an impedance function in Visum.

Table C19. Mode choice models

	Kirchhoff	Logit	BoxCox	Lohse
Utility function	$U = R^{-\beta}$	$U = e^{-\beta R}$	$U = e^{-\beta \frac{R^{\tau}-1}{\tau}}$	$U = e^{-\left(\beta\left(\frac{R}{R_{min}}-1\right)\right)^2}$
R	R = impedance of a connection	R = impedance of a connection	R = impedance of a connection	R = impedance of a connection R_{min} = minimum impedance of all connections per OD pair
Calibrated values of factors	β=1.0	β=0.01	β=0.1 T=0.5	β=0.5

In the following table, the results of the various mode choice models based on impedance functions are presented. These results were calculated with the method of simulations and validation against the SP disaggregated data from the survey. The best fitting model is the Kirchhoff while the second-best fitting model is Box-Cox.

Table C20. Validation for the various mode choice models

alternatives	SP survey	Kirchhoff		Logit		Box-Cox		Lohse	
		model	diff	model	diff	model	diff	model	diff
SEA	41.9%	42.0%	-0.1%	40.6%	1.3%	41.3%	0.7%	38.8%	3.1%
CAT	31.5%	31.6%	-0.1%	32.4%	-0.9%	32.1%	-0.5%	33.7%	-2.2%
AIR	26.6%	26.4%	0.2%	26.9%	-0.4%	26.7%	-0.1%	27.4%	-0.9%
Sum abs diff			0.4%		2.6%		1.3%		6.2%

14.3. Conclusions of the use of the RP and SP survey elements

The RP and SP survey elements for mode choice were initially processed with Biogeme with maximum likelihood estimation procedures. Due to the scattering deficiency of the ride time by airplane and the small sample size, none of the estimated econometric models in Biogeme had a good fit. Still these elements contained useful information for our analysis.

The RP elements of travel choice were used to estimate a fare model that would address the issue of trip costs per passenger and can be later integrated into the impedance function for mode choice as well as for path choice.

The SP elements of travel choice were used to calibrate an impedance function and to select the best fitting mathematical equation for mode choice with the method of simulations. This is only useful as an approach to the mode choice problem with its inherent uncertainties in the study area. As also mentioned previously, it is observed that each island is a special market when it comes to travel mode choices. For example, although Paros and Mykonos lie at approximately the same direct distance from Athens, the domestic air mode share of Mykonos is three times higher than the one of Paros in the reference year 2017 (year total from INSETE source).

Table C21. Paros and Mykonos example for mode shares for the whole year 2017

Destination	Direct Distance from Athens in km	Air (domestic)	Sea
Mykonos	161	25%	75%
Paros	171	8%	92%

There are reference studies (e.g. Polydoropoulou and Litinas, 2007) that address the mode choice issue on the level of a single island (e.g. Chios), with a limited number of interviews. However, there is no reference study to propose a mode choice model for all the islands of the Aegean Archipelagos with a universal mathematical equation.

In the lack of a big sample size that would allow more accurate estimations and conclusions on the mode choice issue, the current approach can be considered as an initial discussion point that could be further investigated with more studies.

15. RANKING EXERCISE

15.1. Introduction and concept

Ranking questions calculate the average ranking for each answer-choice so you can determine which choice was most preferred overall. The answer-choice with the largest average ranking is the most preferre one. We apply weights to ensure that when the data is presented on a chart, it's clear which answer choice is most preferred. Weights are applied in reverse. In other words, the respondent's most preferred choice (which they rank as #1) has the largest weight, and their least preferred choice (which they rank in the last position) has a weight of 1[2]. In this case the Ranking questions have 9 answer choices and therefore, weights are assigned as follows:

- The #1 choice has a weight of 9
- The #2 choice has a weight of 8
- The #3 choice has a weight of 7
- The #4 choice has a weight of 6
- The #5 choice has a weight of 5
- The #6 choice has a weight of 4
- The #7 choice has a weight of 3
- The #8 choice has a weight of 2
- The #9 choice has a weight of 1

The average ranking is calculated as follows, [3]

$$Score_{\#i} = \sum_{i=1}^{n} x_i w_i$$

or equal to $x_1w_1 + x_2w_2 + x_3w_3 \dots x_nw_n$

where:

[2] https://help.surveymonkey.com/articles/en_US/kb/How-do-I-create-a-Ranking-type-question
[3] https://en.wikipedia.org/wiki/Weighted_sum_model

w = weight of ranked position

x = response frequency of choice

The charts presented in the following figures are the result of the weighted average for each answer choice in combination with the following ranking :

#1	#2	#3	#4	#5	#6	#7	#8	#9
Extremely Important	Very Important	Important	Somewhat Important	Neutrally Important	Slightly Indifferent	Not Important	Not Important at all	Totally Indifferent

15.2. Ranking of Sea Mode choice

For the ranking of the importance of the decision parameters for sea as mode choice, the question was set like this:

"How would you rate the importance of the following aspects of travelling by sea in the mode choice decision of your specific trip to the Aegean island? Please, select an answer for each item."

The total number of respondents to this question was 156.

Table C22. Ranking of Sea Mode choice

Question for ranking	score	#1	#2	#3	#4	#5	#6	#7	#8	#9
1 Destination is close	6.11	15%	18%	21%	11%	15%	6%	3%	2%	10%
2 No airport at the main destination island	5.13	16%	9%	12%	13%	13%	6%	5%	6%	20%
3 I want to travel with my car	5.97	25%	13%	18%	9%	7%	4%	3%	4%	16%
4 There were no air tickets available	4.56	10%	10%	12%	11%	10%	4%	7%	6%	29%
5 It is cheaper than airplane	6.72	32%	16%	17%	11%	9%	2%	3%	1%	9%
6 I enjoy travelling by sea for holidays	5.92	17%	15%	15%	8%	22%	3%	8%	3%	8%

From the table above, it is concluded that some questions are positively assessed while others are not considered important. The three most important parameters for their decision are: "It is cheaper than airplane", "Destination is close", "I want to travel with my car". The two parameters that have been ranked as less important are "No air ticket available", and "No airport at the main destination island". In the following figure, the ranking scores are presented in a graph.

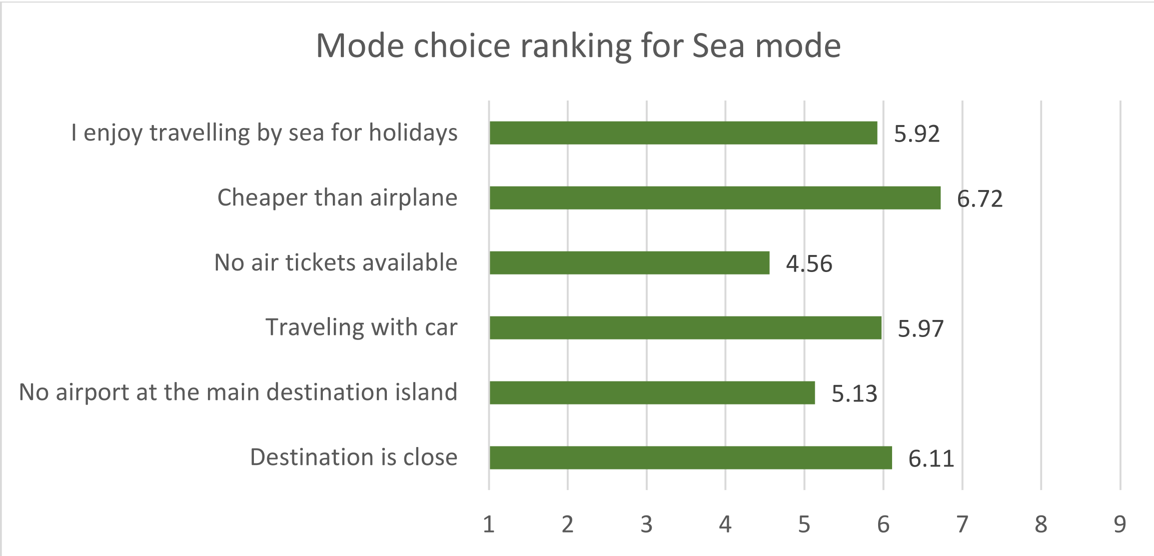


Figure C17. Ranking of Sea Mode choice decision parameters

15.3. Ranking of Air Mode choice

For the ranking of the importance of the decision parameters for air as the preferred mode, the question was set like this:

"How would you rate the importance of the following aspects of travelling by airplane when making the decision about mode choice of your specific trip to the Aegean islands? Please, select an answer for each item."

The total number of respondents to this question was 112.

Table C23. Ranking of Air Mode choice

	Question for ranking	score	#1	#2	#3	#4	#5	#6	#7	#8	#9
1	Destination is distant	7.62	47%	21%	17%	3%	2%	4%	2%	0%	4%
2	Limited holiday time-no time to spend on the ship	7.39	40%	27%	12%	5%	5%	3%	2%	1%	5%
3	To reserve time for staying at the destination	7.63	42%	26%	14%	9%	2%	3%	0%	0%	4%

From the table above, it is concluded that all questions are very positively assessed. All three parameters for their decision have an equally high score and they are: “To reserve time for staying at the destination”, “Limited holiday time-no time to spend on ship” and “Destination is distant”. In the following figure, the ranking scores are presented in a graph.

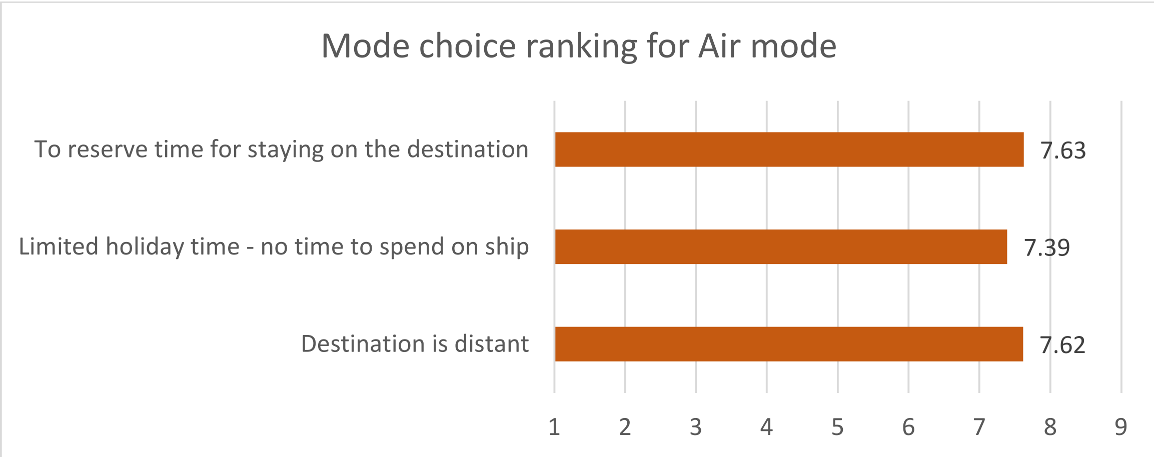


Figure C18. Ranking of Air Mode choice decision parameters

15.4. Ranking of Destination Choice

For the ranking of the importance of the decision parameters for choosing destination for holidays, the question was formulated like this:

“How would you rate the importance of the following aspects of a destination when making a decision about the choice of your next holidays to the Aegean islands? Please, select an answer for each item.”

Table C24. Ranking of the importance of attractions at the destination island

	Question for ranking	score	#1	#2	#3	#4	#5	#6	#7	#8	#9
1	Nice beaches	7.97	37%	38%	16%	4%	2%	1%	1%	0%	1%
2	Sport Activities, trekking, scuba diving, etc.	5.52	8%	7%	10%	17%	24%	8%	11%	6%	9%
3	Landscapes, architecture and nature	7.61	27%	30%	27%	11%	4%	1%	1%	0%	1%
4	Hospitality and quality service	7.87	37%	30%	19%	6%	5%	2%	1%	0%	0%
5	Quality of accommodation (hotel, camping)	7.61	33%	28%	20%	8%	5%	2%	2%	0%	2%

	Question for ranking	score	#1	#2	#3	#4	#5	#6	#7	#8	#9
6	Vivid nightlife (bars, clubs etc.)	5.52	6%	7%	14%	21%	19%	10%	7%	7%	9%
7	Cultural sites & events (museums, festivals)	6.72	12%	17%	21%	25%	14%	5%	3%	1%	2%
8	Nice food (restaurants, pastry shops etc.)	7.53	27%	27%	25%	10%	7%	2%	1%	1%	1%
9	Silence, tranquility, relaxing opportunities	7.53	35%	22%	23%	7%	6%	3%	1%	0%	3%
10	Affordable prices	8.20	53%	28%	12%	3%	3%	0%	0%	0%	2%
11	Good for family holidays	6.29	18%	17%	11%	12%	19%	4%	3%	5%	11%
12	Local products and shopping	6.52	13%	12%	22%	21%	15%	8%	4%	1%	4%

From the table above, it is concluded that all questions are positively assessed. The three most important parameters for their decision are: "Affordable prices", "Nice beaches" and "Hospitality and quality service". On the other hand, "Sport activities such as trekking, scuba diving etc." and "Vivid night life" are ranked as neutrally important parameters of their decision. In the following figure, the ranking scores are presented in a graph.

The total number of respondents to this question was 332.

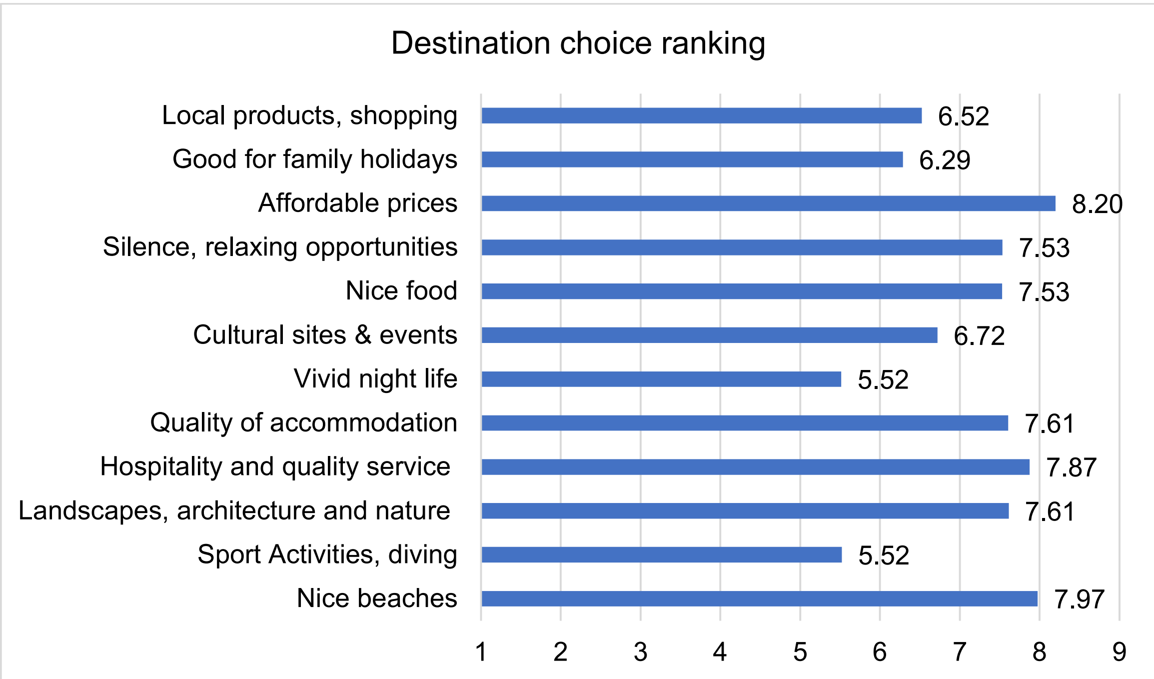


Figure C19. Destination attractions choice ranking

15.5. Conclusions of the ranking exercise

As a result of the ranking exercise, the most important parameters of sea ferry as the chosen mode for holidays, are its reduced cost compared to the airplane, the proximity of the island from the mainland to specific destinations and the wish to travel by the private car. Less important is the lack in the availability of last-minute air tickets and the lack of an airport on the destination island.

For choosing airplane as transport mode for holidays, the respondents find it equally important for their decision, when the destination is distant, when they have limited holiday time meaning that they do not want to spend a lot of hours to reach their holiday destination but they prefer instead to reserve time for staying in the island.

In the decision regarding the destination, the most important parameters are the affordable prices, whether the island has nice beaches, the hospitality of the locals and the quality of the service. As less important parameters were ranked sport activities and facilities and vivid nightlife.

16. TESTING OF NEW CONNECTIONS VIA ISLANDIC HUBS

To improve the transport system of the study area as described in the relevant maps, new connections were tested through a stated preference survey conducted in 2017 to assess the acceptance of using intermediate stops in islands rather than the mainland major ports. As an example, two such connections were tested and more specifically the connection of Chios-Mykonos via Andros port and Chios-Samothraki via Limnos port. The first connection is an alternative to the mainland ports of Attica and the second one is an alternative to the major ports of Northern Greece, while the ports of Andros and Limnos are their islandic alternatives as minor hubs for trip with interchanges.

This concept is connected with the first part of the thesis with the transport modelling of the existing transport system in the Aegean Archipelagos, where we have identified two important missing links of the study area among others. These links were:

1. Andros (Gavrio)-Chios
2. Limnos –Samothraki

16.1. Public transport practices for network design

According to the literature (Dodson et al. 2011, Nielsen et al. 2005, Vuchic 2005, Mees 2010), public transport operates in the most successful way, when the network is designed in a unified manner for multi-destination travel rather than to support a series of individual routes of specified OD pair sets. Public transport systems as seamlessly integrated networks, is a planning task that in some cases contradicts 'legacy' routes in well-established transport operation services and markets that have been developed empirically over the years. On the other hand, there are changes over the years in the performance objectives of a transport system and changes in the travel patterns that the traditional route structures may not address properly nor in a modern way. To some extent, these arguments and discussion points are relevant to the transport system of the Aegean Archipelagos which is a public transport system of long-distance trips. Some network structure configurations commonly used in public transport are summarised below and presented schematically in the following figures.

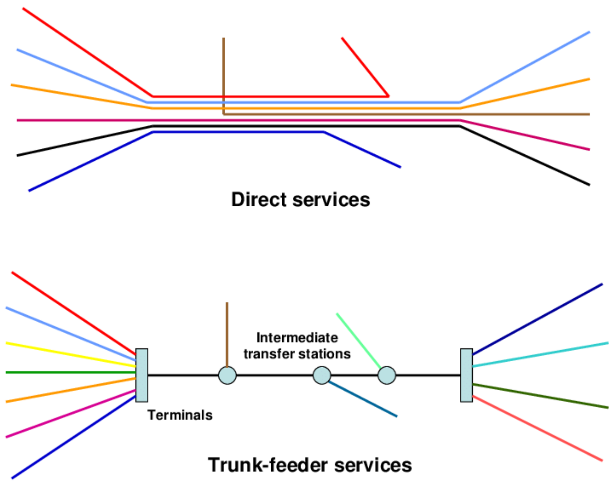


Figure C20. Direct and Feeder-Trunk-Distributor Services illustrative comparison[4]

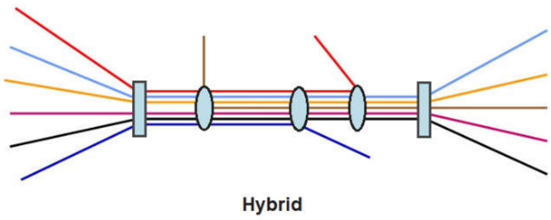


Figure C21. Hybrid Services (mix of direct and trunk-feeder services)

The direct services network alignments connect specific origin destination pairs in a relatively direct way although intermediate stops may apply but not in a planned way to complement with other routes but rather as end stops for some passengers. The feeder-trunk configuration is aggregating in the main line many feeders. It provides interchange opportunities to connect more origins and destinations and it increases the connection frequencies; but it requires a significant number of transfers at the intermediate stops even for passengers traveling on the major OD pairs.

In most of the public transport networks a hybrid combination of the direct services and the truck feed services apply. This is a very common practice in metro networks. The hybrid approach on public transport networks and services connects more OD pairs and, in this way, it extends the existing network to cover in an acceptable level more destinations with limited transfers. This approach is proposed for the policy testing exercise for the minor insular hubs.

[4] source: Bus Rapid Transit Planning Guide, Institute for Transport and Development Policy 2007

16.2. Testing an Intermediate Stop at Andros

16.2.1. Introduction and concept

In reference to Part A of the thesis, this potential new service is introducing a connection between cluster 1 and cluster 8, reducing isolation and bringing cohesion not only between the specific OD pair but between all possible pairs between the connected clusters. Furthermore, it restores the proximity between these two areas that they are very close in geographical terms but very far away in accessibility terms with the existing transport system of the base year 2013. The cost of the proposed connection is inconsiderable as it is based on an intermediate stop on the way to the major destinations that do not increase significantly the main travel times and its success is based on the time schedule coordination between the main lines of the Northern Aegean islands (region EL41 Voreio Aigaio) from Piraeus and the lines of Nothern Cyclades (region EL422 Kyklades) with Piraeus and Rafina (region EL30 Attiki).

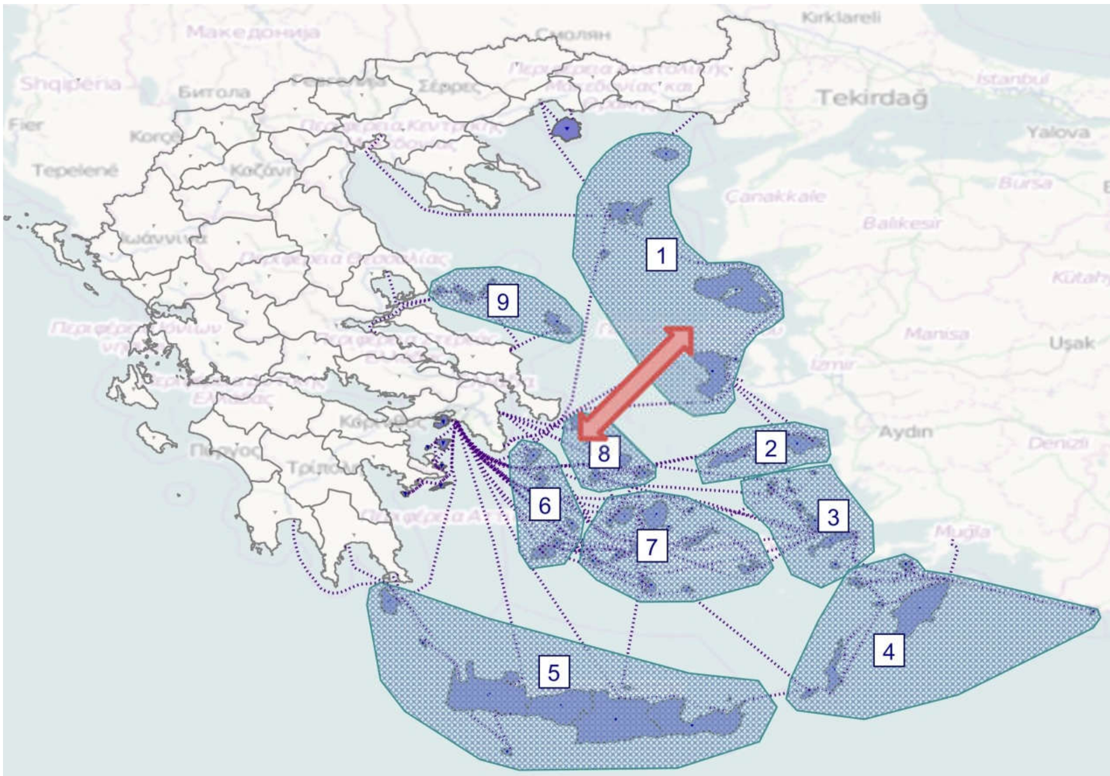


Figure C22. New connection between clusters 1 and 8

More specifically the clusters 1 and 8 include the island of Agios Efstratios, Chios, Lesvos, Limnos, Psara, Samothraki and Andros, Mykonos, Syros, Tinos respectively as follows:

Table C25. List of connected clusters and their islands

Cluster 1	Cluster 8
Agios Efstratios	Andros
Chios	Mykonos
Lesvos	Syros
Limnos	Tinos
Psara	
Samothraki	

This potential new service is introducing a connection between cluster 1 and cluster 8, reduces isolation and achieves cohesion not only for the specific origin-destination pair of Chios-Mykonos via Andros but between all possible pairs among the connected clusters. Furthermore, it restores the proximity between these two areas that despite being in close proximity geographically are very distant in terms of accessibility under the existing transport system of the reference year. The cost of the proposed connection is negligible as it is structured upon an intermediate stop on the way to the major destinations. Likewise, it does not increase significantly the main travel times and its success depends on the appropriate time schedule coordination between the main lines of the Northern Aegean islands from Piraeus in Attica and the lines of Northern Cyclades with Piraeus and Rafina port also in Attica.

More specifically the clusters 1 and 8 include the island of Agios Efstratios, Chios, Lesvos, Limnos, Psara, Samothraki and Andros, Mykonos, Syros, Tinos, respectively.

16.2.2. Existing Connections Between Chios and Mykonos via mainland

In the following figure we present the map visualization of the existing route via interchange at the Piraeus port. The existing timetable connection can be considered as theoretical given that firstly, the connecting times are not feasible at the Piraeus port and secondly, the two different operators involved do not guarantee interchange possibility and itinerary time-schedule reliability as is allowed for airline interchanges between operators belonging to the same alliance.

Figure C23. Existing route via interchange at the Piraeus port of Attica

This service is offered 3 times per week during the summer of the reference year, on Tuesdays, Thursdays and Saturdays as in the following table. The source of this table is own analysis based on minimum path search in Visum model and input data from the operators' webpages for the detailed itineraries.

Table C26. Route connecting timetable between Chios and Mykonos via Piraeus

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In vessel time	Total time	Distance
1	Chios		Chios port	Piraeus port	SEA	HELLENIC 3 Hellenic to Piraeus < 1	Tue 23:10	Wed 06:25		7h 15min	7h 15min	288km
2			Piraeus port			Transfer			35min		0h 35min	0km
3		Mykonos		Mykonos Port	SEA	SEA JETS 4 Sea Jets 4 from Piraeus > 1	Wed 07:00	Wed 10:05		3h 5min	3h 5min	178km
summary	Chios	Mykonos	Chios port	Mykonos Port			Tue 23:10	Wed 10:05	35min	*10h 20min*	*10h 55min*	*466km*

An alternative route exists with two interchange points, one at Piraeus port and the other at Rafina port, Attica region. This route is more complicated and it requires a road trip part between Piraeus port and Rafina port. The route is presented here.

Figure C24. Existing alternative route via interchange at Piraeus and at Rafina ports of Attica

This route includes a road part which makes the trip completion even more complicated and for this reason we have not considered it as a realistic alternative in the exiting situation. Still for reasons of assessment of the existing situation we have presented it here. This service is offered once per week during the summer of 2015 which is the reference year, on Sundays.

Table C27. Route connecting timetable between Chios and Mykonos via Rafina port

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In vessel/ vehicle time	Total time	Distance
1	Chios		Chios port	Piraeus port	SEA	BLUE STAR FERRIES 5 Blue Star 5 to Piraeus	Sun 11:55	Sun 19:55		8h	8h	288km
2			Piraeus port			Transfer			0h		0h	0m
3				Rafina port	P+R	Road part PuT Aux P+R	Sun 19:55	Sun 20:45		50min	50min	48km
4			Rafina port			Transfer	Sun 20:45	Sun 22:45	2h		2h	0km
5		Mykonos		Mykonos Port	SEA	FAST FERRIES 2 Fast Ferries 2B from Rafina	Sun 22:45	Mon 02:30		3h 45min	3h 45min	133km
sum mary	Chios	Mykonos	Chios port	Mykonos Port			Sun 11:55	Mon 02:30	2h	*12h 35min*	*14h 35min*	*469km*

16.2.3. New Connection Between Chios and Mykonos via Andros

In the next figure we present a visualization of a potential new route connecting clusters 1 and 8 via an interchange at Andros. The route is formed by existing routes and it only requires a modification with an intermediate stop at Andros port.

Figure C25. Potential new route via interchange at Andros

This route allows everyday connection of clusters 1 and 8 without introducing new service lines. There is 1 connection per day between Chios and Piraeus and there are at least 3 connections per day between Andros and Mykonos, with lines either starting from Piraeus or Rafina. The theoretical new connection is described in the table below.

Table C28. Route connecting theoretical timetable between Chios and Mykonos via Andros port

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In-vessel time	Total time	Distance
1	Chios		Chios port	Andros Port Gavrio	SEA	BLUE STAR FERRIES 5 Blue Star 5 to Piraeus 1	11:55	17:10		5h 15min	5h 15min	178km
2			Andros Port Gavrio			Transfer			2h 35min		2h 35min	0km
3		Mykonos		Mykonos Port	SEA	FAST FERRIES 2 Fast Ferries 2A from Rafina	19:45	22:10		2h 25min	2h 25min	74km
summ ary	Chios	Mykonos	Chios port	Mykonos Port			11:55	22:10	2h 35min	*7h 40min*	*10h 15min*	*252km*

16.2.4. Design of Stated Preferences Experiment of Andros as an intermediate stop

In order to test the acceptance of such a new service and the users' willingness to travel, wait and pay, a stated preference was designed and addressed to eligible respondents who are users of the transport system under study, have travelled recently in the region of the Aegean Sea and have travel plans for holidays to any island of the connected clusters. In the SP experiment travelers were introduced to the hypothetical scenarios as follows:

In the existing situation it is only possible to connect the islands of the North-Eastern Aegean (Limnos, Lesvos, Chios, Oinouses, Psara) with Andros and its connecting lines (Mykonos, Naxos, Tinos, Paros etc.) via Piraeus. This is a major detour. The existing route from Piraeus to Chios could make an intermediate stop at Andros port (Gavrio) increasing the travel time to Chios and Lesvos by 40 minutes but allowing transfer to the sealines of Cyclades and offering various connection possibilities between the island of NE Aegean with the Cyclades. Please select among the various scenarios.

Example:

	Scenario 1	*Scenario 2*
Scenario	(1) Existing situation with no intermediate stop at Andros. Connection of NE Aegean islands to Cyclades via Piraeus	(2) New connection possibilities of NE Aegean islands to the Cyclades via Andros
Travel time eg.Chios-Mykonos including transfer time at Piraeus (scenario 1) or at Andros (scenario 2)	12h	10h
Transfer waiting time at Piraeus (scenario 1) or at Andros port (scenario 2)	4h	4h
Trip cost eg.Chios-Mykonos one-way for one person in EUR	40€	60€

Not all of the respondents are eligible for answering this part of the survey as we only want the opinion of travellers who have stated their preference for travelling to one of the islands of cluster 1 or one of the islands of cluster 8 and neighbouring ones, for their holidays next year or they have revealed one of these islands as their trip destination or origin in the base year 2017 of the syrvey. With this eligibility criteria we target travellers that have already travelled or they are making plans to travel in one of these islands or they are inhabitants of these islands. For the abovementioned reasons they have some experience or interest in the specific area and they have a potential benefit from a new connection between clusters 1 and 8 including its neighbouring ones, while the rest of the travellers are excluded from this part of the survey.

In order to test the acceptance of such a new service and the willingness to travel/wait and pay of the users we have included in our questionnaire the following exercise:

Each eligible respondent had to answer 4 questions with random variations of travel time, waiting time and cost pairs. The range of the travel time levels are 8-10-12-14h, the range of the waiting times are 2-4-6-8h and the range of the cost is 30-40-50-60-70€.

There were defined 6 Within-Concept Prohibition in the abovementioned levels, for the proportion between the travel time (TT) and waiting time (WT) combinations. To be within a range of realistic alternatives we decided to keep the waiting times lower than the travelling times.

16.2.5. Stated frequency of use of the connection via Andros

The question on the potential frequency of use of the connection Chios-Mykonos was stated like this:

In case of intermediate stop at Andros, how many trips per year between Northern Eastern Aegean Islands (Agios Efstratios, Lesvos, Limnos, Oinousses, Samothrace, Chios, Psara) and Eastern Cyclades (Andros, Mykonos, Syros, Tinos, Paros, Antiparos, Naxos) would you consider?

1. *None within five years' time*
2. *One within five years' time*
3. *One within three years' time*
4. *One within two years' time*
5. *One per year*
6. *More than one per year*

Table C29. Frequency of responses on the acceptability of the connection Chios-Mykonos

Row Labels	Frequency of answers	Frequency in%
1. None within five years' time	19	11%
2. One within five years' time	29	17%
3. One within three years' time	27	16%
4. One within two years' time	31	18%
5. One per year	46	27%
6. More than one per year	21	12%
Grand Total	**173**	**100%**

Up to 40% of the users of the system have stated that they would be willing to use the new service/ connection between Chios and Mykonos by sea with a transfer at Andros one or more times per year. This is a piece of evidence that a potential new service like this with coordinated routes and time schedules to allow reasonable transfer times, would be very well accepted by the users of the system. A potential new induced demand is foreseen in a case like this for a pair of origin-destination that previously or in the existing situation is close to zero due to very bad connection via Piraeus/Rafina resulting in very long travel times, more than 15 hours including a road part.

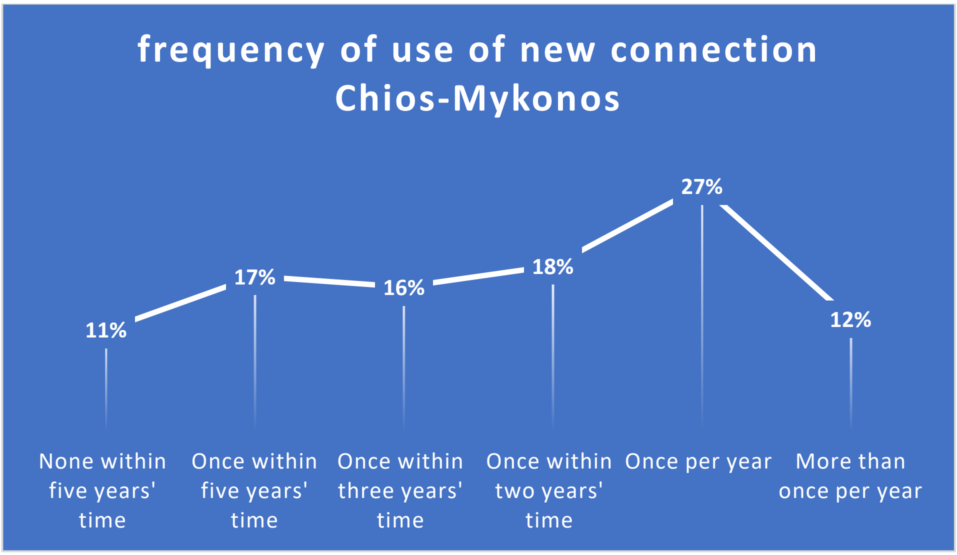


Figure C26. Frequency of use of the new connection Chios-Mykonos

16.3. Testing an Intermediate Stop at Limnos

16.3.1. Introduction and concept

In reference to the Part A of the thesis, this potential new service is introducing a connection between Lemnos and Samothraki with a parallel upgrade of the interconnections within cluster 1. It reduces isolation and brings cohesion not only between the specific OD pair but between all possible pairs between the connected islands and introduces a sea connection between Thessaloniki and Samothraki without the need for a road trip. Furthermore, it restores the proximity within this area, with islands that are very close in geographical terms but very far away in accessibility terms with the existing transport system and as missing links in this area have been already been identified in Part A. The cost of the proposed connection is relatively low as it is based on an intermediate stop on the way to the major destinations that do not increase significantly the main travel times. But it also requires a new small sea line between Lemnos and Samothraki. Its success is mainly based on the time schedule coordination between the main line of the Northern Aegean islands (Region of Voreio Aigaio) from Thessaloniki and Kavala (Region of Central Makedonia) and the new small distance line Lemnos-Samothraki.

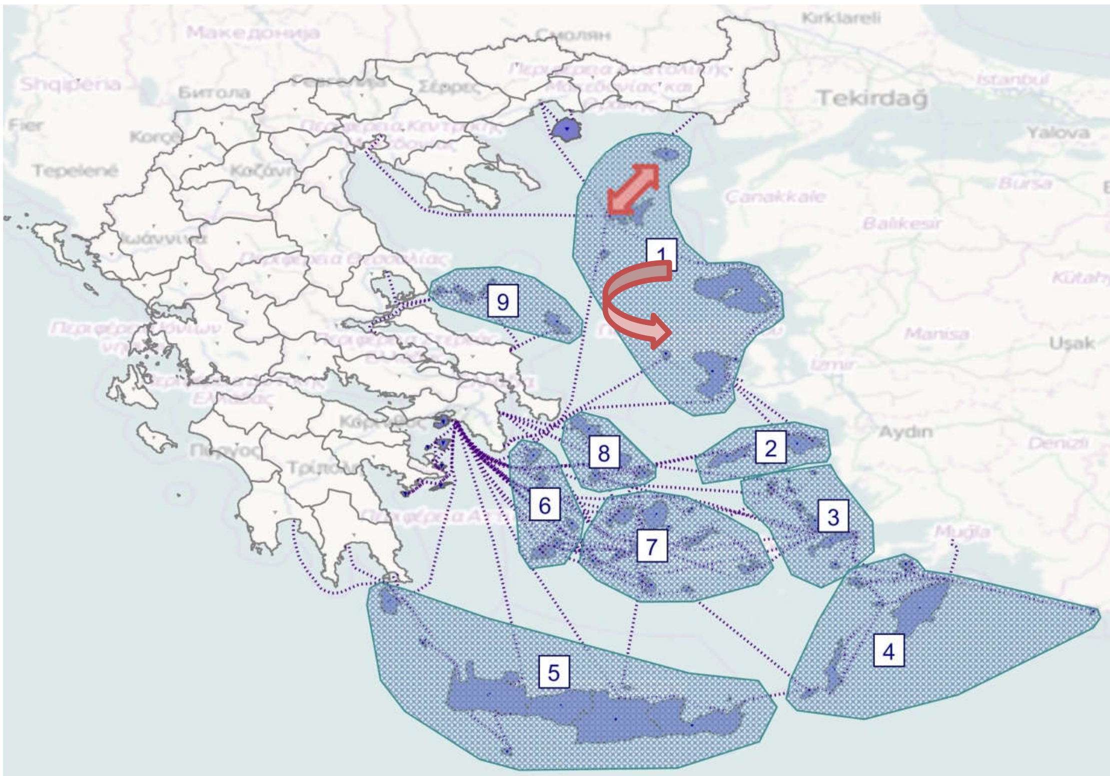


Figure C27. New connection Lemnos-Samothraki and improved interconnections within cluster 1

More specifically cluster 1 includeσ the islands of Agios Efstratios, Chios, Lesvos, Limnos, Psara, and Samothraki. The immediate area of influence includes connected islands of Cluster 2 such as Samos and Ikaria since there is a line between Chios-Samos and Ikaria.

16.3.2. Existing Connections Between Chios and Samothraki via mainland

In the next figure we present a map visualization of the existing route via an interchange at the Kavala and Alexandroupoli ports of Northern Greece. Additionally, we present the existing timetable connection which can be perceived as theoretical only since it includes a large road part and furthermore the connecting times are not coordinated, due to the fact that are two different operators who do not guarantee coordinated interchange possibility and itinerary time-schedule reliability as air operators of the same alliance offer.

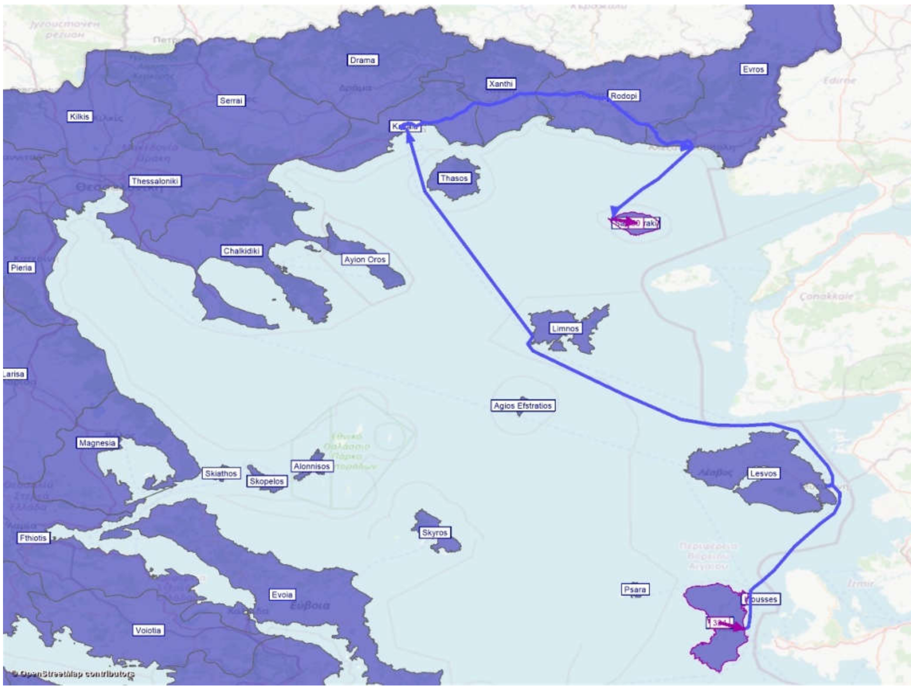


Figure C28. Existing route via interchanges at the Kavala and Alexandroupoli ports of Northern Greece

This service is offered 3 times per week during the summer of the reference year, on Tuesdays, Thursdays and Saturdays as follows:

Table C30. Route connecting timetable between Chios and Samothraki via Kavala and Alexandroupoli ports

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In vessel/ vehicle time	Total time	Distance
1	Chios		Chios port	Kavala port	SEA	NEL 4 NEL 4B to Kavala < 1	Tue 21:10	Wed 13:50		16h 40min	16h 40min	402km
2						Transfer			0h		0h	0km
3			Kavala port	Alexandroupoli port	P+R	Road part PuT Aux P+R	Wed 13:50	Wed 15:20		1h 30min	1h 30min	157km
4						Transfer			40min		40min	0km
5		Samothraki	Alexandroupoli port	Samothraki Port	SEA	SAOS 1 SAOS 1 from Alexandroupoli > 1	Wed 16:00	Wed 18:10		2h 10min	2h 10min	55km
summary	Chios	Samothraki	Chios port	Samothraki Port			Tue 21:10	Wed 18:10	40min	*20h 20min*	*21h*	*614km*

An alternative route exists via Thessaloniki port and Alexandropouli port or the region of Northern Greece as shown in the following figure. This route is not attractive for travelers as it requires a large road trip part between Thessaloniki and Alexandroupoli. The route is presented here.

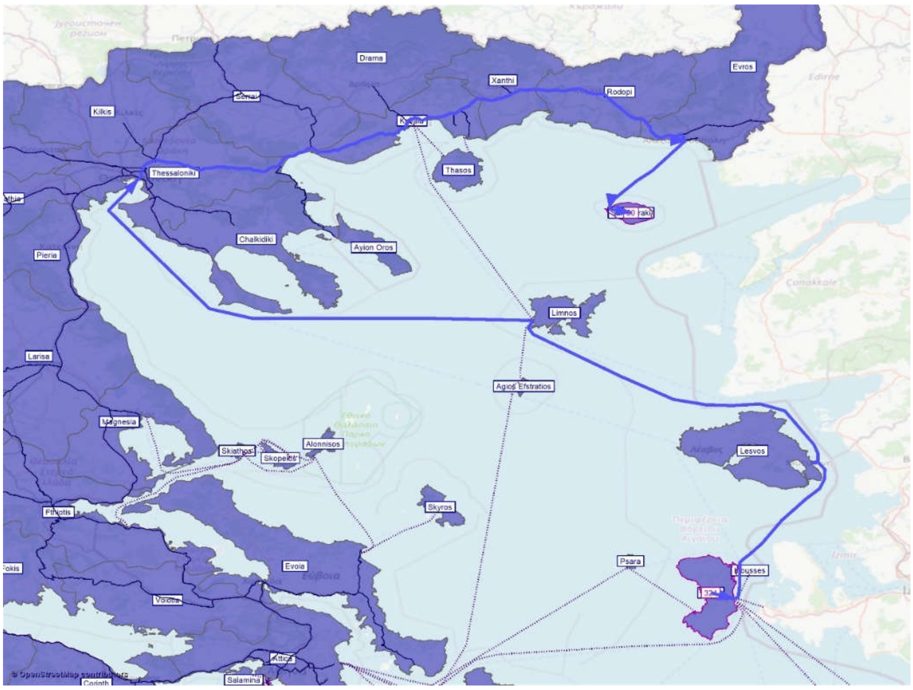


Figure C29. Existing alternative route via an interchange at Thessaloniki and at Alexandroupoli ports

The route includes a road part larger than the previous existing alternative via Kavala, which makes the trip completion even more complicated. Still for reasons of assessment of the existing situation we are presenting it here. This service is offered once per week during the summer of the reference year, on Sundays.

Table C31. Route connecting timetable between Chios and Samothraki via Thessaloniki and Alexandroupoli ports

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In-vessel/ vehicle time	Total time	Distance
1	Chios		Chios port	Thessaloniki port	SEA	NEL 4 NEL 4A to Thessaloniki < 1	Sun 11:30	Mon 08:30		21h	21h	519km
2						Transfer			0h		0h	0km
3			Thessaloniki port	Alexandroupoli port	P+R	Road part PuT Aux P+R	Mon 08:30	Mon 11:20		2h 50min	2h 50min	303km
4						Transfer			4h 10min		4h 10min	0km
5		Samothraki	Alexandroupoli port	Samothraki Port	SEA	SAOS 1 SAOS 1 from Alexandroupoli > 1	Mon 15:30	Mon 17:40		2h 10min	2h 10min	55km
summary	Chios	Samothraki	Chios port	Samothraki Port			Sun 11:30	Mon 17:40	4h 10min	*26h*	*30h 10min*	*877km*

In the recent years the old slow ferry Theofilos by NEL operator in the route has been replaced by a faster one and another operator is now on this line. As a result, the travel time between Chios and Kavala is approx. 12hours instead of 17hours.

16.3.3. New Connection Between Chios and Samothraki via Limnos

None of the two abovementioned existing routes are attractive for travelers as the total travel times are very high. In the following we present a visualization of a potential new route connecting the islands within cluster 1 via an interchange at Limnos and a new sea connection between Limnos and Samothraki.

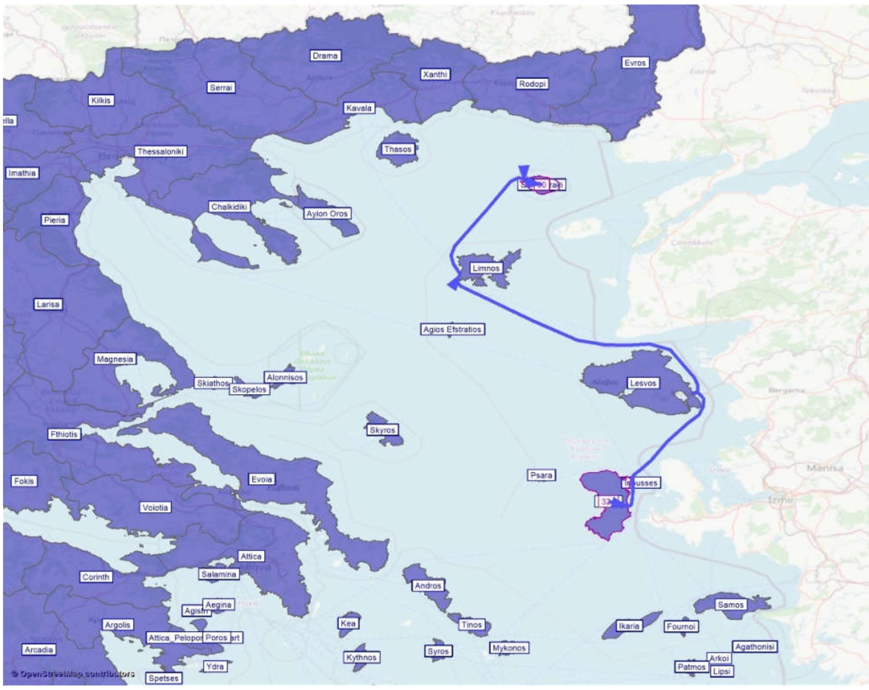


Figure C30. Potential new route via interchange at Limnos

This route allows for an everyday connection with the islands of cluster 1 by introducing a new service line and it is described in the next table. There is 1 connection per day between Chios and Limnos and 2-3 new connections per week could be introduced between Limnos and Samothraki as an extension to the existing line Alexandroupoli-Samothraki.

Table C32. Route connecting a theoretical timetable between Chios and Samothraki via Limnos port

Path index	Origin zone name	Destination zone name	From stop area	To stop area	TSys code	Time profile key string	Departure	Arrival	Wait time	In vessel time	Total time	Distance
1	Chios		Chios port	Limnos port	SEA	BLUE STAR FERRIES to Kavala < 1	06:30	14:30		8h	8h	271km
2			Limnos port			Transfer			3h		3h	0km
3		Samothraki		Samothraki Port	SEA	Operator 1 to Limnos	17:30*	18:30*		3h	3h	87km
summary	Chios	Samothraki	Chios port	Samothraki Port			06:30	18:30*	3h	11h	14h	*358km*

** Theoretical arrival and departure times*

16.3.4. Design of Stated Preferences Experiment of Limnos as an intermediate stop

In order to test the acceptance of such a new service and the willingness to travel/wait and pay of the users we have included in our questionnaire the following questions:

"In the existing situation it is only possible to travel to Samothraki via Alexandroupoli port. In case of a new itinerary Limnos-Samothraki it would make possible the sea connection of Samothraki to the Northern-Eastern Aegean Islands (Agios Efstratios, Lesvos, Oinousses, Chios, Psara). Additionally the sea connection to Thessaloniki-Samohtraki would be possible. For these new possibilities, a transfer at Limnos would be necessary. Please select among the various scenarios."

Example:

	Scenario 1	*Scenario 2*
Scenario	(1) Existing situation with no sea connection with Samothraki from Limnos-Lesvos-Chios	(2) New possibilities for sea connection of NE Aegean islands to Samothraki via Limnos
Travel time from eg.Chios to Samothraki including transfer time either from ferry to car to ferry (scenario 1) or from ferry to ferry (scenario 2)	11h	10h
Transfer time from ferry to car to ferry (scenario 1) or from ferry to ferry (scenario 2)	4h	3h
Travel cost in EUR one-way for one person including fuel cost, tolls and ferry ticket	40€	60€

Not all of the respondents are eligible for answering this part of the survey as we only want the opinion of travelers who have stated their preference for travelling to one of the islands of cluster 1 for their holidays next year or they have revealed one of these islands as their trip destination or origin in the base year of the research. With this eligibility criteria we target travelers that have already travelled or they are making plans to travel in one of these islands or they are inhabitants of these islands. For the abovementioned reasons they have some experience or interest in the specific area and they have a potential benefit from a new connection within the islands of cluster 1, while the rest of the travellers are excluded from this part of the survey.

Each eligible respondent had to answer 4 questions with random variations of travel time, waiting time and cost pairs. The range of the travel time levels are 8-9-10-11h, the range of the waiting times are 1-2-3-4h and the range of the cost is 30-40-50-60€.

There were defined 6 Within-Concept Prohibition in the abovementioned levels, for the proportion between the travel time (TT) and waiting time (WT) combinations. To be within a range of realistic alternatives we decided to keep the waiting times lower than the travelling times.

16.3.5. Stated frequency of use of the new connection via Limnos

The question on the potential frequency of use of the connection Chios-Samothraki was stated like this:

In case of a new itinerary that would connect Thessaloniki-Limnos-Samothraki and through this the Northern Eastern Aegean Islands of Agios Efstratios, Lesvos, Oinousses, Chios, Psara) how many trips per year between the connected origins to Samothraki would you consider?

7. *None within five years' time*
8. *One within five years' time*
9. *One within three years' time*
10. *One within two years' time*
11. *One per year*
12. *More than one per year*

Table C33. Frequency of responses on the acceptability of the connection Chios-Samothraki

Row Labels	Frequency of answers	Frequency in%
7. None within five years' time	20	13%
8. One within five years' time	29	19%
9. One within three years' time	24	16%
10. One within two years' time	22	14%
11. One per year	43	28%
12. More than one per year	14	9%
Grand Total	**152**	**100%**

Up to 40% of the users of the system have stated that they would be willing to use the new service/ connection between Chios and Samothraki with a transfer at Lemnos, one or more times per year. This is a piece of evidence that a potential new service like this with coordinated routes and time schedules to allow reasonable transfer times, would be very well accepted by the users of the system. A potential new induced demand is foreseen in a case like this for a pair of origin-destination that previously or in the existing situation is close to zero due to very bad connection via Thessaloniki resulting in very long travel times, more than 15 hours including a road part.

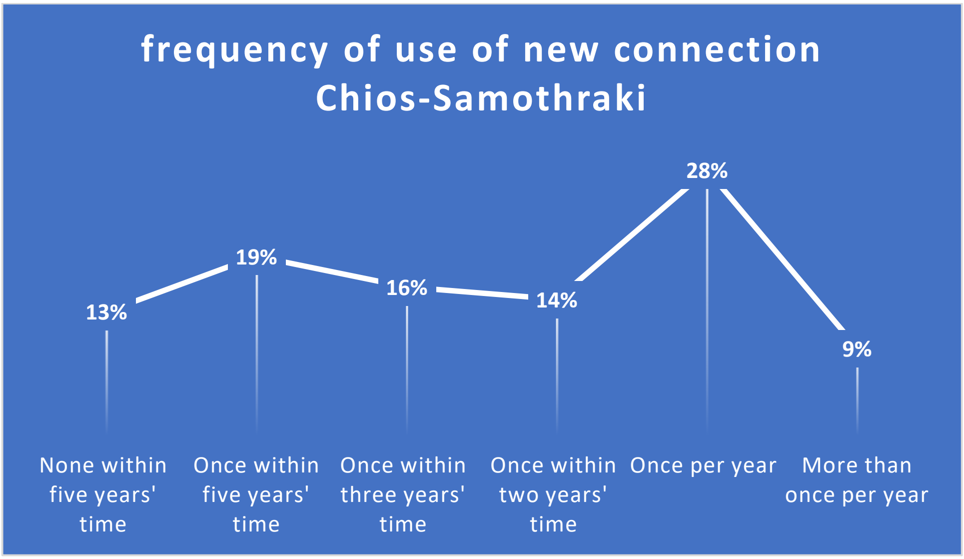


Figure C31. Frequency of use on new connection Chios-Samothraki

16.4. Results of the SP insular hubs experiment

For estimating the discrete choice models we combine the data set for the two intermediate hubs, one in the north Aegean and one in the North Cyclades. The sample consisted of a total of 1260 responses after data cleaning. Out of those 39% chose alternative 1 - the existing connection via the established mainland major ports; and 61% chose alternative 2 - the proposed new connection via island ports as minor hubs.

16.4.1. Discrete choice model results

The utilities of the alternatives were a function of travel time (TT), waiting time (WT) and travel cost (COST). A dummy variable hub1 was created taking the value of 1 1 for the Andros experiment, and 0 for the Limnos experiment. The effect of socioeconomic variables on choice behavior was tested. More specifically, independent variables include the income of the respondents per year in thousands of euros as a continuous variable; the employment status as categorical with a dummy variable taking the value of 1 if salaried employee or self-employed or own business, and 0 if student or pensioner or unemployed. When estimating the models other socioeconomic variables such as age, education and gender but were found insignificant. In the table below, the frequencies of chosen route alternatives are summarised.

Table C34. Frequencies of discrete choice answers

Chosen alternative	number of observations	frequencies
Existing route via mainland ports	492	39%
New alternative route via islandic ports	768	61%
Total number of observations	1,260	100%

Out of the total number of 1,260 responses, 39% chose alternative 1 - the existing connection via the established mainland major ports; and 61% chose alternative 2 - the proposed new connection via island ports as minor hubs. The model specification and results are summarized in the tables below.

Table C35. Specification table islandic minor hubs model

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8
Existing route via mainland hubs	0	Cost of existing route	Travel time of existing route	Waiting time for transfer at the mainland port	0	0	0	0	0
Alternative route via islandic hubs	1	Cost of alternative route	Travel time of alternative route	0	Waiting time for transfer at the islandic port	1 if Andros experiment; 0 if Limnos experiment	Income in 1000€	1 if traveller works as an Employee; 0 if otherwise	1 if traveller works as Self Employed; 0 if otherwise

Table C36. Model estimation islandic minor hubs report

Variables	Multinomial Logit	Model (MNL)
	Coefficient	*t*-Stat
Alternative Specific Constant_ β_0	0.396	2.02
Cost of route_β_1	-0.0357	-9.55
Travel time_β_2 (in-vehicle/vessel time + transfer walk time)	-0.116	-2.17
Waiting Time for transfer at the major mainland port_ β_3	-0.272	-4.18
Waiting Time for transfer at the minor islandic port_ β_4	-0.200	-3.31
Hub1 _β_5 (1 if Andros experiment; 0 if Limnos experiment)	-0.491	-2.53
Income in 1000€_β_6	-0.0163	-2.79
Employee_β_7 (1 if traveller works as an Employee; 0 if otherwise)	0.67	4.25
Self employed_β_8 (1 if traveller works as Self-employed; 0 if otherwise)	0.84	4.15
	Summary statistics	
Sample size:	1260	
Init log likelihood:	-873.365	
Final log likelihood:	-678.39	
Rho-square for the init. model:	0.223	
Rho-square-bar for the init. model:	0.213	

The parameter of travel cost is negative and statistically significant as expected. An increase of the travel cost of the alternative insular hub path by 10€ will result in a utility reduction of this path choice by 10%. The parameter of travel time is also negative and statistically significant, as was expected. An increase in the duration of the alternative route by 2 hours results in 5% fewer passengers choosing this option.

The parameter of transfer wait time at the mainland ports of the existing route travel is negative and statistically significant and it is higher in an absolute value than the parameter of travels lime and also than the parameter of transfer wait time at the minor islandic ports. The utility of the existing route decreases at 0.272 if the transfer wait time at the mainland port increases by 1 hour. The utility of the alternative route via the islandic ports decreases at 0.2 if the transfer wait time at the mainland port increases by 1 hour.

The parameters of the socio-economic characteristics in the model are interpreted as follows:

The parameter of income of the travellers is negative and statistically significant. An increase in the annual income results in a slight decrease of the minor hub path alternative. But this effect is not very strong as the estimated income (in 1000€ per year) coefficient of 0.0163 is relatively low.

The parameter of islandic hub in Andros is negative and statistically significant. If the passenger chooses this internal hub of Andros then the utility of the alternative route via the islandic port is decreased by 0.491. It means that in the case study connection of the north between Chios and Samothraki, the individuals have a much more positive predisposition for choosing the alternative insular hub route via Limnos. The route in the north has a significant road part for the completion of the trip which makes it a combined sea+road+sea path. The road part is avoided using Limnos as an internal stop, and for this reason the respondents want to avoid it, which is reasonable and expected.

The findings of the model estimations are very interesting, with important policy implications. It is observed that the new connection via the island port is preferred over the existing situation via the ports of the mainland. The users are less willing to spend time waiting for their transfer than they are to spend time on the ship. This finding is consistent with the general practice of public transport land modes for both short-distance and long-distance trips but it has never before been tested for sea lines in the region. Users are willing to wait less in the mainland ports than they are to wait at the smaller island hubs of the case study. The results of the model show in particular that an increase in waiting times will pose a larger negative effect on the utilities of the existing route via Piraeus and Rafina or Thessaloniki and Kavala than on those of the new proposed route via Andros or Limnos minor hubs. The in-vessel value of time for travelling for tourism by ferries is 3.25€/h, while the value of time for waiting at the intermediate stops is 7.62€/h for the mainland ports and 5.60€/h for the alternative islandic hubs. These results are comparable to the findings of Polydoropoulou A. et al., 2004 in their research for the Greek Transport Observatory.

The results show a clear preference towards the new proposed route using the islandic ports as an interchange hub. This preference is still reflected even in the unusual case where the two alternative routes (existing and proposed new one) have the same travel time, waiting time for interchange and same ticket cost in the above example with values of TT 11h, WT 5h, COST 50€. For these values a user who is an employee and with an annual income of 15,000€ would prefer the new connection with a 67% probability of choosing it over 33% probability of choosing the existing route via Piraeus in the case of Chios-Mykonos via Andros port. Similar to the connection Chios-Samothraki, the results show a clear preference towards the new proposed route using Limnos as interchange hub with 77% for the same indicative values.

In the following figures we present the model application with the predicted probabilities for various hypothetical values of travel times in hours, waiting times in hours and costs in Euros.

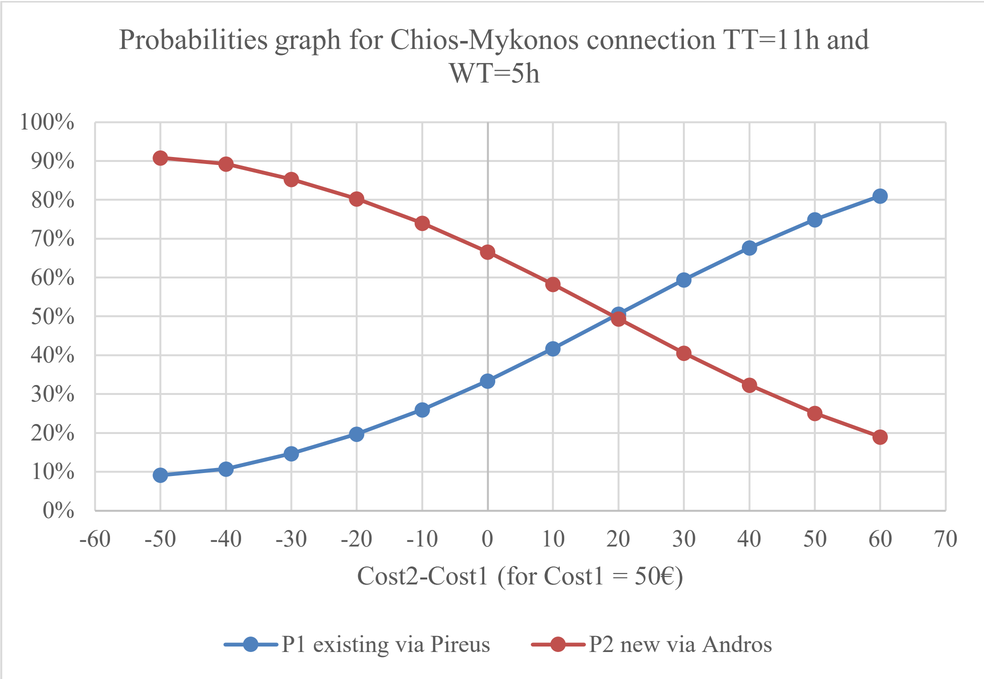


Figure C32. Probabilities graph for Chios-Mykonos connection for cost variable

The preference of the alternative path is still reflected even in the unusual case that the proposed new connection is more expensive up to the marginal cost difference of 20€ for the case of Andros compared to the existing one via Piraeus, while keeping the rest of the values the same. This is derived from the graph above.

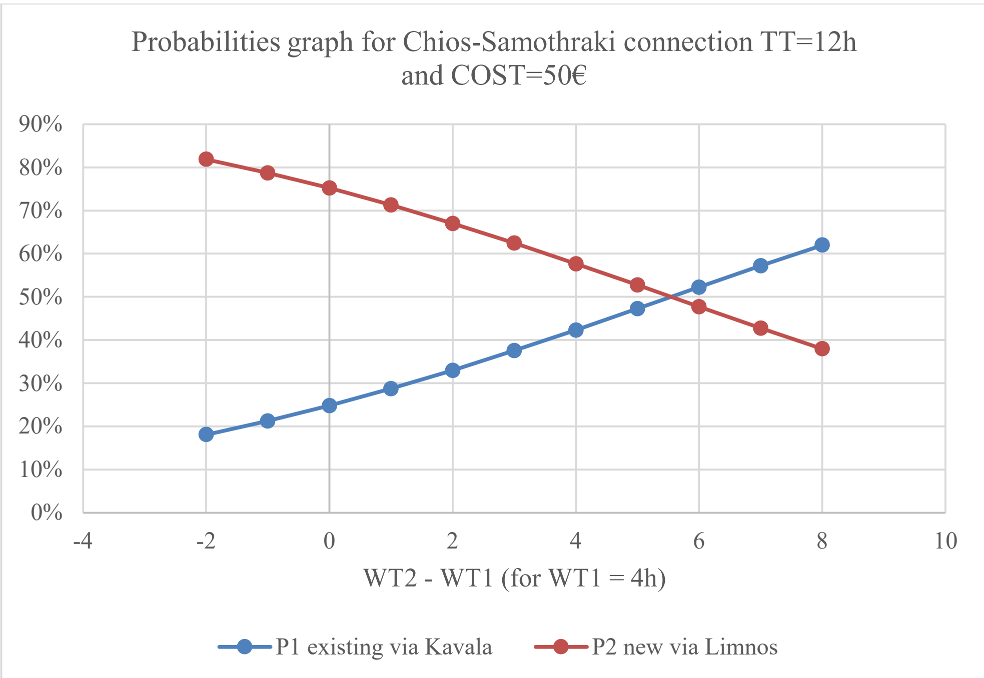


Figure C33. Probabilities graph for Chios-Samothraki connection for waiting time variable

The preference of the alternative path is still reflected even in the unusual case that the waiting time at the islandic hubs is longer than the waiting time at the mainland hub. It is found that this trend is still valid for up to a time difference of 5h of additional waiting time at the port of Limnos, while keeping the rest of the values the same.

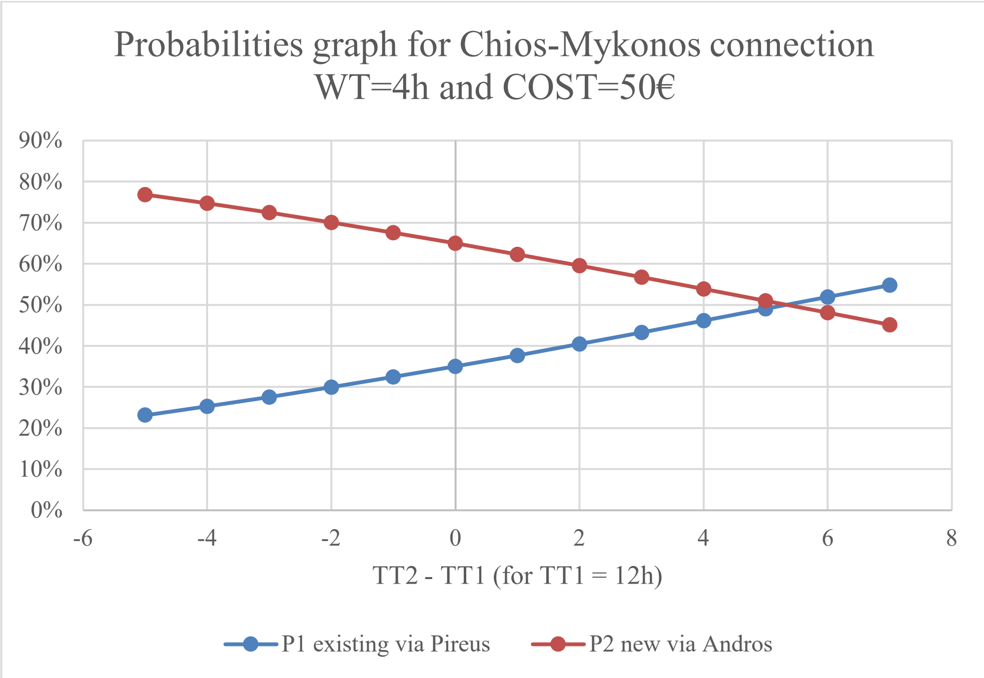


Figure C34. Probabilities graph for Chios-Mykonos connection for in-vessel travel time variable

The preference for the alternative path remains strong even in the unusual case that the proposed new connection has a longer in vessel travel times up to 5 hours for the case of Chios-Mykonos via Andros compared to the existing one via Piraeus, while keeping the rest of the values the same. This is depicted in the probability graph above.

In an additional question of the survey on the frequency of potential use of the new services, up to 40% of the users of the system have stated that they would be willing to use the new connections once or more times per year. This is another evidence that a potential new service like this with coordinated routes and time schedules to allow reasonable transfer times, would be very well accepted and induce new demand.

16.4.2. Results of the SP experiment for holiday trips with sea as the main mode

As a general assessment of the survey we cross check the estimated VOT of the total travel time that is comparable to other reference studies. The utilities of the alternatives were a function of the travel ride time (TRT) as the summary of in-vehicle/vessel time, transfer walk tome and transfer wait time, and travel cost (COST). The model specification and results are summarized in the tables below.

Table C37. Specification table of sea mode model for holidays

	β_0	β_1	β_2	β_3	β_4	β_5	β_6
Existing route via mainland hubs	0	Cost of the existing route	Travel ride time of existing route	0	0	0	0
Alternative route via islandic hubs	1	Cost of the alternative route	Travel ride time of alternative route	1 if Andros experiment; 0 if Limnos experiment	Income in 1000€	1 if traveller works as an Employee; 0 if otherwise	1 if traveller works as Self Employed; 0 if otherwise

Table C38. Model estimation sea mode for holidays report

Variables	**Multinomial Logit**	**Model (MNL)**
	Coefficient	***t*-Stat**
Alternative Specific Constant_ β_0	0.571	4.21
Cost of route_β_1	-0.0361	-9.74
Travel ride time_β_2 (in-vehicle/vessel time + transfer walk time + transfer wait time)	-0.176	-12.6
Hub1 _β_3 (1 if Andros experiment; 0 if Limnos experiment)	-0.319	-2.4
Income in 1000€_β_4	-0.0166	-2.84
Employee_β_5 (1 if traveller works as an Employee; 0 if otherwise)	0.665	4.22
Self employed_β_6 (1 if traveller works as Self-employed; 0 if otherwise)	0.853	4.21
	Summary statistics	
Sample size:	1260	
Init log likelihood:	-873.365	
Final log likelihood:	-679.633	
Rho-square for the init. model:	0.222	
Rho-square-bar for the init. model:	0.214	

The findings of the model estimations are verifying a value of time for travelling for tourism by sea as the main mode with one or mode transfers for the total travel time at 4.88€/h for Greece for 2017 Euro value. This is comparable to the findings from another relevant study by Polydoropoulou, A., S. Kapros, and E. Pollatou, 2004 in their work for the Greek Observatory study (2002-2003). They developed a national mode choice model and they estimated the VOT for travelling by sea for personal purposes at 4.3€/h. In another relevant study by Masvoulas 2005 the value of time of the ship in the area of the Aegean Sea for all trip purposes is 5.05€/h. [5]

Shortly after the year 2008 and the outbreak of the global financial crisis, Greece faced a severe local debt crisis, which led to an unprecedented regression of its economy. This is reflected in the figure below with GDP per capita values for the years 2000-2017. In the most recent years 2017-2019, the Greek economy started to improve until the spring of 2020 when the Covid pandemic led to a new, ongoing and yet not fully assessed, financial depression affecting largely both the Transport and the Tourism Sector as mobility restrictions are enforced.

There is no published assessment of travel values after the regression that hit the Greek economy. Adjusting roughly the values VOT of the two abovementioned reference studies to the year 2017 by using the changes of GDP per capita from the reference figure of the Annex we conclude in a value of 4.8€/h for both cases, which is consistent with the current research estimations.

16.5. Transport model verification of islandic ports as minor interchange hubs

Transport modelling is the recommended method to assess transport initiatives, strategies and policies (ATAP, 2016). It provides the technical means to quantify, visualise and understand existing and future issues of the transport sector. Through an overview of the various parameters and aspects of the transport systems, models offer opportunities to reverse fragmentations and move towards integration and sustainability (Furnish P. and Wignall D., 2009).

Testing the connections on the transport model tool, provides interesting findings, evidence and visualizations on the use of the minor insular transport hubs at these two specific locations. The thematic map of contingent transfers in experimental runs for existing network connections and lines but not considering the waiting times, shows a totally different picture of the loaded network

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[5] *Masvoulas, G. (2005). Demand and supply time series passenger analysis in the North Aegean. Unpublished MSc Thesis, University of the Aegean, Greece.*

that we are used to. Ina case like this with regular daily services twice a day, the insular ports are transformed into important transfer hubs that improve significantly the interconnections between the islands of the Aegean Archipelagos.

Considering the abovementioned findings and taking the discussion one step further we can argue that the system shortcomings when it comes to interconnectivity are not necessarily due to the missing links but due to lack of time-schedule coordination and transport service integration. While the system is well-coordinated from Piraeus and the rest of mainland ports, the existing transfer waiting times at the insular hubs are very long up to approximately 9 hours.

16.5.1. Transport model verification of islandic ports as minor interchange hubs

According to the calibrated transport model, the vast majority (greater than 80%) of the interchanges between sea routes at Piraeus port is generated by the domestic travellers to the islands. The rest (less than 20%) is due to the impact of foreign tourists from Turkey. In the following table the aggregated OD pairs that use Piraeus port as an interchange hub for transfers between sea routes are presented. The majority of transfer flows are between the Cyclades and the islands of the North Aegean. All values have as a reference period the peak summer week and they are indicative as the model offers only an approach to the problem and no validation data on transfers exist.

Table C39. Indicative Piraeus sea + sea transfers in the existing situation for domestic travellers

	Crete	Cyclades	Dodecanese	North Aegean	Attica prefecture islands
Crete		400	50	400	200
Cyclades	400	100	300	900	500
Dodecanese	50	300		300	300
North Aegean	400	900	300	50	400
Attica prefecture islands	200	500	300	400	50

The category of Attica prefecture islands includes the Saronic islands, Kythera and Antikythera.

Visualisations of the transfer flows between sea routes at port hubs of the area are given below where the role of Piraeus prevails.

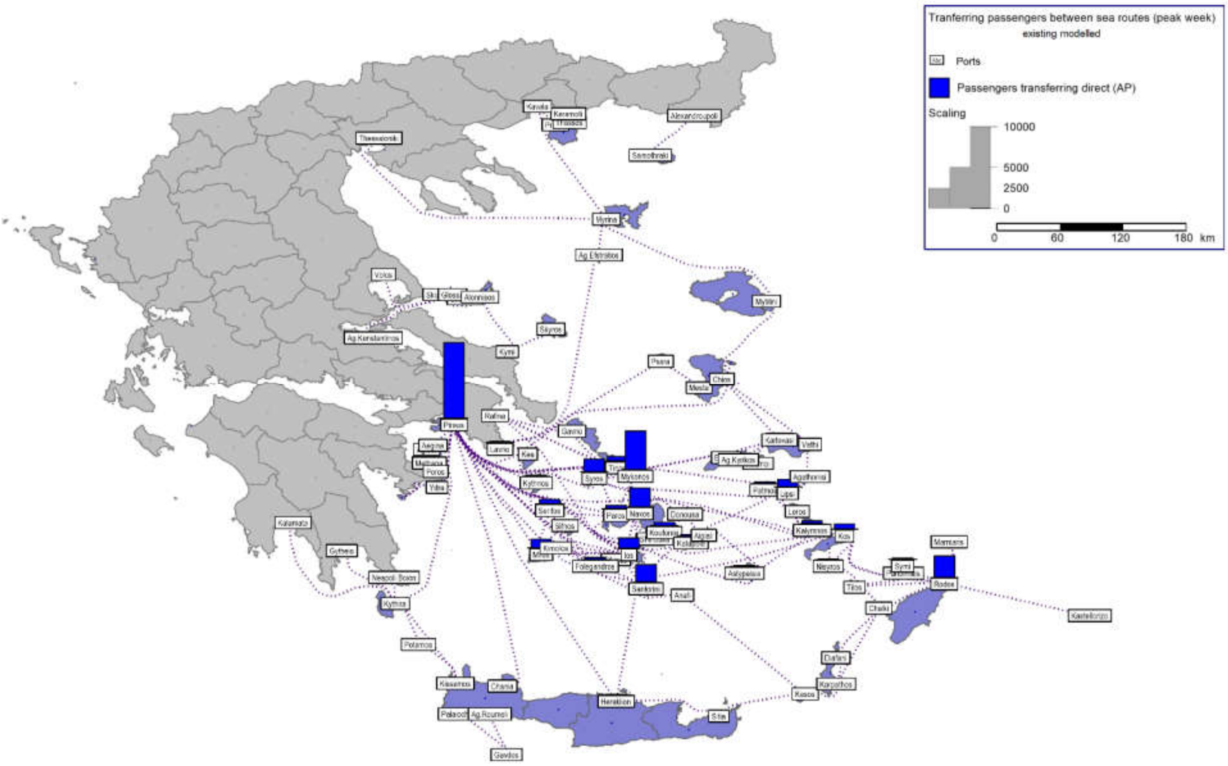

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Figure C35. Visualisation of interchanges between sea routes in the existing situation

In the situation after implementing the two new minor hubs, Andros port is becoming significant in the area.

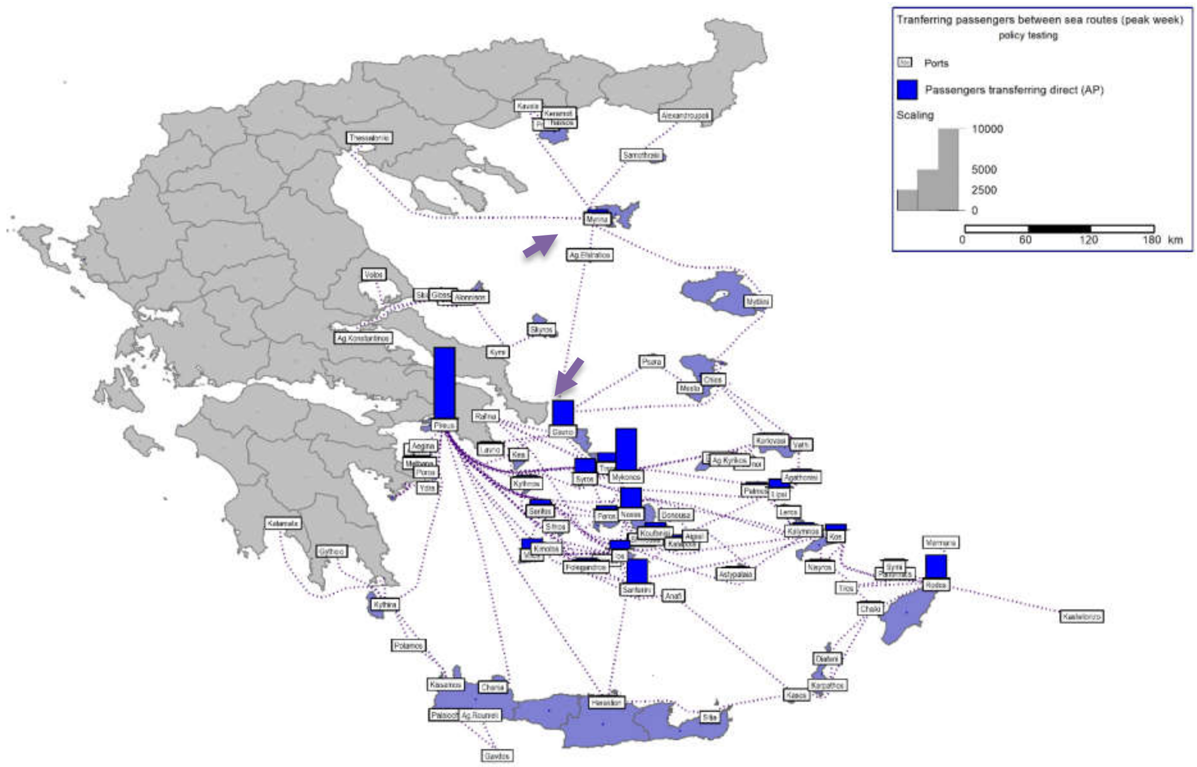

Figure C36. Visualisations of interchanges between sea routes after implementing the two minor hubs

The above figures are visualisations of the passenger transferring volumes between sea modes in the study area. The former is for the existing situation and the latter is for the case of implementation of two minor hubs at Andros and Limnos islands. The impact of these new minor hubs is more evident in the next table where selected insular hubs in the area are compared to interchanges at Piraeus mainland port of Attica. All values have as a reference period the peak summer week and they are indicative as the model offers only an approach to the trip chain exercise in the study area.

Table C40. Indicative transfer flows by sea modes from policy testing in the model

Transport hub	Location	Transfer flows by sea modes	
		Existing situation (calibrated model)	New connections With coordination effect
Piraeus	mainland port	9,300	8,700
Andros port - Gavrio	insular port	0	3,000
Mykonos port	insular port	4,700	5,100
Limnos port - Myrina	insular port	10	400
Sum of selected hubs		14,010	17,200

In the tested scenario, with a coordinated timetable system in favour of the interconnections between the islands and new connections via Andros and Limnos, the number of interchanges at Piraeus, the mainland major hub, is decreasing significantly. On the contrary some insular hubs are coming to prominence as significant in case the coordination is scheduled in favor of these ports. Andros and Limnos are functioning well as minor hubs in the model with significant potential demand for transfers even in the case that induced demand is not considered. Also, other insular hubs in the area are becoming more important than they already are in the existing situation, such as Mykonos. Servicing a big number of passenger transfers at the insular ports raises some capacity restrain issues at these ports that need to be further discussed during the next policy implementation phases that follow the strategic planning.

16.6. More interchange transport hubs

Additionally to the interchanges between sea routes, more interchange opportunities exist in the study area. These opportunities are observed between air routes as well as in intermodal paths that combine sea and air routes in the region. Pieces of evidence on route interchanges and intermodality exist in the revealed preference survey. Further analysis and justification is made and presented below through the calibrated transport model assignment results.

16.6.1. Insular air transport hubs justification

As also discussed in Part A, there is a large number of airports in the islands of the Aegean archipelagos. Yet, there are no major aviation hubs in the islands of the Aegean Sea that could serve as connection points between two air routes, with a smaller island as the final destination. The airport of Heraklion can be considered as a small hub providing connections to the islands of Ikaria, Kos, Kythira, Mytilini, Rhodes and Santorini. Also, Rhodes airport plays the role of a smaller hub with connections on offer to the islands of Karpathos, Kastellorizo, Kos, Limnos, Mytilini, Samos and Santorini, which were provided in the summer of 2013. The transport model justifies this initial observation and proposal.

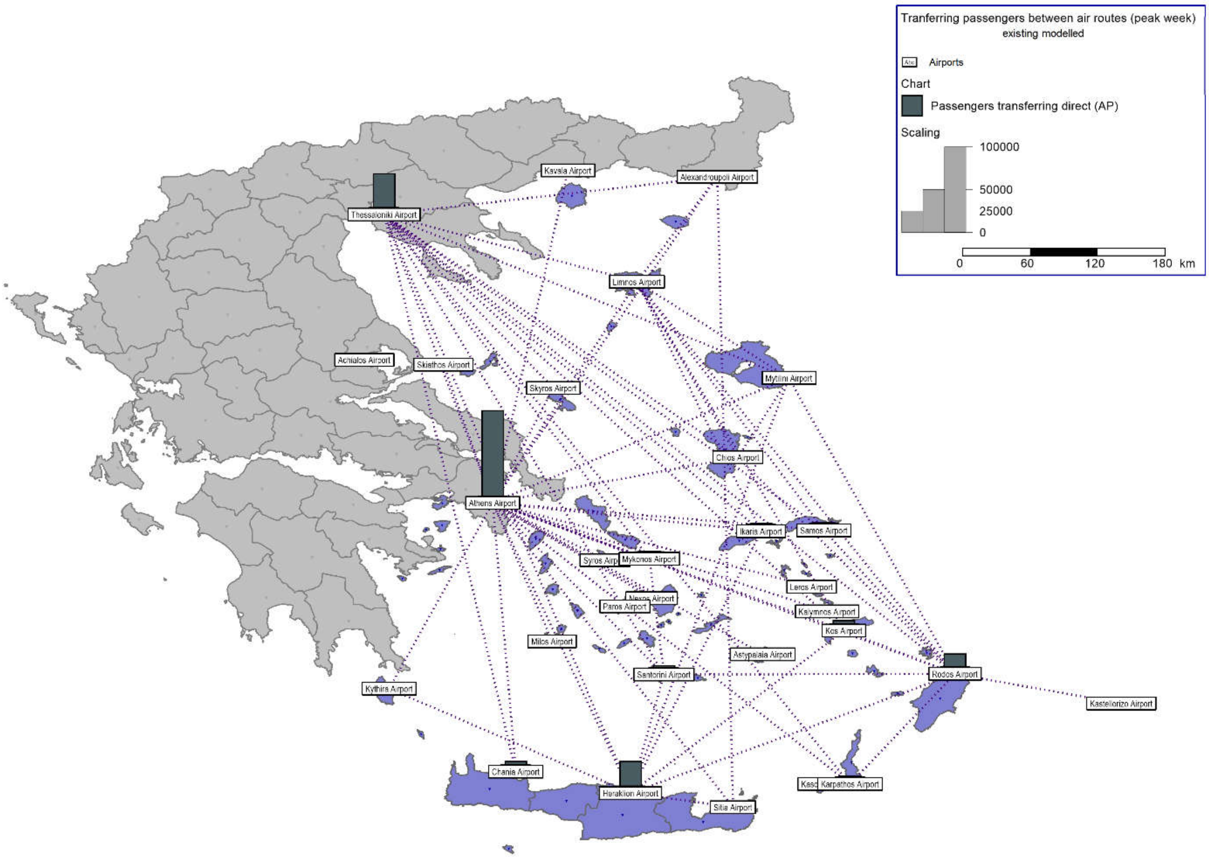

Figure C37. Visualisation of interchanges between air routes in the existing situation

The above figure depicts the potential passenger transferring volumes between air modes in the study area in the existing situation of the reference year. The airport hubs of Athens, Thessaloniki, Heraklion and Rhodos are distinguished. An upper scaling limit applies on the thematic bar of transfers at Athens international airport to allow bar visibility of the secondary hubs. It is noted that the number of transfers at the mainland ports describes exclusively the trips to the islands of the Aegean Sea.

16.6.2. Combined Maritime and Air Transport multimodality assessment

Restrictions exist as multimodality in large distance passenger trips requires coordinated scheduling and punctual arrival services, which are not guaranteed by the various private operators, who are uncoordinated. Furthermore, last-mile accessibility connections between ports and airports in the islands of the Aegean Sea constitute a problematic issue. In most cases, there is no public transport i.e. bus service, for transfers between ports and airports in the islands. Nevertheless, at all islands there a well-operating taxi service is in place, with taxi ranks situated at all ports and airports offering transportation between them at a low price. This issue could better be addressed in the near future with demand responsive transport services based on smartphone apps and car-sharing solutions on a commercial basis.

In spite of the lack of coordination in the trip schedules, the airports of Heraklion, Mykonos, Rhodes and Santorini, already serving as small interchange hubs between air and sea transport modes, to smaller airportless islands.

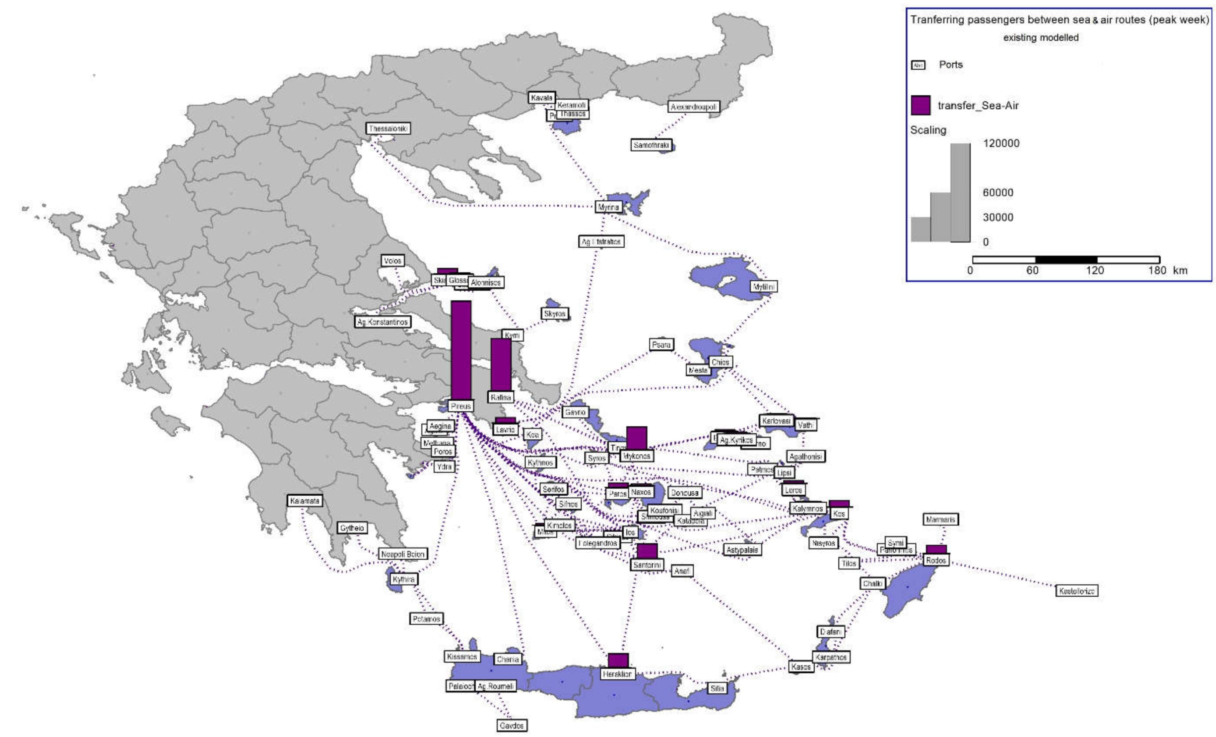

Figure C38. Transfer flows between sea and air routes at ports in the existing situation (calibrated model)

The previous figure visualises the passenger transferring volumes between sea modes and air mode in the study area. An upper scaling limit applies on the thematic bar of transfers at Pireus port to allow bar visibility of the secondary hubs.

The volume of intermodal passenger volumes at the main transport hubs of the area sums up to 13% of the total trips and it is consistent with the findings of the revealed preference survey for combined trips.

A concept of alliances between ferry and airline companies could further optimize accessibility to the islands of the Aegean Archipelagos.

17. CONCLUSIONS OF PART C

In this part of the Thesis, the acceptance of two new maritime passenger services in the study area is tested. In the first case a new intermediate stop in the course of an existing line is proposed that will improve accessibility within the islands via an intermediate island hub at Andros. In the second case, a new connection that has been identified as a missing link in Part A of the thesis is proposed and tested, which will also improve the accessibility of the islands using Limnos port as a small interchange hub. Some more arguments and articles on this connection are presented in the Annex.

Both exercises were addressed with stated preference survey methods combined with discrete choice modelling tools. This exercise doesn't address the issues of induced demand between these newly connected areas. This can be further tested in the simulation model with the necessary and theory of induced demand for new transport services. The results for both cases Andros and Limnos as interchange stop points have notable similarities. We summarise here the main findings:

1. Both interchange hubs are well accepted by the users. In both cases the users show a strong preference in using the new service instead of using the existing service via the mainland ports.

2. Up to 40% of the users of the system have stated that they would be willing to use the new service/ connection between Chios and Samothraki with a transfer at Lemnos, one or more times per year and the same percentage applies for using the new service/ connection between Chios and Mykonos by sea with a transfer at Andros for one or more times per year.

3. In both cases the users are more willing to wait for their transfer at the island port than wait for the transfer at the mainland port.

4. It is noted that in the two exercises the value of time for waiting at the interchange port/ hub was found higher than the value of time for traveling on the vessel. In other words, the users are not so willing to wait for their transfer as they are to spend time on the vessel. This finding is consistent with the general practice in public transport land modes for both short-distance and long-distance trips but it has never before been tested for sea lines in the region of the Aegean Archipelagos. Specifically, researchers recommend that walking and waiting time be valued at 200% to 250% of in-vehicle travel time as highlighted by P.

Mackie, et al (2003). In our analysis for long-distance recreation trips, waiting time for transfer at the major mainland ports is valued at 234% of in-vessel travel time and 172% for waiting at the minor islandic hubs tested. Therefore, it is considered a significant finding of this research. This also indicates the importance of coordinated timetables in cases of interchanges like this, at smaller or bigger hubs, and minimization of waiting times for the success of such a new service. Finally, there is evidence that the disutility of waiting times to transfer is not flat at every interchange point but users tend to prefer specific hubs more than in other hubs.

This research tested the attractiveness of two new small hubs in the islands of the Aegean Sea. The two island hubs offer a shorter connection for a number of origin destination pairs in the study area as an alternative to large detours via the existing well-established mainland terminal ports of Piraeus, Rafina, Thessaloniki, Kavala and Alexandroupolis. The preferences were assessed by developing and estimating discrete choice models utilizing data from a stated preferences survey.

The results show a significant preference for the small proposed internal hubs of the Aegean Archipelago. Even for marginally worse total travel times and marginally more expensive ticket, the respondents show their preference to the island interchange ports. This is explained by the fact that they are smaller ports and much more attractive than the large mainland ports. The travellers don't need to walk or drive for their transfer at the island hubs as would be the case at the mainland terminals. Furthermore, in all minor islandic ports of the Aegean Archipelago, the passenger terminals are situated at the islands' capital town and the seafront recreation areas are within the walking distance of 10 minutes or less, thus making these minor ports much more attractive to wait for a transfer when compared to the mainland ports.

The findings support a potential new policy for improved accessibility and better interconnection between the islands of the Aegean Sea. To a certain degree, such a policy may also contribute to the decongestion of the mainland ports. The policy aims at connecting clusters of islands in the study area that though being in proximity to one another, there is lack of ferry connections between them and to achieve this without involving a major detour. Such a system does not require large scale investments but rather some new facilities/terminals for the waiting passengers at the minor hubs. These types of facilities could potentially be financed by private investments as they may include cafes, rest areas, luggage safe areas and souvenir shops that may produce profit.

It should be noted that the methodology of this research, is applicable and transferable to other regions of the world where there are ferry lines in a network formulation close to the mainland such as for example the Baltic Sea, the Caribbean Sea, the Bahamas complex, the Mergui Archipelago in Myanmar, Indonesia and Solomon Sea.

The method also allows the calculation of the ferry's values of time. Smaller values of time for in-vessel travel time and larger values of time for waiting to be transferred are observed, which though common in land transport, it has not priorly been evaluated for ferry transport in Greece.

The values of travel and waiting time calculated by the estimated coefficients of the route choice, will be utilized to update the generalized cost function of the simulation model. The values also affect the mode choice model as for some origin destination pairs, the estimated values are important components of the choice of the ferry over the air and also the new smaller paths could produce a small shift from the air mode to sea modes in regards to the inland aviation.

As mentioned, up to 40% of the respondents have stated that they would be willing to use the new connections once or more times per year in the future, while the current demand between the affected origin destination pairs is close to zero as the existing total travel times are very high. Further analysis can be carried out on the induced demand, as the new service of internal hubs will improve the total travel times and possibly make a significant number of origin destination pairs in the study area much more attractive. Likewise, there is a potential generated travel demand as some clusters are now easier to access and overall, we expect an impact on the whole cycle and process of transport demand modelling and assignment to the network. The magnitude of this impact remains to be studied in the context of further research. Also, the minor islandic hubs could be assessed as a system integrating some additional ports in strategically selected locations.

Finally, there are major benefits for tourists with additional island-hopping opportunities and for the islanders to reach other islands previously inaccessible by means of a scheduled transport connecting service. Evidence on the validity of the methodology of the current research and its conclusions lies in the consistency check and alignment to the reference studies as they are presented at the beginning of Part C as well as in other report sections.

SUMMARY AND CONCLUSIONS

18. SUMMARY OF CONCLUSIONS AND FURTHER RESEARCH

18.1. Summary of conclusions

By analysing the transport system of the Aegean Archipelagos with the introduced transport simulation tools and other methods, it became evident that there is room for improvements especially in the interconnections among the islands in order to address the double insularity challenge in the region and establish cohesion. Similar to any land region, the major settlements of the Archipelagos should be interconnected to an acceptable level and accessible with one another as well as with the proximate settlements of the mainland.

In the course of this research, evidence is provided that there is a possibility of extending the passenger transport network of the Aegean Archipelagos with small changes as soft measures that will allow trips with a transfer at an insular port. In that way, investing on minor insular transport hubs at strategic locations in the area becomes meaningful and adds value to the system. The concept uses ideas from the public transport network design and configuration principals. It entails adding intermediate stops at specific routes that they intersect, adding small missing links and implementing timetable coordination at specific routes. Facilitating passenger transfers at these minor insular hubs with modern terminals equipped with rest areas is also important.

All the abovementioned apply for sea+sea transfers at insular ports as well as for the intermodal air+sea transfer opportunities that exist at specific insular airports provided that there will be shuttle bus services for the small land part connecting ports with airports at the specific islands. The field survey shows willingness to use the new minor interchange hubs that are introduced as an example and their corresponding new travel connections for origin-destination pairs that were previously misconnected. Moreover, the survey indicates a significant potential induced demand for trips between these origins and destinations. Last, a system of minor insular hubs at selected locations would give more opportunities for island hopping trips that is a very popular trend in the region.

The method presented in this Thesis proposes the combination of data from various sources on the aggregated and disaggregated user level, data cleaning and fusion with the help of advanced data processing methods, analysis with statistical and transport simulation tools and policy testing applying concepts of public transport planning and modelling. As a result, findings and insights on the performance of the transport system are discussed and opened for further research.

18.1.1. Internal trips in the study area

A significant share of 32% of the respondents revealed that their last trip to the islands of the Aegean Sea had a secondary islandic destination. This effect is very popular in the area and it is described by Lonely Planet in 2019 as: “the perfect Greek island-hopping adventure”. The majority of visitors are spending 5 nights at the main destination of the Aegean Sea for all trip purposes and 1 night at the secondary destination in case there is one.

18.1.2. Sea+Air Intermodality

The results of the analysis presented here, show the estimated shares of combined trips to the islands for up to 12% for all passenger types and 22% for Greek inhabitants. In the absence of a specific policy for promoting intermodal transport and interoperability in the region, the significant number of combined trips as they are revealed, show that there is need and potential in the area for better cooperation between the two main modes. The lack of coordination and cooperation among the various transport operators of the two main modes that they are perceived currently as competitive, could change in the future with the help of new technologies and MaaS concepts. There are indications and arguments that the two modes are complementary in this area and that improving intermodality and interoperability facilities and services will improve the performance of the overall transport system of the Aegean Archipelago. The model designed for this Thesis could test further policies and services towards mode integration and cooperation.

18.1.3. Capacity constrains

Processing the aviation passenger data which are very detailed, it is concluded that the air transport system in the study area operates at the capacity level during the summer season. Very high occupancy rates of volume to capacity ratios between 0.85 and 0.9 for the domestic aviation and for the international aviation respectively, are observed. Charter flights of international aviation with direct flights at the islands, have their share also in the high V/C levels. In any case the high volumes and high V/C ratios, cause congestion at the airport. There is evidence of excessive demand for air trips that is constrained by the capacity of the transport system. This results either in shifts to sea modes that are less congested which is the good scenario, or shifts to other holiday destinations which is the bad scenario for Greece, as the country has an interest to increase its tourism market share. Capacity constraints of the air mode strongly affect the mode choice for holiday trips and its elasticity. The fare cost as the main determinant of the model choice becomes less important as the system works at capacity levels. Offering faster sea modes to compete with the domestic air connections would be an option as proposing an increase of the flight frequencies is not always feasible due to airport congestion restrictions. The expansion of the holiday period would ease the congestion issues and regulate the strongly peaking demand for trips to the Aegean Archipelagos of July and August.

18.1.4. Applicability to the winter season

The current analysis is focusing on the summer peak period but it could be adjusted and applied likewise to the winter season. This would allow the analysis of the performance of the transport system during the winter months, identification of shortcomings, new network configuration and policy testing for the off-peak season. Therefore, it adds value to the transport model methodology developed in the Thesis as seasonality issues of the system under study can be also addressed with some adjustments.

18.1.5. Transferability to other regions

The Aegean Archipelagos due to its geographical and spatial particularities, tourism patterns and seasonality issues, form a unique case and a study area with challenges in addressing accessibility and mobility for assessment and future planning. It is not a representative study area but it can be identified with similar archipelagic ones.

More specifically, the study area has similarities with archipelagic formations in Norway, Finland, Canada, Sweden, Malay, Indonesia, Philippines, The Bahamas, Japan, Australia and Croatia among others. Therefore, the approach and methodologies discussed and justified in this Thesis are transferable to the abovementioned regions given that some necessary adjustments to the specific conditions and network of these regions will be made.

18.1.6. Planning ahead, sizing and scalability of transport infrastructure of the future

According to the UNWTO estimations and forecasts, tourists market globally will rebound to the levels of 2019 in the years to come after the Covid pandemic namely in 2023-2024. Besides the current uncertainties in tourism industry and based on the macroscopic forecasts before 2020 it is highly possible that tourists demand will continue to grow after this reset period. This will affect also the tourists' market with destination to the Greek islands. Already there were positive signs of recovery in the 2021 summer period. If the scenarios of dynamic growth of tourism in Greece become true, the transport system of the Aegean Archipelagos with its hinterland will face more challenges in the future if no new and innovative policies, measures and configurations are going to be implemented for the summer peak season. The methodology developed for this research is a planning tool that allows policy testing, sizing and scalability provisions of the infrastructure of the future towards sustainable solutions in the region of the Aegean.

18.1.7. Learning cycle and integration of parts A-B-C, transport demand model and simulation

Some of the findings of Part C are useful to calibrate the transport demand model developed in Part B. These inputs are listed below.

- Calculation of sea and air fares for all the routes of the study area as an input of cost for mode choice and for path choice formulation.
- Development of an Impedance based Kirchhoff mode choice model in lack of a big sample that would allow mode utility estimations with maximum likelihood statistical analysis
- Estimation of the value of travel time and its components namely, in-vessel travel time and waiting time for transfers by sea modes as an input to the mode choice and for path choice formulation

Findings of Part C are also used to produce updated skim matrices described in Part A that feed sequentially Part B. In this manner the transport model is improved overall, through a concept of learning cycle as depicted schematically in the following figure, by incremental adjustments. Incremental improvement is an approach to increase efficiency and accuracy in this case, in small steps as small findings of the analysis are added in the transport model updates.

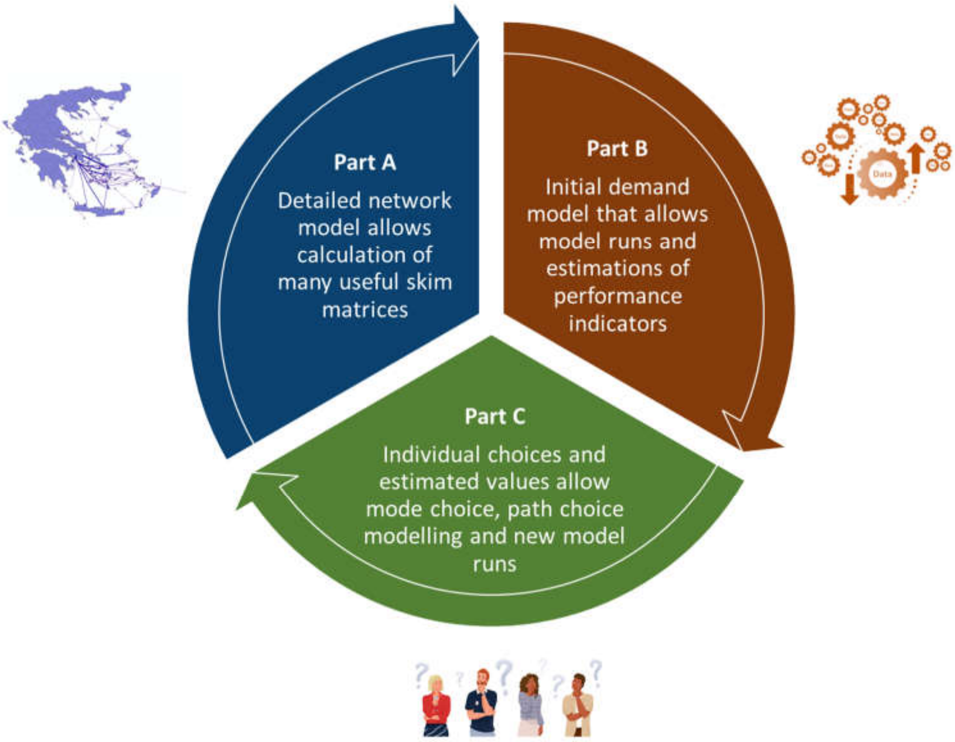

Figure D1. Learning cycle of Parts A-B-C

The transport demand model and simulation provide insights into the system under analysis. Additionally, a well calibrated model allows testing of policy scenarios, designs and projects for their sustainability assessment prior to the implementation. This is a powerful tool for decision-making before significant time and cost have been invested. Its success and reliability of forecasts, depend on the accuracy of the model.

18.1.8. Limitations and uncertainties

Not all of the findings of the Thesis are transferable and applicable to other regions of the world as the specific study area of the Aegean Archipelagos and its transport system has some unique elements that differentiate it from similar insular complexes. The elements are: the large number of islands, the short distances between the islands and the proximity to the mainland, the big number of airports in the area, the remarkable and complex coastal shipping network, the strongly peaking demand during summer.

For example, the Canary Islands, their natural mainland is Africa thought their geopolitical mainland is Europe and specifically Spain, which is far away. Indonesia has no mainland part it is purely archipelagic, etc.

Nevertheless, with the necessary adjustments, the method and approach presented here are transferable and applicable to other similar parts of the world.

There are limitations in modelling the whole region using the same path choice parameters and fare models, as there are specific markets with special characteristics e.g. the case of Athens-Crete with a strong coastal shipping share in spite of the long distance. This could be the reason why the majority of the references in the bibliography focus on case studies of a specific connection eg. Athens-Chios. In the current Thesis, it is intended to model all connections at an acceptable level of accuracy through validation processes with overall mathematical equations.

The system has a lot of uncertainties and it is sensitive to changes. For example, the abolishment of the air cabotage for domestic flights in Greece caused changes in the mode shares and trip patterns. Also, the effect of island hopping has never been assessed, there is a lack of specific surveys and studies in the fields of mobility of foreign tourists, passenger transfers etc. Additionally, unofficial or unplanned transfer hubs, need to be further investigated and the trends need to be quantified.

18.2. Restate contribution of the Thesis approach

The research was an incremental approach to the initial problematic and research scope, conducted in the following steps:

- **Step 1.** Collect data
- **Step 2.** Apply analytics
- **Step 3.** Visualise the results
- **Step 4.** Interpret insights

Knowledge, understanding, and appreciation of the transport system of the Aegean Archipelagos and its connections to the mainland and to distant countries are summarised in Part A of the Thesis. More aspects of the transport system, the demand side and travel decisions are discussed in detail throughout the whole Thesis.

5 Conclusions

Critical analysis of related work is provided with analytics and visualisations in Part B and C. Furthermore, in each one of the three parts of the Thesis, extended literature references and cross checks are presented.

Contributions, relevance and importance of this research lie in the insights, details, results and findings that are summarised; also, in the identification of missing information where a set of assumptions and working hypothesis are considered as a first approach to bridge the research gaps.

The approach and steps are presented also here in the schematic way of a pyramid, including the combination of sources and tools used in each intermediate step.

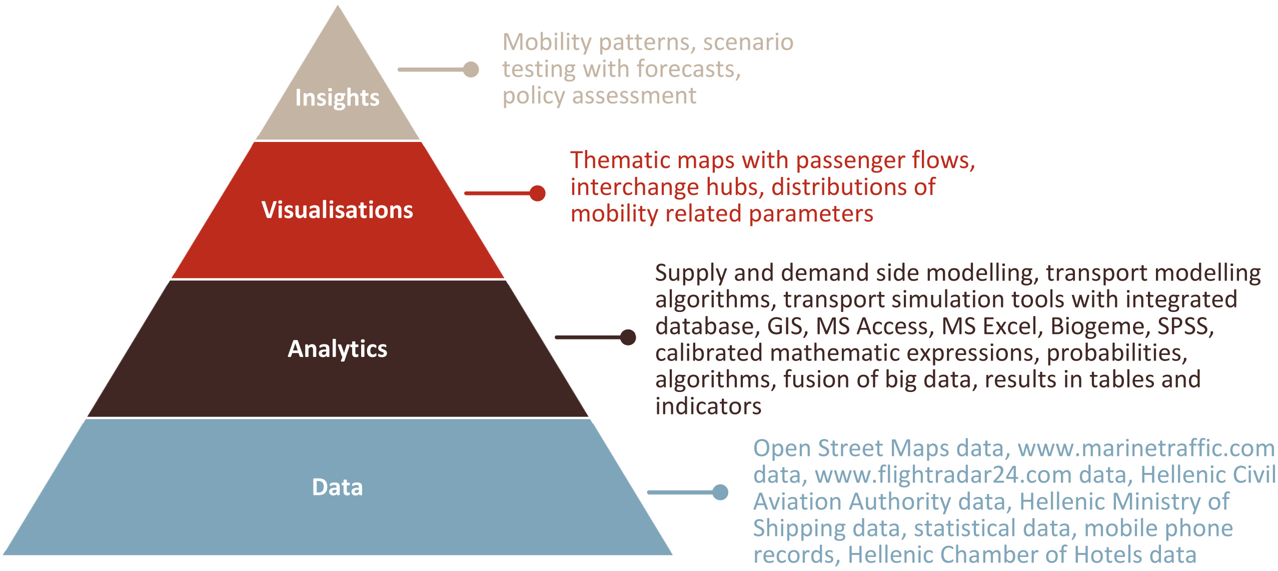

Figure D2. Schematic pyramid of the current research approach

In the current research, data is the collected information, network characteristics, demand characteristics, aggregated and disaggregated statistics, including surveys conducted for this research.

For the analytics step, in order to understand and explain that information, a variety of combined methods and tools is used, with cross checking of the results in each intermediate stage of the process.

Visualisations, offer added value and new information as they allow for geographical representations of characteristics of the transport system that wouldn't be possible only via performance indicators and tabular results.

Insights are pieces of knowledge and perception of the transport system under study, gained from understanding the mobility patterns in the area of the Aegean Archipelagos. These insights provide essential wisdom about the operation of the transport system and its users. Furthermore, it allows future forecasts and policy scenario assessment for further research.

18.3. Addressed research questions

All of the initial research questions are addressed as follows:

1. What are the strong points of the transport system of the Aegean and what are its weaknesses? Is the existing transport network integrated and to what extend? Is there complementarity of the transport modes in the area?

These questions are discussed thought the Thesis but more particularly in Part A and in Part C. Strong points of the transport system are very good and frequent connections from the transport hubs ie. ports and airports of the mainland to the major insular destinations. The existing transport system offers in overall, a fairly good level of service for travelling to the majority of the islands. There are adequate capacities of sea modes even in the peak summer season. Mode alternatives and respective fare options are available for the majority of the destinations.

Shortcomings of the network are observed primarily in the interconnection between the islands. It is calculated that 20% of the internal (between islands) OD pairs are only connected with maritime routes via Pireus. The level of network integration is described as insufficient with route structure of direct services and lack of organised and coordinated mode and route complementarity. Some missing links or connections are noted as well as isolated destinations. The air connections are strongly restricted by capacity in the high season with V/C ratios greater than 0.85. Double insularity challenges exist.

The complementarity of the two modes i.e. passenger maritime and aviation in the region of the Aegean Archipelago, is proved even in the existing situation with unorganized and uncoordinated transport services. The important intermodal hubs in the region are presented in thematic maps in Part C of the Thesis.

2. Is the mode choice modelling technique sufficient to describe and simulate the transport system of an Archipelagos, or does using multimodal paths instead offer a better solution?

Modelling separately land+air and land+sea paths and using modal OD matrices is not the best fitting solution as a significant share of trips are not properly represented with this approach. The

5 Conclusions

RP survey has indicated that a share of 15-20% of the trips to the Aegean Sea islands are following more complex multimodal paths where land, air and sea modes are combined. This introduces a multimodal and intermodal dimension in the analysis of the system that needs to be properly addressed in the model as well. It extends beyond the combination of a private or public mode for the land part of the trips to the Aegean Archipelagos and a public transport mode from the mainland transport hubs to the islands either by sea or air. To model effectively the combination and complementarity of the passenger maritime and aviation modes in the study area, the use of multimodal path assignment in place of the mode choice and assignment to the network is essential.

3. Can we model sufficiently the transport system of an Archipelagos when poor quality data is available and uncertainties exist in regard to modal share, trip chains, external to internal trip ratio, destination choice, demand segmentation into domestic and foreign tourists? Are big data from mobile phones a useful source of information on the question above as well as for identifying trip patterns in the Archipelago?

The topic of modelling the transport system of the archipelagos when only poor data is available refers mainly to underlying uncertainties on the demand side and characteristics of the trips. The question is yes, it is possible to calibrate the transport model and cover the demand side adequately using a large set of statistical data on the aggregated level, adding disaggregated data surveys of limited scale, exploiting big data from mobile phone records, combining the various datasets and defining some assumptions when necessary. Most of these issues are concluded in Part C but there are arguments in all other parts of the Thesis as well. The magnitude of the internal trips in an Archipelagos, in lack of sufficient data, is only partially solved in Part B when developing the demand model. Indications on the effect of internal trips exist also in the mobile phone records' analysis.

The use of big data from mobile phone records analysis is justified and presented in Part B. This process is proved a useful source of information in lack of detailed data and field surveys in this particular region. In the case of extracting geolocation anonymously of the travellers through their mobile phone devices, the spatial discontinuity in the Archipelagos turns into an advantage that allows clear tracing of passengers travelling by sea. Thorough processing of these records has proved that domestic tourists travel 20% longer distances by sea than foreigners. This constitutes a major difference in the mobility between domestic and international tourism in the area. The demand is therefore segmented in two major groups ie. domestic tourists and foreigners. The sensitivity of the final multimodal calibrated model is proved in the policy testing of the insular hubs.

As an exception, it is noted that there are some uncertainties in the system that fall outside the scope of this research and therefore are not addressed here, as the tourism sector is not a stable market but rather a dynamic one that follows its own trends as well as the regional[1] and/or global circumstances[2].

4. Are concepts of Public Transport planning applicable in the Aegean Archipelagos and similar areas?

This question is addressed in Part C of the Thesis where concepts of public transport planning focusing on the network structure and services relevant to the study area are presented. Arguments are provided for the applicability of specific network configurations in the Archipelagos. Shifting from direct services for the passenger maritime routes towards the hybrid services which is a mixture of direct and trunk-feeder services is advised. Such a configuration is further tested in the transport model with the example of two new minor insular hubs. Evidence is presented on the effectiveness of this policy that is derived from public transport planning practices for hybrid route structures and services.

5. Does an advanced public transportation modelling approach address adequately any technical matter related to the challenge of double insularity in an Archipelago context?

The double insularity challenge in an Archipelago context is discussed thoroughly in the bibliography with many different approaches but it is rarely explained with numbers. The findings of other papers and research works are confirmed in the Thesis and extended with the use of the advanced transport modelling tool. The particularities of the region are considered in the model that was developed for this analysis to deliver quantified results on the insularity effect, to highlight specific OD pairs with problematic connections and to identify missing links within the study area. Using detailed public transport modelling techniques, with some adjustments for long-distance trips and trip chains, offers a better alternative to the traditional modelling tools for researchers and practitioners who want to study an archipelagic transport system in detail. The modelling

[1] e.g. Natural disaster, political instability etc.
[2] e.g. Pandemic outbreak, economic recession etc.

approach that has been developed and presented, provides insights into the system and allows testing of various policy scenarios, for system improvements.

6. Would a transport policy of introducing minor islandic hubs in the study area improve network integration and the double insularity conditions in an Archipelago area? Are the users willing to transfer at insular hubs rather than at the traditional mainland ports? Is such a policy for implementing minor insular hubs justified by simulating and scenario testing in the transport model?

The willingness to use the new system with two minor hubs is reflected in the discrete choice survey and on the frequency of use question of the survey. The disutility of transferring at the insular ports is significantly lower than at the mainland ports indicating the acceptance of the alternative insular hubs. Specific numerical examples are presented in the probabilities graph of Part C where the preference of the alternative hubs is reflected even in the unusual case that the new routes are more expensive or the transfer wait times are longer etc. The new maritime routes via insular hubs are tested in the transport model and the effectiveness of the alternative hubs is justified, quantified and explained. The results are visualised and presented in thematic maps and graphs as well as in tables.

18.4. Contribution and innovation areas summary

The contribution and innovation of the Thesis lie in the following three areas: Data, Model and Policy. Innovation in the Data area includes employment of big data from mobile phone records (year 2013) that resulted in useful findings on tourists' mobility and segmentation. An innovative stated preference survey complements the Data sources to capture the disutilities of complex internal trips with chains. Contribution in the Model area lies in transferring techniques of detailed public transport modelling commonly used in urban mobility plans, adjusted accordingly to model and analyse long-distance holiday trips to archipelagic areas. Moreover, the conventional 4-step modelling is altered and a multimodal path choice combined step is adopted instead of the mode choice and assignment to the network steps. Discrete choice modelling is applied to assess willingness to use alternative port hubs for transfers in the archipelagos and to estimate VOTs of the various trip components.

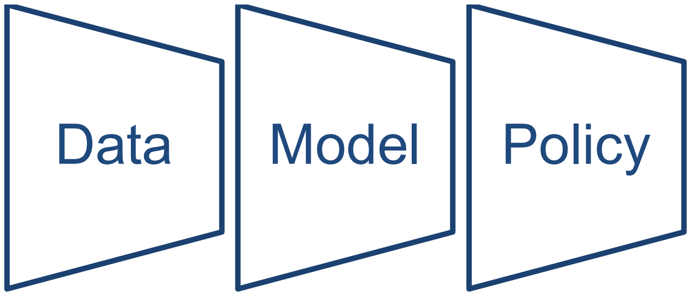

Figure D3. Contribution and innovation areas

The contribution of the areas Data and Model are integrated into Policy to deliver innovative methods and tools for mobility assessment and planning in archipelagic regions. In the area of Policy, the contribution is summarised in the justification of a hybrid public transport system with a small number of insular transport hubs at strategic locations in the Archipelagos for network integration and complementarity of the maritime and aviation modes. The particularities of the transport system of the Aegean Archipelagos add value and innovation qualities in the methodologies used for the main research areas of the Thesis.

18.5. Further research

18.5.1. Internal trips demand assessment

In the course of this analysis, a gap in the research and central data collection system has been identified that concerns the demand assessment of the internal trips in the Aegean archipelagos. The internal trips are generated by the following three reasons:

1. Visitors travelling to secondary islandic destinations for holidays or island-hopping effect eg. Mykonos-Santorini
2. Islanders traveling to other islands of the study area for work, business, education, social interaction or holidays trips eg. Chios-Lesvos
3. Final destination is only reachable via an interchange at a larger island, eg. Crete-Gavdos

This could be a significant component of the total demand for trips with destinations at the islands of the Aegean Archipelagos. Excluding strait connections such as Paros-Antiparos, Piraeus-Salamina, Kavala-Thassos, Thira-Thirassia, Chios-Oinousses etc., the demand for longer internal trips has never been studied before. The current research can only provide some indications that the demand for internal trips is significant and that additional induced demand could be generated in case the accessibility among the islands improves with new connections using a system of strategically located minor insular hubs in the area. Further studies that will target at recording the internal ODs and magnitude of this demand per traveller category, could justify in a more accurate way the proposed policies.

18.5.2. Trip scheduling and trip chains

Trip scheduling and trip chains is a significant component of travelling to the island of the Aegean Archipelagos. In Part A of the thesis a trip scheduling platform is presented as an application of the transport model developed for this research. This is becoming more important considering the findings of the current research that shows significant demand for combined trips, of trips to secondary holiday destinations and the island-hopping trend. In the current situation (reference year 2017) there is no provision of trip information and facilitation for trip chains. In the most recent years, a small number of commercial trip scheduling platforms were developed for the Greek islands. Still further research to better address this issue is summarised as follows:

- MaaS applications for the study area that enable users to plan, book, and pay for multiple types of mobility services through a joint digital channel.
- Interconnection between ports and airports at each island and interoperability of the two modes.
- Last mile connection of the airports and the islandic Chora i.e.capital and between the ports and Chora of each island.
- Alliances of operators to offer complete origin to destination travel services and single ticketing opportunities.

18.5.3. Mobility-as-a-Service for complicated trip chains to the Aegean islands

The lack of coordination and cooperation among the various transport operators of the two main modes that they are perceived currently as competitive could change in the future with the help of new technologies and Mobility-as-a-Service or MaaS concepts (Smith G. and Hensherd D., 2020).

5 Conclusions

The concept of Mobility-as-a-Service (MaaS) as defined by Smith (2020) is to integrate public transport with car-sharing and other similar services by providing digital applications for trips scheduling, booking and payment for a package of coordinated transport services. An added value of the transport model developed in the context of the current research is to serve as a platform for trip scheduling especially for complicated chains and intermodal trips in towards MaaS concepts in the specific area. The transport model serves as a detailed information system offering directions and alternatives on best routes, mode combinations on specific dates and specific time intervals. It also contains real times for the landside part of the journey when connecting major Greek cities of the peninsula to the Aegean Island. An indicative application towards MaaS concepts of this useful tool is presented in the following table with an example of combined land, air and sea transport.

Table D1. MaaS example for Attiki-Gavdos connection by sea & air combined

PATH INDEX	ORIG ZONE\ NAME	DEST ZONE\ NAME	FROM STOP AREA NO	TO STOP AREA NO	TSYS CODE	TIME PROFILE KEYSTRING	DEP	ARR	TIME	LENGTH	COST
1	Attiki		Athens Airport	Chania Airport	AIR	AEGEAN Airlines	31/7 05:05	31/7 05:55	50min	267km	120€
2			Chania Airport	Chania Airport		Transfer	31/7 05:55	31/7 06:30	* 35min	0km	0€
3			Chania Airport	Palaiochora Port	P+R TAXI	Road segment	31/7 06:30	31/7 08:10	1h 40min	90km	100€
4			Palaiochora Port	Palaiochora Port		Transfer	31/7 08:10	31/7 08:30	* 20min	0km	0€
5		Gavdos	Palaiochora Port	Gavdos Port	SEA	ANENDYK Gavdos Sealines	31/7 08:30	31/7 11:55	3h 25min	72km	20€
sum	*Attiki*	*Gavdos*	*Athens Airport*	*Gavdos Port*			*31/7 05:05*	*31/7 11:55*	*5h 50min*	*430km*	*240€*

*transfer time

18.5.4. Transport model tool for policy testing

The transport model that has been developed for the purpose of this thesis could be updated and enriched to test more policies and transport services in the region of the Aegean Archipelagos. This research, approach, methodology and findings are transferable with some adjustments to other regions of the world with insular networks.

The currently developed transport model with the combined use of pubic transport policy concepts can be expanded for the analysis, scenario testing and optimisation of the configuration of the "thin lines" during the winter season. In the Aegean Archipelago as well as in similar insular regions where there are state subsidised routes, optimising with this method can result in significant cost savings.

Alternative new travel mode policies such as on-demand services, for boat sharing and boat hailing to accommodate small distance sea trips, can be tested by expanding the transport model with more modes apart from the standard ones.

18.5.5. Green Deal and fuels, alternative ferry modes eg. coastal shipping with sails

The European Green Deal is a set of policy initiatives by the European Commission aiming at reversing or decelerating the climate change effect and reduce significantly greenhouse gas emissions in the European Union by 2050[3]. According to the International Maritime Organization (IMO), shipping accounts for 2-3% of global emissions which is higher than the 2% share generated by civil aviation in the year 2018.

Reducing greenhouse emissions from shipping can be done through more efficient and innovative ships that move at slower speeds and exploit renewable technologies such as sails. Coastal shipping for passenger trips with the use of sails could drastically reduce emissions in the short term and introduce a new era of renewable energy and zero-carbon fuels for shipping in the near future. There is a fast-growing share of people who are getting sensitive to the environmental footprint of travelling and tourism which could promote the acceptance of slower and/or more expensive zero-emission fuels. There is a work in progress study by a spanish team of experts on the implementation and the acceptance of coastal shipping services with sails in the region of the Aegean Archipelagos. They capitalise on the possible positive utilities of the holiday travelling experience with sail boats of massive transport even with lower speeds than the conventional fuel vessels. More concepts of environmentally sustainable shipping tested worldwide are electric, wind rotor, hybrid, kite and liquefied natural gas (LNG) ferries. The transport model that was developed for this Thesis can be expanded to include the new alternative energy vessels as new maritime modes and assess the difference in the environmental impact in the region.

Smart routes coordinated and optimised to reduce the travelled ship miles and still service all the insular destinations, is another measure that can be further investigated in the archipelago regions and give results in the short term. The transport model that was developed for this Thesis can be

[3] https://en.wikipedia.org/wiki/European_Green_Deal

used in this direction for route optimisations especially during the low season where the vessel occupancy is low and there is potential in increasing the occupancies with optimised routes structures. At the same time this solution decreases the total operational costs of the ferry service network. Appling a policy of one transfer could also be an option for the optimisation of the network, provided that the transfers are seamless, the transfer waiting times are reasonable and rest areas exist at the transfer ports with waiting facilities.

18.5.6. Agent-based modelling and special groups such as families

The transport demand model that was developed for this Thesis could be expanded and upgraded to an agent-based model (ABM) in order to analyse in more detail special groups or categories of travellers to the islands of the Aegean Sea. Agent-based are state-of-the-art models that are becoming popular nowadays as computational capacities and data availability increases with modern processors, tools and technologies including path recording from google maps, tom-tom and other platforms. ABMs analyse in a disaggregated level the travelling decisions of the agents that can be individuals or group entities of similar characteristics, to address their travel choices in a precise way. In the transport model that was developed for the current Thesis, there were two major groups of travellers at the peak season, i.e. domestic and foreign tourists.

The demand analysis could further be segmented to islanders and to special categories of tourists such as family groups as long as their travel decision parameters are calibrated and their special travel patterns are identified. There are approximately 1.4 million inhabitants of the islands in the study area including the ones of Argosaronicos gulf, Sporades and Thassos. This is a group of travellers with different characteristics than the tourists, affecting their trip purposes, choices on destination, mode and path level.

Another special group are families with children that their mobility and travelling decisions for holidays are ruled by distinct parameters that need to be further investigated. According to the heatmap of travelling companion per trip purpose graph presented in Part C and based on processing of data from the RP survey, 27% of the respondents which are domestic travellers stated that they were travelling for holidays with their family of one or more children. Therefore, family holiday trips are a significant share of the tourists' market in the Aegean Archipelagos that require further analysis.

The dimension of spatial interaction is another modelling component to be studied in better detail with the help of the ABM approach. Activity-based techniques can be integrated into the analysis to model adequately secondary holiday destinations, daily excursions to smaller islands, island hopping trips and other travel chains around the main holiday destination.

18.5.7. Lessons learned and closing comment

This research investigates the merits of PT simulation models of the urban passenger modelling theory to capture possible elements of the multi-domain, transportation architecture of the Aegean Sea (not captured by traditional methods) and yield lessons that could be transferred as success stories to other cases. It shows that the considered models have been of significant success concerning the linkage between network characteristics and performance, and demand satisfaction in the Aegean Sea. The Thesis suggests that such considerations may also be of use when assessing the efficiency of other Archipelagos' networks in different institutional contexts, and suggests that researchers should consider shifting their attention beyond the traditional methods of regional development and insularity theory.

The Aegean Archipelagos on the eastmost side of the Mediterranean Sea is considered by many as a cradle of civilization. Culture, writing, arts, science and prosperity together with the trade growth in this region, have caused the evolution of a dense transport network here since ancient times.

Combining the history of the region, the challenge of double insularity and the need for continuous progress that is also historically connected to the evolution of the transport systems, the following idea emerges: high-quality transport services, integrating innovation, new and smart technologies for mobility should be demonstrated here in the Aegean Archipelagos, this unique area that nowadays attracts millions of visitors from all over the world.

ANNEXES

19. ANNEXES

19.1. Annex A

19.1.1. Detailed external zoning system

The study area and its direct region of influence around the Aegean Sea constitute the core study area. The inland core study area is divided and examined in a NUTS 3 level 2013 (existing administrational level in 2013) while the Aegean islands are divided into smaller units in order to facilitate detailed and accurate system representation. The following table presents the detailed NUTS3 level zoning system in relation to the smaller TAZ level of the Aegean islands.

Table E1. Administrational level and related zoning system of the transport model

NUTS_2 ID AND NAME	NUTS_3 ID	NUTS_3 NAME	ISLANDS TAZ smaller regions
EL11 Anatoliki Makedonia-Thraki	EL111	Evros	Samothraki
	EL112	Xanthi	
	EL113	Rodopi	
	EL114	Drama	
	EL115	Kavala	Thassos
EL12 Kentriki Makedonia	EL121	Imathia	
	EL122	Thessaloniki	
	EL123	Kilkis	
	EL124	Pella	
	EL125	Pieria	
	EL126	Serres	
	EL127	Chalkidiki	
EL13 Dytiki Makedonia	EL131	Grevena	
	EL132	Kastoria	
	EL133	Kozani	
	EL134	Florina	
EL14 Thessalia	EL141	Karditsa	
	EL142	Larisa	
	EL143	Magnisia	Alonissos Skiathos Skopelos
	EL144	Trikala	

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NUTS_2 ID AND NAME	NUTS_3 ID	NUTS_3 NAME	ISLANDS TAZ smaller regions
EL21 Ipeiros	EL211	Arta	
	EL212	Thesprotia	
	EL213	Ioannina	
	EL214	Preveza	
EL22 Ionia Nisia	EL221	Zakynthos	
	EL222	Kerkyra	
	EL223	Kefallinia	
	EL224	Lefkada	
EL23 Dytiki Ellada	EL231	Aitoloakarnania	
	EL232	Achaia	
	EL233	Ileia	
EL24 Sterea Ellada	EL241	Voiotia	
	EL242	Evoia	Skyros
	EL243	Evrytania	
	EL244	Fthiotida	
	EL245	Fokida	
EL25 Peloponnisos	EL251	Argolida	
	EL252	Arkadia	
	EL253	Korinthia	
	EL254	Lakonia	
	EL255	Messinia	
EL30 Attiki	EL300	Attiki	Aegina Agkistri Antikythira Hydra Kythira Poros Salamina Spetses
EL41 Voreio Aigaio	EL411	Lesvos	Agios Efstratios Lesvos/Mytilini Limnos
	EL412	Samos	Fournoi Ikaria Samos
	EL413	Chios	Chios Oinousses Psara
EL42 Notio Aigaio	EL421	Dodekanisos	Agathonisi Astypalaia Chalki Kalymnos Karpathos Kasos Kos Leipsoi

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<table>
<tr><th>NUTS_2 ID AND NAME</th><th>NUTS_3 ID</th><th>NUTS_3 NAME</th><th>ISLANDS TAZ smaller regions</th></tr>
<tr><td rowspan="2"></td><td></td><td></td><td>Leros
Megisti/Kastelorizo
Nisyros
Patmos
Rhodes
Symi
Tilos</td></tr>
<tr><td>EL422</td><td>Kyklades</td><td>Amorgos
Anafi
Andros
Antiparos
Donoussa
Folegandros
Ios
Irakleia
Kea
Kimolos
Koufonisi
Kythnos
Milos
Mykonos
Naxos
Paros
Thira/Santorini
Schinoussa
Serifos
Sifnos
Sikinos
Syros
Tinos</td></tr>
<tr><td rowspan="4">EL43 Kriti</td><td>EL431</td><td>Heraklion</td><td></td></tr>
<tr><td>EL432</td><td>Lasithi</td><td></td></tr>
<tr><td>EL433</td><td>Rethymno</td><td></td></tr>
<tr><td>EL434</td><td>Chania</td><td></td></tr>
</table>

19.1.2. Ports and airports as stops

Table E2. List of ports in the study area

s/n	name	description
1	Aegina Port	islandic port
2	Ag.Konstantinos Port	islandic port
3	Agathonisi Port	islandic port
4	Agios Efstratios Port	islandic port
5	Agios Kirykos Port - Ikaria	islandic port
6	Agistri Port	islandic port
7	Aigiali Port - Amorgos	islandic port
8	Alonnisos Port	islandic port
9	Anafi Port	islandic port
10	Andros Port	islandic port
11	Astypalaia Port	islandic port
12	Chalki Port	islandic port
13	Chios Port	islandic port
14	Diafani Port Karpathos	islandic port
15	Donoussa Port	islandic port
16	Evdilos Port - Ikaria	islandic port
17	Folegandros Port	islandic port
18	Fournoi Port	islandic port
19	Gavdos Port	islandic port
20	Glossa Port - Skopelos	islandic port
21	Ikaria Airport	islandic port
22	Ios Port	islandic port
23	Irakleia Port	islandic port
24	Kalymnos Airport	islandic port
25	Kalymnos Port	islandic port
26	Karlovasi Port - Samos	islandic port
27	Karpathos Port	islandic port
28	Kasos Airport	islandic port
29	Kasos Port	islandic port
30	Kastellorizo Port	islandic port
31	Katapola Port - Amorgos	islandic port
32	Kea Port	islandic port
33	Kimolos Port	islandic port
34	Kos Port	islandic port
35	Koufonisi Port	islandic port

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36	Kythira port	islandic port
37	Kythnos Port	islandic port
38	Leros Port	islandic port
39	Lipsi Port	islandic port
40	Mesta Port - Chios	islandic port
41	Methana Port	islandic port
42	Milos Port	islandic port
43	Mykonos Port	islandic port
44	Myrina Port	islandic port
45	Mytilini Port	islandic port
46	Naxos Port	islandic port
47	Nisyros Port	islandic port
48	Panormitis Port_Symi	islandic port
49	Paros Port	islandic port
50	Patmos Port	islandic port
51	Poros Port	islandic port
52	Potamos Port_Antikythira	islandic port
53	Prinos Port - Thassos	islandic port
54	Psara Port	islandic port
55	Rhodes Port	islandic port
56	Samothraki port	islandic port
57	Santorini Port	islandic port
58	Serifos Port	islandic port
59	Schinoussa Port	islandic port
60	Sifnos Port	islandic port
61	Sikinos Port	islandic port
62	Skiathos Port	islandic port
63	Skopelos Port	islandic port
64	Skyros Port	islandic port
65	Spetses port	islandic port
66	Symi Port	islandic port
67	Syros Port	islandic port
68	Thassos Port	islandic port
69	Tilos Port	islandic port
70	Tinos Port	islandic port
71	Vathi Port	islandic port
72	Hydra Port	islandic port
73	Agia Roumeli Port	inland port of Crete

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74	Chania Port	inland port of Crete
75	Heraklion Port	inland port of Crete
76	Kissamos Port	inland port of Crete
77	Palaiochora Port	inland port of Crete
78	Sitia Port	inland port of Crete
79	Alexandroupoli Port	inland port of Greek peninsula
80	Ermioni port	inland port of Greek peninsula
81	Gytheio Port	inland port of Greek peninsula
82	Kalamata Port	inland port of Greek peninsula
83	Kavala Port	inland port of Greek peninsula
84	Keramoti Port - Kavala	inland port of Greek peninsula
85	Kymi Port	inland port of Greek peninsula
86	Lavrio Port	inland port of Greek peninsula
87	Neapoli Voion port	inland port of Greek peninsula
88	Piraeus Port	inland port of Greek peninsula
89	Rafina Port	inland port of Greek peninsula
90	Thessaloniki Port	inland port of Greek peninsula
91	Volos Port	inland port of Greek peninsula
92	Cesme Port Turkey	inland port of Turkish peninsula
93	Marmaris Port Turkey	inland port of Turkish peninsula

Table E3. List of airports in the study area

s/n	name	description
1	Alexandroupolis International Airport (AXD/LGAL)	inland airport of Greek peninsula
2	Astypalaia Island National Airport (JTY/LGPL)	Islandic airport
3	Athens Eleftherios Venizelos (ATH/LGAV)	inland airport of Greek peninsula
4	Chania International Airport (CHQ/LGSA)	Islandic airport of Crete
5	Chios Island National Airport (JKH/LGHI)	Islandic airport
6	Heraklion International Airport (HER/LGIR)	Islandic airport of Crete
7	Ikaria Island National Airport (JIK/LGIK)	Islandic airport
8	Kalymnos Island National Airport (JKL/LGKY)	Islandic airport
9	Karpathos Island National Airport (AOK/LGKP)	Islandic airport
10	Kasos Island Airport (KSJ/LGKS)	Islandic airport
11	Kastellorizo Airport (KZS/LGKJ)	Islandic airport
12	Kavala International Airport (KVA/LGKV)	inland airport of Greek peninsula
13	Kithira Island National Airport (KIT/LGKC)	Islandic airport

14	Kos Island International Airport (KGS/LGKO)	Islandic airport
15	Lemnos International Airport (LXS/LGLM)	Islandic airport
16	Leros Municipal Airport (LRS/LGLE)	Islandic airport
17	Milos Island National Airport (MLO/LGML)	Islandic airport
18	Mykonos Island National Airport (JMK/LGMK)	Islandic airport
19	Mytilene International Airport (MJT/LGMT)	Islandic airport
20	Naxos Island National Airport (JNX/LGNX)	Islandic airport
21	Paros National Airport (PAS/LGPA)	Islandic airport
22	Rhodes International Airport (RHO/LGRP)	Islandic airport
23	Samos International Airport (SMI/LGSM)	Islandic airport
24	Santorini Thira National Airport (JTR/LGSR)	Islandic airport
25	Sitia Public Airport (JSH/LGST)	Islandic airport
26	Skiathos Island National Airport (JSI/LGSK)	Islandic airport
27	Skyros Island National Airport (SKU/LGSY)	Islandic airport
28	Syros Island National Airport (JSY/LGSO)	Islandic airport
29	Thessaloniki International Airport (SKG/LGTS)	inland airport of Greek peninsula
30	Volos Nea Anchialos National Airport (VOL/LGBL)	inland airport of Greek peninsula

19.1.3. Maritime Fleet

Table E4. Fleet index 2015. source, http://www.gtp.gr/Ships.asp?International=0

NAME	TYPE	OPERATOR
ACHILLEAS (ACH)	Car Passenger Ferry	Skyros Shipping S.A.
ADAMANTIOS KORAIS (ADK)	Car Passenger Ferry	Zante Ferries A.N.M.E.Z. S.A.
AEOLIS (AEO)	Car Passenger Ferry	Aeolis Lines
AGIOS ATHANASSIOS (ODA)	Hydrofoil (Passenger only)	Agioreitikes Grammes (H.Q.)
AGIOS NEKTARIOS (ANK)	Car Passenger Ferry	ANES-Symi Lines (H.Q.)
ANCHIALOS (ANH)	Catamaran (Passenger only)	Tafion Maritime
ANDREAS KALVOS (AKA)	Car Passenger Ferry	Ionian Ferries (H.Q.)
APOLLON HELLAS (APH)	Car Passenger Ferry	Hellenic Seaways (H.Q.)
AQUA JEWEL (AQJ)	Car Passenger Ferry	NEL-Lesvos Maritime (H.Q.)
AQUA SPIRIT (ASP)	Car Passenger Ferry	NEL-Lesvos Maritime (H.Q.)
ARIADNE (ARD)	Car Passenger Ferry	Hellenic Seaways (H.Q.)
ARTEMIS (ART)	Car Passenger Ferry	Hellenic Seaways (H.Q.)
ATHINA (FDA)	Hydrofoil (Passenger only)	Aegean Flying Dolphins
AXION ESTI (ODE)	Car Passenger Ferry	Agioreitikes Grammes (H.Q.)
BLUE STAR 1 (IOT)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BLUE STAR 2 (BSB)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BLUE STAR DELOS (BDE)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BLUE STAR NAXOS (BSN)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BLUE STAR PAROS (BSP)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BLUE STAR PATMOS (BPA)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
BOB SFOUGARAKIS (BOB)	Motor Vessel (Passenger Only)	Salamina Lines
CAPTAIN ARISTIDIS (KAS)	Car Passenger Ferry	West Ferry Mar. Co.
CHAMPION JET1 (HSJ)	Catamaran - Car ferry	Sea Jets Consortium
DASKALOGIANNIS (DAS)	Car Passenger Ferry	ANENDYK Maritime S.A. (H.Q.)
DESPINA (DSP)	Motor Vessel (Passenger Only)	Kamelia Lines
DIAGORAS (DGR)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
DODEKANISOS EXPRESS (DEX)	Catamaran (Passenger only)	Dodekanisos Seaways
DODEKANISOS PRIDE (DEP)	Catamaran (Passenger only)	Dodekanisos Seaways
EKATERINI P (EKP)	Car Passenger Ferry	Fast Ferries
ERATO (ERA)	Hydrofoil (Passenger only)	Aegean Flying Dolphins
EXPR.SKOPELITIS (SKP)	Car Passenger Ferry	Small Cyclades Lines
EXPRESS SKIATHOS (SUC)	Catamaran - Car ferry	Hellenic Seaways (H.Q.)
FIOR DI LEVANTE (FDL)	Car Passenger Ferry	Levante Ferries (H.Q.)
FLYING CAT III (ATE)	Catamaran (Passenger only)	Hellenic Seaways (H.Q.)
FLYING CAT IV (FLJ)	Catamaran (Passenger only)	Hellenic Seaways (H.Q.)
FLYING CAT V (FLK)	Catamaran (Passenger only)	Hellenic Seaways (H.Q.)

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FREEDOM (FRE)	Motor Vessel (Passenger Only)	Hydra Lines
HIGHSPEED 4 (HIL)	Catamaran - Car ferry	Hellenic Seaways (H.Q.)
HIGHSPEED 5 (HIM)	Catamaran - Car ferry	Hellenic Seaways (H.Q.)
HIGHSPEED 6 (HIN)	Catamaran - Car ferry	Hellenic Seaways (H.Q.)
ILIDA II (ILD)	Hydrofoil (Passenger only)	Nisos Paxon Shipping Co.
IOANNA (IOA)	Caique (Passenger only)	Kalamos Local Lines
IONION PELAGOS (ION)	Car Passenger Ferry	Ionion P. Lines
IONIS (IOO)	Car Passenger Ferry	Ionis Ferries
KALYMNOS DOLPHIN (KAD)	Hydrofoil (Passenger only)	A.N.E. Kalymnou
KASOS PRINCESS (KAP)	Motor Vessel (Passenger Only)	Manousos Georgios Shipping
KATERINA STAR (KAT)	Motor Vessel (Passenger Only)	Spetses Local Lines
MAKEDON (MAK)	Car Passenger Ferry	Goutos Lines
MARMARI EXPRESS (MAX)	Car Passenger Ferry	Karystia Shipping Co.
MASTERJET (MEJ)	Catamaran - Car ferry	Sea Jets Consortium
MEGAJET (MGJ)	Catamaran - Car ferry	Sea Jets Consortium
MEGANISSI II (MEH)	Car Passenger Ferry	Ionios Meganissi Shipping
NEPTOUNE (NPT)	Motor Vessel (Passenger Only)	ANENDYK Maritime S.A. (H.Q.)
NISSOS KALYMNOS (NKL)	Car Passenger Ferry	A.N.E. Kalymnou
NISSOS KEFALONIA (KEF)	Car Passenger Ferry	Kefalonian Lines
NISSOS MYKONOS (NMY)	Car Passenger Ferry	Hellenic Seaways (H.Q.)
OINOUSSES III (OIN)	Car Passenger Ferry	Chios-Oinousses Lines
OLYMPIOS ZEUS (OLZ)	Car Passenger Ferry	ANEM S.A.
PANAGIA FANEROMENI (PAF)	Car Passenger Ferry	Mantalena I Shipping Co
PANAGIA SKIADENI (PSK)	Catamaran - Car ferry	Dodekanisos Seaways
PANAGIA SPILIANI (PSP)	Motor Vessel (Passenger Only)	Kateros Shipping Co.
PANAGIA THEOTOKOS (THE)	Hydrofoil (Passenger only)	Paros-Antiparos Shipping Co
PEGASUS (APE)	Motor Vessel (Passenger Only)	Aspiotis Lines
PORFYROUSSA (PFY)	Car Passenger Ferry	Porfyroussa Maritime
PREVELIS (PRE)	Car Passenger Ferry	Aegeon Pelagos Sea Lines
PROTEUS (PTE)	Car Passenger Ferry	ANES-Symi Lines (H.Q.)
PSARA GLORY (PSG)	Car Passenger Ferry	Agia Marini I Shipping Co
SAMARIA (SMR)	Car Passenger Ferry	ANENDYK Maritime S.A. (H.Q.)
SAOS II (SAO)	Car Passenger Ferry	SAOS Ferries
SEAJET 2 (SEJ)	Catamaran (Passenger only)	Sea Jets Consortium
SOFIA (ODS)	Hydrofoil (Passenger only)	Agioreitikes Grammes (H.Q.)
SPEED CAT 1 (SPC)	Catamaran (Passenger only)	Hellas Speed Cat
SPEEDRUNNER 4 (SSC)	Catamaran - Car ferry	Aegean Speed Lines (H.Q.)
SUPERFAST XII (SUI)	Car Passenger Ferry	Blue Star Ferries (H.Q.)
SUPERFERRY II (SUP)	Car Passenger Ferry	Golden Star Ferries
SUPERJET (SJT)	Catamaran (Passenger only)	Sea Jets Consortium

SYMI (SYM)	Catamaran (Passenger only)	Sea Dreams-Aegean Shipping Company
TAXIARCHIS (TAX)	Car Passenger Ferry	NEL-Lesvos Maritime (H.Q.)
TERAJET (TRJ)	Catamaran - Car ferry	Sea Jets Consortium
THEOLOGOS P (THP)	Car Passenger Ferry	Fast Ferries
VITSENTZOS KORNAROS (VIT)	Car Passenger Ferry	LANE (H.Q.)
ZAKYNTHOS I (ZAK)	Car Passenger Ferry	Kefalonian Lines
ZANADU (ZAN)	Motor Vessel (Passenger Only)	Nisos Paxon Shipping Co.

19.1.4. Connections per operator

Table E5. Seaborne operators and itineraries in the core study area, summer 2013

Seaborne Operators in the study area	Connections
Superfast Ferries	Piraeus - Heraklion Piraeus - Chania
Minoan Lines	Piraeus - Heraklion
Anek Lines	Lavrio - Cyclades Crete - Aegean islands Crete - Cyclades Crete - Dodecanese Piraeus - Aegean islands Piraeus - Sitia Piraeus - Dodecanese Piraeus - Cyclades Piraeus - Heraklion Piraeus - Chania
Hellenic Seaways	Crete - Cyclades Ag. Konstantinos - Skiathos Rafina - Cyclades Piraeus - Northeast Aegean Piraeus - Dodecanese Piraeus - Cyclades Piraeus - Syros Piraeus - Mykonos Piraeus - Paros Piraeus - Kos Piraeus - Rhodes Piraeus - Tinos Piraeus - Naxos Piraeus - Ios Piraeus - Santorini Piraeus - Serifos Piraeus - Sifnos Piraeus - Milos Rafina - Andros Rafina - Tinos Rafina - Mykonos Irakleio - Santorini Irakleio - Ios Irakleio - Paros Irakleio - Mykonos

	Piraeus - Chios Piraeus - Mytilini Piraeus - Samos Piraeus - Hydra Piraeus - Poros Piraeus - Aegina Piraeus - Agistri Volos - Skiathos Volos - Skopelos Volos - Alonnisos Ag. Konstantinos - Skopelos Ag. Konstantinos - Alonnisos
Blue Star Ferries	Piraeus - Irakleia Piraeus - Syros Piraeus - Tinos Piraeus - Mykonos Piraeus - Paros Piraeus - Naxos Piraeus - Ios Piraeus - Santorini Piraeus - Amorgos Piraeus - Schinoussa Piraeus - Koufonisi Piraeus - Donoussa Piraeus - Astypalaia Piraeus - Nisyros Piraeus - Tilos Piraeus - Patmos Piraeus - Leros Piraeus - Kos Piraeus - Rhodes Piraeus - Kalymnos Piraeus - Kastelorizo Rafina - Andros Rafina - Tinos Rafina - Mykonos Thessaloniki - Lesvos Thessaloniki - Chios Thessaloniki - Samos Thessaloniki - Kalymnos Thessaloniki - Kos Thessaloniki - Rhodes
Cyclades Fast Ferries	Rafina - Andros Rafina - Tinos Rafina - Mykonos
Nel Lines	Kavala - Lemnos Kavala - Lesvos Kavala - Samos Kavala - Chios Kavala - Ag. Kirykos Kavala - Ag. Efstratios Piraeus - Chios Piraeus - Mitilini Thessaloniki - Chios Thessaloniki - Lesvos Thessaloniki - Lemnos Thessaloniki - Samos Lavrio - Agios Efstratios

	Lavrio - Andros Lavrio - Folegandros Lavrio - Ios Lavrio - Kavala Lavrio - Kea Lavrio - Kimolos Lavrio - Kythnos Lavrio - Lemnos Lavrio - Chios Lavrio - Milos Lavrio - Naxos Lavrio - Paros Lavrio - Psara Lavrio - Lesvos Lavrio - Sikinos Lavrio - Syros Lavrio - Tinos Volos - Alonnisos Volos - Lemnos Volos - Skiathos Volos - Skopelos
Sea Jets	Rafina - Tinos Rafina - Mykonos Rafina - Paros Piraeus - Milos Piraeus - Folegandros Piraeus - Santorini Piraeus - Naxos Piraeus - Koufonisi Piraeus - Amorgos Crete - Santorini
Aegean Speed Lines	Piraeus - Ios Piraeus - Santorini Piraeus - Sifnos Piraeus - Sikinos Piraeus - Serifos Piraeus - Syros Piraeus - Tinos Piraeus - Mykonos Piraeus - Paros Piraeus - Naxos Piraeus - Milos Piraeus - Kimolos Piraeus - Folegandros
Agoudimos Lines	Rafina - Andros Rafina - Tinos Rafina - Mykonos
Ventouris Sea Lines	Piraeus - Kythnos Piraeus - Serifos Piraeus - Milos Piraeus - Sifnos
Dodecanisos Seaways	Rhodes - Tilos Rhodes - Symi Rhodes - Patmos Rhodes - Nisyros Rhodes - Lipsos Rhodes - Leros Rhodes - Kos

	Rhodes - Kastelorizo Rhodes - Kalymnos Rhodes - Agathonisi Rhodes - Chalki
Zante Ferries	Piraeus - Kimolos Piraeus - Milos Piraeus - Sifnos Piraeus - Serifos Piraeus - Kythnos

Table E6. Airborne operators and itineraries in the core study area, summer 2013

Airborne Operators in the study area	**Connections**
Olympic Air	Athens - Alexandroupoli Athens - Astypalaia Athens - Chania Athens - Chios Athens - Heraklion Athens - Ikaria Athens - Kalymnos Athens - Karpathos Athens - Kavala Athens - Kos Athens - Kythira Athens - Leros Athens - Limnos Athens - Milos Athens - Mykonos Athens - Mytilini Athens - Naxos Athens - Paros Athens - Rhodes Athens - Samos Athens - Santorini Athens - Skiathos Athens - Syros Athens - Thessaloniki Heraklion - Santorini Mykonos - Santorini Rhodes - Karpathos Rhodes - Kastelorizo Rhodes - Kos
Aegean Airlines	Athens - Alexandroupoli Athens - Chania Athens - Heraklion Athens - Kos Athens - Mykonos Athens - Mytilini Athens - Rhodes Athens - Santorini Athens - Skyros Athens - Thessaloniki Thessaloniki - Chania Thessaloniki - Heraklion Thessaloniki - Kos Thessaloniki - Mykonos

	Thessaloniki - Mytilini Thessaloniki - Rhodes Thessaloniki - Santorini
Astra Airlines	Athens - Sitia Thessaloniki - Chania Thessaloniki - Chios Thessaloniki - Karpathos Thessaloniki - Kos Thessaloniki - Mykonos Thessaloniki - Samos Thessaloniki - Santorini
Sky Express	Alexandroupolis - Sitia Athens - Kozani, Kastoria, Heraklion Chios - Mytilini, Samos, Rhodes Heraklion - Mytilini, Ikaria, Rhodes, Sitia, Kos, Athens, Kithyra Ikaria - Limnos, Thessaloniki, Heraklion Kastoria - Athens Kithira - Zakynthos, Heraklion Kos - Heraklion Kozani - Athens Limnos - Thessaloniki, Mytilini, Ikaria Mytilini - Heraklion, Limnos, Chios, Samos, Rhodes Preveza - Sitia, Corfu, Kefalinia Rhodes - Chios, Samos, Heraklion, Mytilini Samos - Chios, Rhodes, Mytilini Sitia - Alexandroupolis, Preveza, Heraklion Skyros - Thessaloniki Thessaloniki - Limnos, Skyros Zakynthos - Kefalinia, Kithira
Cyprus Airways	Athens - Thessaloniki Athens - Chania Athens - Heraklion Athens - Rhodes Thessaloniki - Heraklion Thessaloniki - Rhodes
Minoan Airlines	Athens - Heraklion Heraklion - Kos Heraklion - Mytilini Heraklion - Rhodes Heraklion - Santorini Rhodes - Santorini
Ryanair Airlines	Thessaloniki-Chania

19.1.5. Airline passenger flows on Greek airports

Table E7. Airline flows on Greek airports_Summary table July 2013 (source Hellenic Civil Aviation Authority abbreviated HCAA)

ID	name_gr	domestic_aircraft_arrivals/departures	domestic_passengers_arrivals	domestic_passengers_departures	foreign_aircraft_arrivals/departures	foreign_passengers_arrivals	foreign_passengers_departures	total_passengers_arrivals	total_passengers_departures
1	ΑΡΑΞΟΥ	0	0	0	240	15,129	14,176	15,129	14,176
2	ΑΚΤΙΟΥ	100	355	444	414	34,659	32,784	35,014	33,228
3	ΑΛΕΞΑΝΔ/ΛΗΣ	232	7,564	6,968	16	621	493	8,185	7,461
4	ΑΣΤΥΠΑΛΑΙΑΣ	80	1,104	1,065	0	0	0	1,104	1,065
5	ΑΓΧΙΑΛΟΥ	1	0	0	135	7,458	5,800	7,458	5,800
6	ΖΑΚΥΝΘΟΥ	124	2,351	2,223	1,400	118,853	112,770	121,204	114,993
7	ΗΡΑΚΛΕΙΟΥ	1,079	41,177	42,017	6,264	522,899	495,745	564,076	537,762
8	ΘΕΣ/ΝΙΚΗΣ	1,642	72,545	77,539	2,820	204,547	180,823	277,092	258,362
9	ΙΚΑΡΙΑΣ	184	3,077	2,673	0	0	0	3,077	2,673
10	ΙΩΑΝΝΙΝΩΝ	106	3,042	2,788	0	0	0	3,042	2,788
11	ΚΑΒΑΛΑΣ	152	3,331	3,077	256	17,245	14,992	20,576	18,069
12	ΚΑΛΑΜΑΤΑΣ	102	1,492	1,286	189	12,361	11,278	13,853	12,564
13	ΚΑΛΥΜΝΟΥ	132	1,363	1,304	0	0	0	1,363	1,304
14	ΚΑΡΠΑΘΟΥ	284	4,039	3,092	204	13,416	12,614	17,455	15,706
15	ΚΑΣΟΥ	128	272	221	0	0	0	272	221
16	ΚΑΣΤΕΛΟΡΙΖΟΥ	62	738	711	0	0	0	738	711
17	ΚΑΣΤΟΡΙΑΣ	50	273	301	0	0	0	273	301
18	ΚΕΡΚΥΡΑΣ	365	13,439	12,915	2,762	220,948	203,794	234,387	216,709
19	ΚΕΦΑΛΟΝΙΑΣ	160	2,917	2,649	556	45,284	42,900	48,201	45,549
20	ΚΟΖΑΝΗΣ	32	186	162	0	0	0	186	162
21	ΚΥΘΗΡΩΝ	124	2,348	2,330	18	473	482	2,821	2,812
22	ΚΩ	410	10,984	10,078	2,622	205,403	192,707	216,387	202,785
23	ΛΕΡΟΥ	154	1,940	1,703	0	0	0	1,940	1,703
24	ΛΗΜΝΟΥ	272	4,309	3,332	30	1,950	1,883	6,259	5,215
25	ΜΗΛΟΥ	104	1,852	1,617	6	4	10	1,856	1,627
26	ΜΥΚΟΝΟΥ	558	24,013	25,349	822	51,501	44,260	75,514	69,609
27	ΜΥΤΙΛΗΝΗΣ	486	18,854	15,828	158	10,767	9,875	29,621	25,703
28	ΝΑΞΟΥ	80	1,387	1,393	8	175	176	1,562	1,569
29	ΠΑΡΟΥ	254	3,627	1,701	0	0	0	3,627	1,701
30	ΡΟΔΟΥ	960	34,472	33,164	4,457	377,425	360,603	411,897	393,767
31	ΣΑΜΟΥ	316	8,429	7,174	348	25,810	24,345	34,239	31,519
32	ΣΑΝΤΟΡΙΝΗΣ	690	30,780	35,221	954	61,327	59,108	92,107	94,329
33	ΣΗΤΕΙΑΣ	196	2,027	1,661	24	609	631	2,636	2,292
34	ΣΚΙΑΘΟΥ	66	2,401	2,504	409	29,814	29,381	32,215	31,885

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35	ΣΚΥΡΟΥ	54	2,218	1,926	0	0	0	2,218	1,926
36	ΣΥΡΟΥ	54	683	860	0	0	0	683	860
37	ΧΑΝΙΩΝ	379	19,399	18,201	2,019	176,261	167,059	195,660	185,260
38	ΧΙΟΥ	310	9,420	7,609	52	2,033	1,813	11,453	9,422
39	ΑΘΗΝΩΝ	6,184	233,882	240,696	7,622	508,829	458,008	742,711	698,704
	ΣΥΝΟΛΟ	*16,666*	*572,290*	*573,782*	*34,805*	*2,665,801*	*2,478,510*	*3,238,091*	*3,052,292*

Table E8. Airline flows on Greek airports_Summary table August 2013 (source Hellenic Civil Aviation Authority abbreviated HCAA)

ID	name_gr	domestic_aircraft_arrivals/departures	domestic_passengers_arrivals	domestic_passengers_departures	foreign_aircraft_arrivals/departures	foreign_passengers_arrivals	foreign_passengers_departures	total_passengers_arrivals	total_passengers_departures
1	ΑΡΑΞΟΥ	2	0	0	254	17,022	17,285	17,022	17,285
2	ΑΚΤΙΟΥ	112	606	697	436	33,350	35,924	33,956	36,621
3	ΑΛΕΞΑΝΔ/ΛΗΣ	245	6,624	7,129	31	1,585	1,667	8,209	8,796
4	ΑΣΤΥΠΑΛΑΙΑΣ	82	1,169	1,251	0	0	0	1,169	1,251
5	ΑΓΧΙΑΛΟΥ	2	0	0	168	7,844	8,936	7,844	8,936
6	ΖΑΚΥΝΘΟΥ	126	2,329	2,502	1,502	122,569	127,054	124,898	129,556
7	ΗΡΑΚΛΕΙΟΥ	1,123	40,307	44,157	6,551	532,746	555,662	573,053	599,819
8	ΘΕΣ/ΝΙΚΗΣ	1,679	75,564	75,513	2,854	193,490	210,897	269,054	286,410
9	ΙΚΑΡΙΑΣ	184	3,150	3,457	0	0	0	3,150	3,457
10	ΙΩΑΝΝΙΝΩΝ	106	2,783	2,694	0	0	0	2,783	2,694
11	ΚΑΒΑΛΑΣ	152	2,734	2,887	260	16,430	17,875	19,164	20,762
12	ΚΑΛΑΜΑΤΑΣ	104	1,663	1,787	201	11,673	12,880	13,336	14,667
13	ΚΑΛΥΜΝΟΥ	144	1,230	1,493	0	0	0	1,230	1,493
14	ΚΑΡΠΑΘΟΥ	280	3,950	4,989	256	17,627	17,338	21,577	22,327
15	ΚΑΣΟΥ	128	227	360	0	0	0	227	360
16	ΚΑΣΤΕΛΟΡΙΖΟΥ	62	766	743	0	0	0	766	743
17	ΚΑΣΤΟΡΙΑΣ	52	278	319	0	0	0	278	319
18	ΚΕΡΚΥΡΑΣ	370	13,886	14,501	2,829	213,145	227,536	227,031	242,037
19	ΚΕΦΑΛΟΝΙΑΣ	160	2,776	3,524	584	45,112	47,093	47,888	50,617
20	ΚΟΖΑΝΗΣ	38	205	177	0	0	0	205	177
21	ΚΥΘΗΡΩΝ	124	2,273	2,464	16	314	340	2,587	2,804
22	ΚΩ	412	11,208	13,005	2,683	203,799	213,609	215,007	226,614
23	ΛΕΡΟΥ	180	1,915	1,890	0	0	0	1,915	1,890
24	ΛΗΜΝΟΥ	294	3,674	4,602	34	2,132	2,223	5,806	6,825
25	ΜΗΛΟΥ	104	1,833	1,627	0	0	0	1,833	1,627
26	ΜΥΚΟΝΟΥ	558	24,003	27,315	960	56,232	58,643	80,235	85,958
27	ΜΥΤΙΛΗΝΗΣ	408	14,526	16,891	190	13,028	13,613	27,554	30,504
28	ΝΑΞΟΥ	80	1,379	1,413	8	196	188	1,575	1,601

29	ΠΑΡΟΥ	266	3,463	1,689	0	0	0	3,463	1,689
30	ΡΟΔΟΥ	957	33,311	35,318	4,769	388,820	407,191	422,131	442,509
31	ΣΑΜΟΥ	320	8,361	9,551	362	24,412	25,055	32,773	34,606
32	ΣΑΝΤΟΡΙΝΗΣ	698	31,551	36,771	1,056	65,405	69,658	96,956	106,429
33	ΣΗΤΕΙΑΣ	206	2,318	2,627	24	728	676	3,046	3,303
34	ΣΚΙΑΘΟΥ	62	2,609	2,970	494	33,500	36,051	36,109	39,021
35	ΣΚΥΡΟΥ	58	2,667	2,824	6	3	5	2,670	2,829
36	ΣΥΡΟΥ	52	612	897	0	0	0	612	897
37	ΧΑΝΙΩΝ	374	18,834	20,336	2,026	166,725	178,611	185,559	198,947
38	ΧΙΟΥ	312	8,435	10,229	50	1,837	1,835	10,272	12,064
39	ΑΘΗΝΩΝ	6,245	245,572	219,967	7,767	465,551	528,463	711,123	748,430
	ΣΥΝΟΛΟ	*16,861*	*578,791*	*580,566*	*36,371*	*2,635,275*	*2,816,308*	*3,214,066*	*3,396,874*

19.1.6. International aviation elements

Table E9. International aviation codes of operators for non-regular and/or charter flights

Operator				
s/n	**IATA_code**	**ICAO_code**	**Company Name**	**Country**
5	FTL	FTL	#N/A	#N/A
6	GRV	GRV	#N/A	#N/A
7	HV	#N/A	Transavia	#N/A
9	JAF	#N/A	Jetairfly	#N/A
10	KL	KLM	KLM	Netherlands
11	KM	AMC	Air Malta	Malta
13	LLK	#N/A	#N/A	#N/A
14	LO	LOT	LOT Polish Airlines	Poland
15	LX	SWR	SWISS	Switzerland
16	MDF	#N/A	#N/A	#N/A
17	NJE	#N/A	#N/A	#N/A
18	NSK	#N/A	#N/A	#N/A
21	PGN	PGN	#N/A	#N/A
22	PLM	PLM	#N/A	#N/A
23	PVT	PVT	#N/A	#N/A
25	SK	SAS	SAS	Sweden
26	SRR	SRR	#N/A	#N/A
27	SUQ	SUQ	#N/A	#N/A
28	VLG	VLG	#N/A	#N/A
32	QS	TVS	Travel Service Airlines	
33	KCA	KCA	Trans-Kiev Airlines	Ukraine

34	E4	ENT	Enterair Airlines	Poland
35	3V	TAY	TNT Airways S.A.	Belgium
37	AF	AFR	Air France	France

Table E10. Direct international flights and passengers (summer 2013)

Country - destination	**Passengers via direct international flights (peak week 2013)**
Albania	**480**
Heraklion	288
Rhodes	192
Austria	**17,788**
Chania	1,882
Chios	121
Heraklion	2,475
Karpathos	1,008
Kos	2,911
Mykonos	1,034
Mytilini	447
Rhodes	4,190
Samos	822
Santorini	2,089
Skiathos	809
Belarus	**753**
Heraklion	140
Kos	64
Rhodes	549
Belgium	**19,335**
Chania	2,920
Chios	91
Heraklion	4,090
Kos	4,952
Mykonos	331
Mytilini	241
Rhodes	6,133
Samos	109
Santorini	468
Cyprus	**4,038**
Chania	1,991
Heraklion	443
Mykonos	222
Rhodes	545
Santorini	231

Skiathos	606
Czech Republic	**17,125**
Chania	719
Chios	68
Heraklion	3,596
Karpathos	354
Kos	4,437
Limnos	154
Rhodes	7,287
Santorini	255
Skiathos	255
Denmark	**26,711**
Chania	11,654
Heraklion	758
Karpathos	280
Kos	2,437
Mytilini	697
Rhodes	7,206
Samos	1,105
Santorini	1,878
Skiathos	696
Estonia	**171**
Heraklion	171
Finland	**13,529**
Chania	6,347
Heraklion	595
Kos	1,371
Rhodes	3,699
Samos	818
Santorini	397
Skiathos	302
France	**30,987**
Chania	1,369
Heraklion	17,139
Kos	2,239
Mykonos	1,470
Rhodes	6,657
Santorini	2,113
Germany	**61,631**
Chania	3,995
Heraklion	19,096
Karpathos	467
Kos	14,232
Mykonos	1,192
Mytilini	673

Rhodes	18,970
Samos	1,984
Santorini	772
Skiathos	250
Hungary	**1,815**
Heraklion	659
Rhodes	1,156
Iceland	**368**
Chania	368
Ireland	**463**
Heraklion	463
Israel	**26,129**
Heraklion	11,433
Karpathos	263
Kos	1,871
Mykonos	836
Rhodes	11,726
Italy	**60,306**
Chania	4,067
Heraklion	6,299
Karpathos	2,001
Kos	8,296
Mykonos	12,595
Rhodes	13,968
Samos	829
Santorini	9,207
Skiathos	3,044
Kazakhstan	**221**
Rhodes	221
Latvia	**251**
Heraklion	251
Lebanon	**1,497**
Mykonos	917
Rhodes	454
Santorini	126
Lithuania	**2,511**
Chania	355
Heraklion	316
Kos	901
Rhodes	939
Luxembourg	**1,938**
Heraklion	555
Kos	651
Rhodes	732

Malta	**48**
Heraklion	48
Netherlands	**30,679**
Chania	1,614
Chios	364
Heraklion	7,317
Karpathos	641
Kos	10,447
Mykonos	79
Mytilini	1,632
Rhodes	5,956
Samos	1,903
Santorini	482
Skiathos	244
Norway	**35,541**
Chania	15,011
Chios	210
Heraklion	1,403
Karpathos	528
Kos	3,124
Mytilini	236
Rhodes	10,806
Samos	682
Santorini	2,311
Skiathos	1,230
Poland	**18,393**
Chania	4,663
Heraklion	3,437
Kos	4,386
Rhodes	5,907
Portugal	**126**
Heraklion	126
Romania	**3,481**
Heraklion	982
Kos	482
Mykonos	171
Rhodes	1,064
Santorini	399
Skiathos	383
Russia	**66,005**
Chania	2,934
Heraklion	31,081
Kos	4,076
Rhodes	26,556

Santorini	1,358
Serbia	**2,308**
Chania	263
Heraklion	130
Kos	129
Mytilini	181
Rhodes	1,369
Skiathos	236
Slovakia	**3,186**
Heraklion	344
Kos	355
Rhodes	2,487
Slovenia	**1,984**
Heraklion	164
Karpathos	341
Kos	540
Mytilini	259
Rhodes	340
Samos	150
Santorini	118
Skiathos	72
Spain	**2,818**
Heraklion	453
Kos	238
Mykonos	803
Rhodes	434
Santorini	890
Sweden	**29,767**
Chania	10,268
Heraklion	1,649
Karpathos	828
Kos	2,140
Rhodes	10,921
Samos	1,383
Santorini	1,743
Skiathos	835
Switzerland	**14,529**
Heraklion	4,434
Kos	4,090
Mykonos	1,229
Rhodes	3,849
Samos	323
Santorini	604
Turkey	**1,392**

Heraklion	142
Mykonos	1,250
Ukraine	**6,853**
Heraklion	4,453
Kos	256
Rhodes	2,144
United Arab Emirates	**89**
Chania	89
United Kingdom	**89,523**
Chania	6,937
Heraklion	23,106
Kos	14,702
Limnos	835
Mykonos	3,653
Mytilini	895
Rhodes	28,119
Samos	530
Santorini	4,607
Skiathos	6,139
Grand Total	**594,769**

19.1.7. Determinants of accessibility of Greek islandic airports

Table E11. Determinants of the technical efficiency and accessibility of Greek islandic airports

Airport	Category 1	Category 2	Category 3	Category 4	Mixed use (civil and military)	WLU* per year	Access (km from the nearest city)
Astypalaia				*		18,640	8
Chania	*				*	1,917,838	14
Chios			*			266,590	4
Heraklion	*				*	5,514,584	5
Ikaria				*		26,806	12
Kalymnos				*		19,934	7
Karpathos			*		*	193,849	18
Kasos				*		14,332	1
Kastellorizo				*		9,817	4
Kos	*			*		1,688,309	27
Kythira				*		32,757	8
Leros				*		30,698	8
Limnos	*				*	150,080	22
Milos			*			34,101	6
Mykonos		*				447,937	4
Mytilini	*					586,454	8
Naxos			*			28,982	3
Paros			*			37,093	9
Rhodes	*					3,701,702	16
Samos	*					508,161	17
Santorini		*			*	772,490	7
Sitia		*				36,013	1
Skiathos		*				278,769	4
Skyros				*	*	13,182	11
Syros				*		7,915	3

**A Workload Unite (WLU) is defined as one passenger or 100 kgs of cargo*

Source: Greek Airports: Efficiency Measurement and Analysis of Determinants

Notes:

Category 1: International airports servicing both domestic and international scheduled and non-scheduled flights.

Category 2: Domestic airports which serve domestic flights and constitute legislated points of inbound and outbound traffic to/from the country through non-scheduled flights.

Category 3: Domestic airports which serve domestic flights and constitute occasional points of inbound and outbound traffic to/from the country through non-scheduled flights, based upon arrangement with operators/carriers.

Category 4: Purely domestic airports servicing only domestic flights.

19.2. ANNEX B1- Assumptions

19.2.1. Assumptions Used for Estimating Peak Week Demand by Sea

For the calculation of the observation in the SPSS model (obs), data were available per sea route and port at month level for the months Jul-Aug-Sep 2013, at the quarterly level. The reduction to the peak week, which is the reference week, was based on two parameters. Firstly, from the domestic flights network, comparable per-airport data were available at month level for the Jul-Aug-Sep 2013 quarter, as well as accurate passenger traffic data per day in the peak week, which is the reference-study period. Thus, it was possible to estimate a data conversion factor from the month to the peak week for 2013. It was estimated that the factor of reduction was f = 1 / 3.7 (or 0.267705), and the average was obtained between July and August. This figure is indicative of the peak week, especially from domestic tourists as:

$1/4 \leq f \leq 1/3$ or else $0.25 \leq f \leq 0.33$

f is greater than 0.25 that would reflect the direct reduction of the month to the week

Taking into account that there is also a 2nd parameter, the domestic flights were within the capacity limit (V/C=0.8), which means that the system does not precisely capture the peak as it is limited by the capacity.

However, the maritime passenger system has a much higher transport capacity and namely 7 times greater capacity than the domestic air transport passenger system, as it has been estimated from the research conducted based on data collected and processed. In this estimation the comparison between arrivals by sea and by air for islands, where at least one air connection is available, was used and the average number of the various cases was utilized.

Due to the fact that the capacity of the specific transport system by sea is subject to much lesser limitations than the air transport one, the assumption of a higher factor of reduction f (est) = 1/3 or 0.33 is thus justified.

For the strait connections, passenger traffic statistics were available on a quarterly basis rather than per month. In this case assumptions were made based on data available from other ports. For example, for the island of Salamis the factor 0.4 was used for the average passengers per month from the dataset July-August. The coefficient 0.4 was derived from the statistical processing of the other ports, where data were available per month.

19.2.2. Assumptions for the Sea Distribution of Demand in Crete

The attractions via SEA in the island of Crete, which is divided into 4 TAZ (one for each prefecture) with only 2 main entrance gates for tourists, was calculated using shares from the mobile phone data as follows:

Table E12. Summary of demand data with destination Crete

	Passengers alighting in ports	TAZ share from mob. Data	Estimated TAZ Attractions by SEA	Passengers alighting in airports	Estimated TAZ Attractions by AIR	Source: ITEP * (based on bed numbers)
Chania	21,022	30%	17,232	5,446	4,451	25.93%
Rethymno	0	15%	8,616	0	2,226	18.65%
Herakleio	36,082	40%	22,976	8,986	5,935	40.72%
Siteia	337	15%	8,616	406	2,226	14.70%
Total	57,441	100%	57,441	14,838	14,838	100%

* Hellenic Institute for Tourism Research and Forecasts (ITEP)

The percentages presented in the last column of the previous table are crossed examined using another source in the following table. More specifically the data presented here comes from the Eltis database. The results are consistent with the shares estimated in the previous table.

Table E13. Eltis database 2006 on tourists' accommodation supply in Crete

	Eltis code	Number of bedrooms in accommodation facilities	Number of bed-places in the region by 'bed-places in tourist campsites'	Number of bed-places in the region by 'bed-places in hotels and similar establishments'	share
Chania	113040304	22,243	856	40,795	25%
Rethymno	113040303	16,224	570	30,703	19%
Herakleio	113040301	34,587	870	66,353	41%
Lasithi/ Siteia	113040302	12,353	483	23,727	15%

19.3. ANNEX B2- Reference tables

19.3.1. Reference tables for demand model revision

Table E14. Basic figures of incoming tourism of the Region of Crete, year 2016

Region	Countries of origin	Arrivals in 1000
Crete	Germany	1,059.1
	United Kingdom	604.4
	France	447.0
	Netherlands	261.1
	Italy	224.2
	Belgium	186.0
	Switzerland	150.7
	Russia	150.0
	Rest	1,454.6
	Total	**4,537.0**
	% of the total for the whole country	**16.0%**

Source: Border crossings survey of the Bank of Greece, processing by INSETE Intelligence Greek Tourism Confederation

Table E15. Region of Crete, data on arrivals in hotel accommodation, 2013-2016

Regional units NUTS3		2013	2014	2015	2016
Heraklion	Arrivals of foreign visitors	1,264,996	1,328,598	1,331,789	1,510,454
	Arrivals of domestic visitors	123,694	133,864	139,427	146,543
Lasithi	Arrivals of foreign visitors	430,591	477,682	476,938	573,188
	Arrivals of domestic visitors	40,283	39,785	41,511	41,873
Rethymnon	Arrivals of foreign visitors	377,514	404,554	441,362	476,432
	Arrivals of domestic visitors	54,861	46,037	45,295	72,787
Chania	Arrivals of foreign visitors	668,130	719,802	732,725	774,776
	Arrivals of domestic visitors	106,018	100,588	107,357	110,808
total	**Arrivals of foreign visitors**	**2,741,231**	**2,930,636**	**2,982,814**	**3,334,850**
	Arrivals of domestic visitors	**324,856**	**320,274**	**333,590**	**372,011**

Source: Greek Tourism Confederation INSETE

Table E16. Basic figures of incoming tourism of the Region of Northern Aegean, year 2016

Region	Countries of origin	Arrivals in 1000
Northern Aegean	Turkey	143.4
	United Kingdom	43.9
	USA	23.4
	Germany	17.7
	Rest	99.7
	Total	**328.1**
	% of the total for the whole country	**1.2%**

Source: Border crossings survey of the Bank of Greece, processing by INSETE Intelligence Greek Tourism Confederation

Table E17. Region of Northern Aegean, data on arrivals in hotel accommodation, 2013-2016

Regional units NUTS3		2013	2014	2015	2016
Lesvos	Arrivals of foreign visitors at Lesvos	62,041	76,251	90,201	53,358
	Arrivals of foreign visitors at Limnos	3,404	3,520	15,120	13,185
	Arrivals of domestic visitors at Lesvos	48,469	46,257	41,432	38,525
	Arrivals of domestic visitors at Limnos	9,328	9,628	9,608	11,201
Samos	Arrivals of foreign visitors at Samos	94,163	99,609	104,817	89,177
	Arrivals of foreign visitors at Ikaria	1,590	2,418	3,447	2,050
	Arrivals of domestic visitors at Samos	19,582	18,997	19,713	20,196
	Arrivals of domestic visitors at Ikaria	5,737	8,433	6,463	6,732
Chios	Arrivals of foreign visitors	30,049	33,553	37,628	30,166
	Arrivals of domestic visitors	25,769	24,866	24,935	21,870
Totals	**Arrivals of foreign visitors**	**191,247**	**215,351**	**251,213**	**187,936**
	Arrivals of domestic visitors	**108,885**	**108,181**	**102,151**	**98,524**

Source: Greek Tourism Confederation INSETE

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Table E18. Basic figures of incoming tourism of the region of South Aegean (Cyclades and Dodecanese), year 2016

Prefecture	Country of Origin	Visitors in 1000
South Aegean	Germany	798.7
	United Kingdom	671.8
	Italy	488.3
	France	421.6
	USA	357.5
	Poland	220.7
	Netherlands	213.1
	Russia	176.5
	Rest of countries	1,878.4
	Totals	**5,226.5**
	% of totals	**18.4%**

Source: Greek Tourism Confederation INSETE

Table E19. Region of Cyclades, data on arrivals in hotel accommodation, 2013-2016

Regional units NUTS3	Cyclades	2013	2014	2015	2016
Syros	Arrivals of foreign visitors	2,948	3,698	4,094	3,766
	Arrivals of domestic visitors	17,538	18,239	25,543	27,314
Andros	Arrivals of foreign visitors	3,671	4,343	4,887	4,365
	Arrivals of domestic visitors	13,190	13,804	11,645	17,972
Thira (Santorini)	Arrivals of foreign visitors at Santorini and Anafi	117,434	154,474	175,114	153,549
	Arrivals of domestic at Santorini and Anafi	12,309	11,275	11,822	14,956
	Arrivals of foreign visitors at Ios	11,298	14,330	19,969	18,306
	Arrivals of domestic visitors at Ios	3,140	3,545	4,069	5,429
	Arrivals of foreign visitors at Folegandros and Sikinos	2,429	2,932	3,333	2,919
	Arrivals of domestic visitors at Folegandros and Sikinos	1,059	1,075	1,022	1,204
Kea - Kythnos	Arrivals of foreign visitors	93	126	181	401
	Arrivals of domestic visitors	1,976	2,230	2,435	5,157
Mylos	Arrivals of foreign visitors at Mylos and Kimolos	6,786	8,802	6,955	7,954
	Arrivals of domestic visitors at Mylos and Kimolos	4,659	4,963	6,308	6,705
	Arrivals of foreign visitors at Serifos	730	969	581	648
	Arrivals of domestic visitors at Serifos	1,677	1,657	1,885	1,962
	Arrivals of foreign visitors at Sifnos	2,326	3,440	3,094	3,592
	Arrivals of domestic visitors at Sifnos	3,076	3,043	3,306	3,629
Mykonos	Arrivals of foreign visitors	172,518	221,653	237,373	288,717
	Arrivals of domestic visitors	32,048	31,768	26,794	33,208
Naxos	Arrivals of foreign visitors at Amorgos	1,134	1,371	1,411	1,408

	Arrivals of domestic visitors at Amorgos	348	350	494	715
	Arrivals of foreign visitors at Naxos and Small Cyclades	12,547	19,243	33,140	20,430
	Arrivals of domestic visitors at Naxos and Small Cyclades	8,499	10,584	12,758	27,958
Paros	Arrivals of foreign visitors at Paros	41,043	52,194	58,422	51,852
	Arrivals of domestic visitors at Paros	18,509	19,720	15,588	21,241
	Arrivals of foreign visitors at Antiparos	1,201	1,348	1,423	1,276
	Arrivals of domestic visitors at Antiparos	266	243	235	360
Tinos	Arrivals of foreign visitors	3,039	3,539	2,088	2,889
	Arrivals of domestic visitors	41,559	42,128	43,921	31,539
Totals	**Arrivals of foreign visitors**	**379,197**	**492,462**	**552,065**	**562,072**
	Arrivals of domestic visitors	**159,853**	**164,624**	**167,825**	**199,349**

Table E20. Region of Dodecanese, data on arrivals in hotel accommodation, 2013-2016

Regional units NUTS3	Dodecanese	2013	2014	2015	2016
Kalymnos	Arrivals of foreign visitors at Kalymnos	6,346	6,293	5,547	6,077
	Arrivals of domestic visitors at Kalymnos	4,149	3,882	3,627	5,358
	Arrivals of foreign visitors at Agathonisi	0	0	0	0
	Arrivals of domestic visitors στο Agathonisi	0	0	0	0
	Arrivals of foreign visitors at Astypalaia	264	305	278	376
	Arrivals of domestic visitors at Astypalaia	589	515	477	573
	Arrivals of foreign visitors at Leros & Leipsoi	1,188	1,352	1,470	1,138
	Arrivals of domestic visitors Leros & Leipsoi	2,049	1,668	1,165	1,612
	Arrivals of foreign visitors at Patmos	8,022	9,595	10,329	9,890
	Arrivals of domestic visitors at Patmos	7,437	7,048	7,953	11,675
Karpathos	Arrivals of foreign visitors	33,855	36,101	35,013	38,164
	Arrivals of domestic visitors	3,669	3,629	4,029	4,290
Kos	Arrivals of foreign visitors at Kos	655,009	690,290	773,091	621,660
	Arrivals of domestic visitors at Kos	33,986	32,519	36,439	34,865
	Arrivals of foreign visitors at Nisyros	673	777	737	520
	Arrivals of domestic visitors at Nisyros	1,231	1,021	1,462	1,683
Rhodos	Arrivals of foreign visitors at Rhodos & Kastelorizo	1,360,663	1,468,681	1,508,201	1,687,058
	Arrivals of domestic visitors at Rhodos & Kastelorizo	99,568	98,277	91,262	104,528
	Arrivals of foreign visitors at Symi & Chalki	6,555	7,457	6,632	6,365
	Arrivals of domestic visitors at Symi & Chalki	2,543	2,573	2,827	3,228
	Arrivals of foreign visitors at Tilos	735	736	647	654
	Arrivals of domestic visitors at Tilos	125	115	176	145
Totals	**Arrivals of foreign visitors**	**2,073,310**	**2,221,587**	**2,341,945**	**2,371,902**
	Arrivals of domestic visitors	**155,346**	**151,247**	**149,417**	**167,957**

Table E21. Region of Sporades, data on arrivals in hotel accommodation, 2013-2016

Regional units NUTS3	Sporades	2013	2014	2015	2016
Skiathos	Arrivals of foreign visitors	-	55,924	59,265	58,821
	Arrivals of domestic visitors	-	19,784	15,635	20,128
Allonissos	Arrivals of foreign visitors	-	5,953	5,813	5,288
	Arrivals of domestic visitors	-	3,921	3,590	4,744
Skopelos	Arrivals of foreign visitors	-	12,280	13,092	13,267
	Arrivals of domestic visitors	-	12,802	9,332	11,946
Totals	**Arrivals of foreign visitors**	**-**	**74,157**	**78,170**	**77,376**
	Arrivals of domestic visitors	**-**	**36,507**	**28,557**	**36,818**

Source: Sporades Regional Operational Programme for 2014-2020

Table E22. Visitor flows per quarter at North Sporades

	mode	2014	2015	2016	2017
1st quarter	By air	1,406	1,463	1,716	2,570
	By sea	34,900	32,302	35,226	38,936
2nd quarter	By air	84,460	91,991	97,476	109,086
	By sea	126,898	137,249	136,877	147,484
3rd quarter	By air	224,301	254,562	287,708	286,549
	By sea	423,855	395,095	477,740	522,133
4th quarter	By air	5,230	5,067	8,101	10,113
	By sea	45,170	42,862	37,882	49,471
totals		946,220	960,591	1,082,726	1,166,342

* all passenger flows are summarizing arrivals and departures

* air passenger flows are for the airport of Skiathos

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Table E23. Passenger flows of the sea route Volos-Northern Sporades-Kymi

	2014	2015	2016	2017
1st quarter	54,591	50,865	55,402	55,579
2nd quarter	153,791	154,811	157,175	165,536
3rd quarter	483,636	446,238	527,537	546,558
4th quarter	64,599	62,794	55,705	65,968
totals	756,617	714,708	795,819	833,641

Source: Integrated Spatial Investment Business Plan of Northern Sporades Islands in Thessaly, 2019

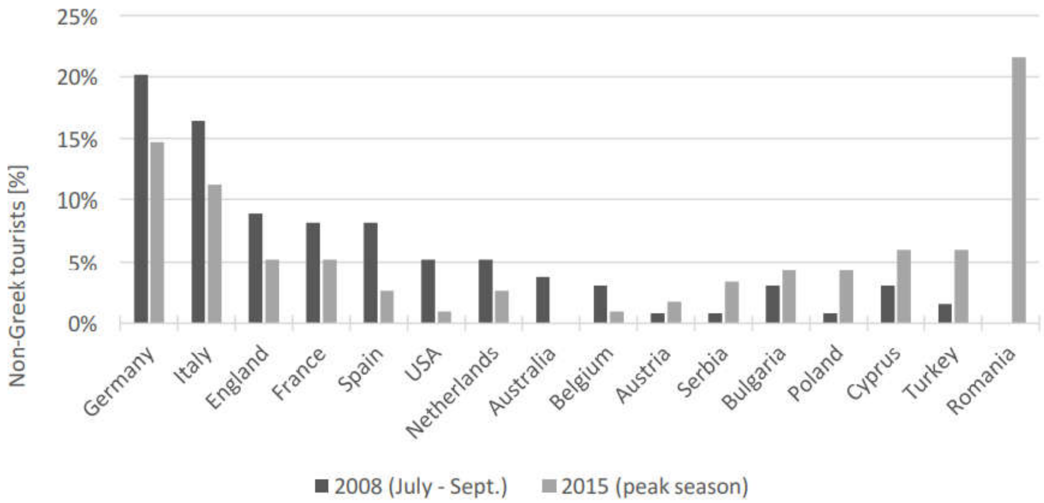

Figure E1. Most frequent origin of Non-Greek tourists in 2008 (July-Sept) (N=134) and the peak season of 2015 (N=116) surveys

Source: N.Schwaiger, Exploring Sustainable Tourism on Samothraki 2017

Table E24. Productions for distant zones

Country	Productions for distant zones % arrivals at hotels 2013 GR totals
Germany	12.81%
United Kingdom	11.57%
France	7.97%
Italy	7.07%
USA	6.43%
Russia	4.63%
Netherlands	4.17%
Sweden	2.71%
Belgium	2.50%
Poland	2.39%

Austria	2.09%
Norway	1.96%
Spain	1.76%
Denmark	1.69%
Switzerland	1.63%
Czech Republic	1.58%
Cyprus	1.50%
Australia	1.48%
Bulgaria	1.47%
Finland	1.33%
Canada	1.18%
Japan	0.78%
Turkey	0.66%
China	0.54%
Summary total	81.90%

source: ELSTAT

Table E25. Validation of the revised trip distribution

ZONE :NO	NAME	DTRAFFIC (IMEDAPOI)	ATTRACTIONS _ IMEDAPOI	DTRAFFIC (ALLODAPOI)	ATTRACTIONS _ ALLODAPOI
30	Heraklion	13,970	8,910	91,197	91,197
31	Chania	9,552	8,363	52,678	52,678
32	Lasithi	3,995	3,150	33,474	33,474
33	Rethymnon	5,536	5,892	40,499	40,499
50	Samothraki	4,436	4,367	1,024	1,024
55	Thasos	13,138	12,773	47,478	47,478
58	Antikythira	77	76	50	50
64	Kythira	1,765	1,668	1,093	1,093
74	Ydra	3,145	3,096	2,030	2,030
78	Poros	2,996	2,898	1,900	1,900
87	Aegina	18,664	18,342	12,026	12,026
98	Salamina	4,061	3,092	2,027	2,027
106	Anafi	756	749	333	333
108	Thirasia	81	73	698	698
109	Santorini	6,610	6,176	58,834	58,834
112	Folegandros	1,081	1,061	2,430	2,430
113	Sikinos	256	249	570	570
114	Milos	4,936	4,812	7,012	7,012
116	Ios	2,350	2,298	8,294	8,294
120	Kimolos	1,219	1,197	1,743	1,743
123	Irakleia	225	221	327	327
127	Shinousa	320	314	464	464
133	Amorgos	954	906	2,949	2,949
134	Koufonisi	1,622	1,612	2,377	2,377
141	Sifnos	4,871	4,808	3,642	3,642
142	Antiparos	1,265	1,235	5,589	5,589
150	Donousa	181	177	261	261

153	Paros	11,349	11,008	24,388	24,388
155	Naxos	12,183	11,727	17,300	17,300
156	Serifos	3,875	3,840	1,670	1,670
165	Kythnos	5,091	5,056	238	238
166	Mykonos	8,972	8,619	46,276	46,276
167	Syros	14,465	13,931	2,343	2,343
170	Tinos	23,456	23,239	1,696	1,696
171	Kea	7,972	7,910	373	373
174	Andros	12,193	11,966	3,336	3,336
176	Kasos	84	58	532	532
192	Chalki	185	168	432	432
203	Rhodos	12,065	8,270	113,347	113,347
204	Tilos	122	101	597	597
219	Nisyros	367	342	187	187
220	Ano Symi	1,936	1,859	4,782	4,782
221	Astypalaia	582	551	246	246
226	Kos	4,274	3,127	60,689	60,689
229	Pserimos	6	4	6	6
233	Telendos	7	4	6	6
237	Kalymnos	1,595	1,200	1,838	1,838
242	Leros	2,222	2,024	1,174	1,174
250	Lipsi	639	619	359	359
257	Patmos	2,117	2,032	2,192	2,192
259	Arkoi	69	68	1	1
261	Agathonisi	129	125	1	1
284	Skyros	5,274	5,203	636	636
303	Skopelos	5,277	5,152	4,950	4,950
304	Skiathos	6,650	6,485	18,363	18,363
307	Alonnisos	1,716	1,646	2,501	2,501
321	Inousses	420	401	466	466
324	Chios	7,402	6,126	7,134	7,134
325	Psara	238	228	266	266
329	Lesvos	9,963	7,816	9,988	9,988
330	Agios Efstratios	162	156	57	57
334	Limnos	5,773	5,356	1,951	1,951
343	Ikaria	5,739	5,530	1,532	1,532
344	Samos	3,445	2,616	12,591	12,591
345	Karpathos	811	643	5,923	5,923
347	Agistri	4,977	4,950	3,245	3,245
348	Kastelorizo	303	291	489	489
349	Gavdos	124	120	99	99
350	Fournoi	852	818	227	227
351	Spetses	2,295	2,197	1,441	1,441

	295,441	**272,096**	**736,866**	**736,866**
PEARSON	0.99		1.00	
R2	0.98		1.00	

Table E26. Validation at port level

STOPPOINT: NO	STOPAREANO	NAME	Arriving passengers (week) modelled	Arriving passengers (week) observed
2	218	Agathonisi Port	118	126
4	135	Agios Kyrikos Port	700	1,100
5	217	Ag.Konstantinos Port	11,286	6,545
10	213	Alonnisos Port	3,795	4,147
13	188	Aigiali Port Amorgos	331	991
14	187	Katapola Port Amorgos	3,381	2,864
16	176	Andros Port_Gavrio	13,976	15,302
20	193	Astypalaia Port	661	512
21	206	Chalki Port	598	600
23	194	Chania Port	22,550	18,072
24	24	Chios Port	9,011	9,823
28	138	Eydilos Port	6,396	5,172
31	181	Folegandros Port	3,260	3,491
32	223	Glossa Port - Skopelos	4,863	3,145
34	189	Heraklion Port	46,357	36,082
38	173	Ios Port	10,615	10,592
43	216	Kalymnos Port	2,296	2,714
44	136	Karlovasi Port	6,249	4,515
45	207	Karpathos Port	1,181	1,527
46	209	Kasos port	567	529
47	221	Kastellorizo Port	456	592
49	49	Kavala Port	4,806	4,142
50	178	Kea Port	7,510	8,283
54	183	Kimolos Port	2,676	2,940
55	55	Kissamos Port	9,253	1,191
56	195	Kos Port	10,727	9,876
58	179	Kythnos Port	4,949	5,294
59	167	Lavrio Port	12,206	13,911

60	215	Leros Port	2,268	2,727
61	140	Lipsi Port	1,560	978
64	171	Mesta Port	1,381	718
65	182	Milos Port	10,714	11,366
66	168	Mykonos Port	46,165	35,381
67	67	Myrina Port	5,495	5,799
68	68	Mytilini Port	10,243	10,650
70	175	Naxos Port	24,249	28,633
74	204	Nisyros Port	529	529
76	172	Paros Port	32,255	34,504
77	139	Patmos Port	4,047	4,224
81	81	Potamos Port_Antikythira	114	125
87	190	Rodos Port	22,445	17,389
90	90	Samothraki port	4,914	5,391
92	185	Serifos Port	5,695	5,510
93	184	Sifnos Port	7,712	8,450
94	180	Sikinos Port	743	819
95	196	Sitia Port	865	337
96	211	Skiathos Port	15,728	16,306
97	212	Skopelos Port	4,930	6,957
98	214	Skyros Port	4,747	5,228
101	166	Syros Port	14,917	16,114
103	103	Thessaloniki Port	782	1,009
104	174	Santorini Port	44,327	41,382
107	205	Tilos Port	647	698
108	177	Tinos Port	23,255	24,935
109	109	Vathi Port	4,185	2,314
110	191	Volos Port	9,308	14,224
165	165	Fournoi Port	971	1,045
167	169	Agios Efstratios Port	197	213
168	170	Psara Port	454	494
169	186	Donousa Port	398	438
170	200	Koufonisi Port	3,873	3,989
171	199	Shinousa Port	705	778
172	198	Irakleia Port	497	548

173	210	Symi Port	5,641	6,641
224	224	Gavdos Port	201	219
226	226	Palaiochora Port	100	166
227	227	Alexandroupoli Port	4,914	5,301
233	233	Diafani Port Karpathos	61	150
234	234	Anafi Port	980	1,082
277	277	Kymi Port	6,289	6,282
283	283	Kythira Port	10,516	1,969
285	285	Kalamata Port	21	369
		SUM	**540,812**	**506,459**
		PEARSON		0.97
		R2		0.96

Table E27. Validation at airport level

STOPPOINT: NO	STOPAREANO	NAME	Arriving passengers (week) modelled	Arriving passengers (week) observed
120	8	Chios Airport	5,453	2,719
122	13	Heraklion Airport	111,884	140,484
124	21	Kythira Airport	466	792
128	15	Kos Airport	53,952	53,940
129	11	Karpathos Airport	5,180	4,889
134	134	Leros Airport	1,300	471
135	4	Limnos Airport	1,494	1,508
138	22	Mykonos Airport	22,231	19,514
140	5	Mytilini Airport	7,812	7,154
143	25	Rodos Airport	103,394	104,228
145	12	Chania Airport	43,229	47,287
146	7	Skiathos Airport	12,149	8,542
147	23	Samos Airport	5,095	8,378
148	19	Syros Airport	1,647	160
150	16	Santorini Airport	33,707	23,628
151	14	Sitia Airport	170	710
153	6	Skyros Airport	573	611
161	10	Milos Airport	2,297	458
162	18	Paros Airport	6,278	892
163	17	Naxos Airport	3,754	394
164	26	Astypalaia Airport	189	285
176	222	Kastellorizo Airport	257	188

182	235	Kalymnos Airport	1,204	324
236	236	Ikaria Airport	374	790
		SUM	**424,089**	**428,346**
		PEARSON		0.99
		R2		0.98

19.4. ANNEX C

19.4.1. VOT summary of main reference study

Table E28. Values of time for Greece, A.Polydoropoulou et.al 2004

No	Transport mode	Total VOT	VOT Purpose Professional	VOT Purpose Personal
1	Car	5.5	5.6	6.1
2	Bus	4.1	4.5	4.4
3	Train	3.6	3.9	2.6
4	Ship	4.7	4.9	4.3
5	Airplane	17.3	20.8	18.8

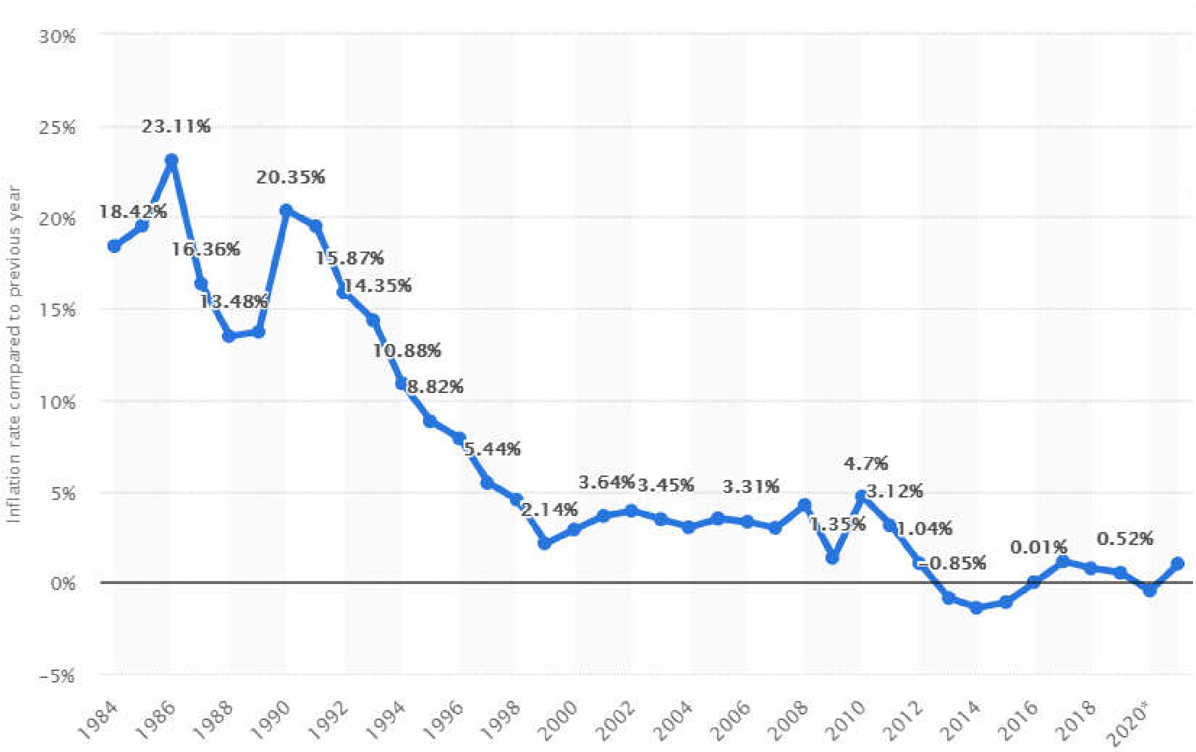

Figure E2. Inflation rates from 1985 to 2020 in Greece

6 Annex

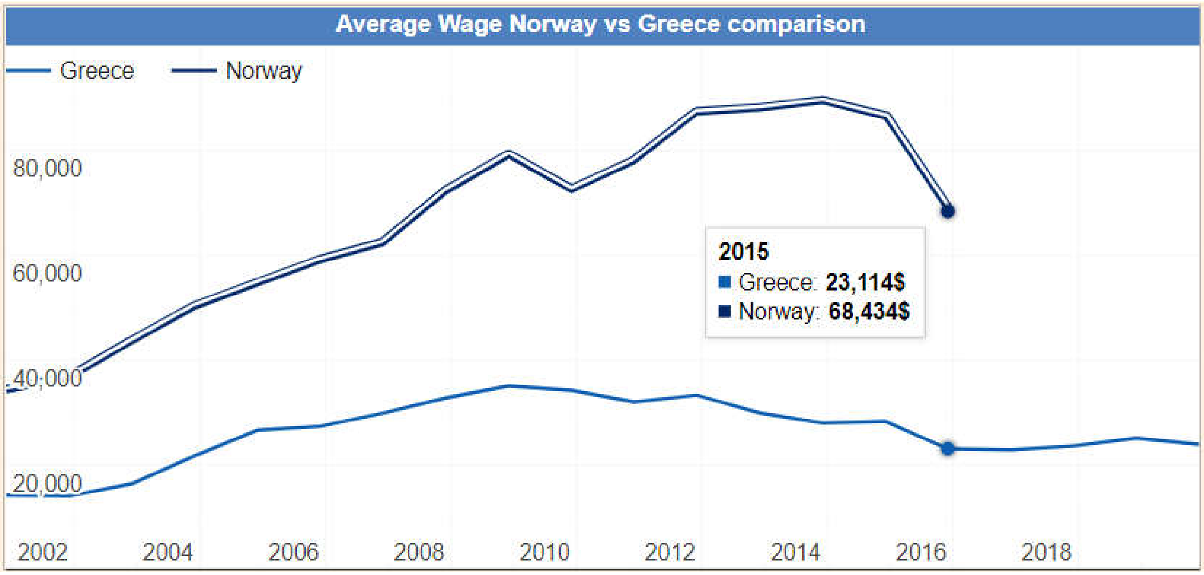

Figure E3. Comparison of average Wage Norway vs Greece

(source https://countryeconomy.com/)

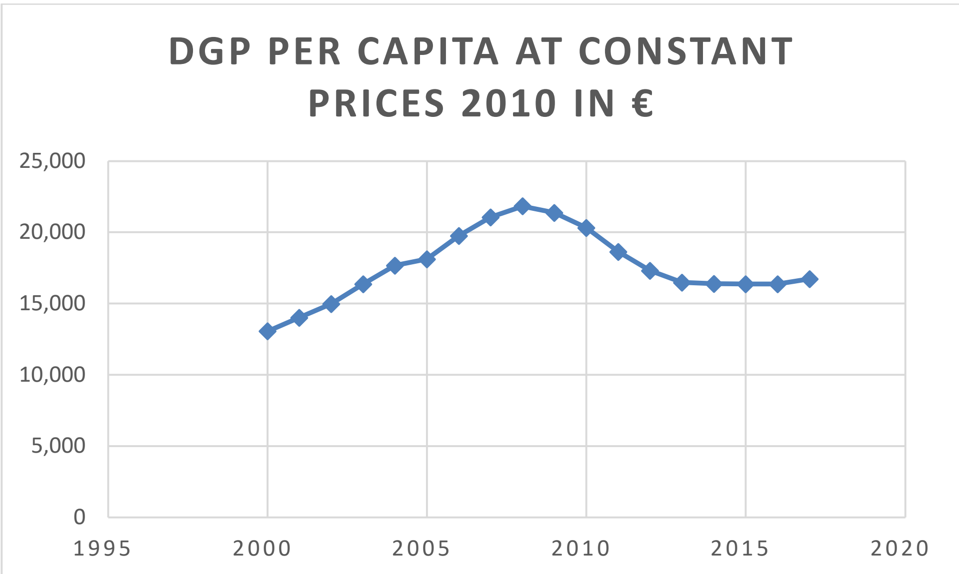

Figure E4. GDP per capita at constant prices 2010 in €

Source: Hellenic Statistical Authority, table A0702_SEL33_TS_AN_00_1995_00_2017_01_P_BI.xlsx

19.4.2. Fare model and costs clarifications

► Air mode

Travel time when it comes to travelling by airplane is more complex than other trip modes. According to the bibliography[1] and considering the Greek airports and their size, the airport time components consist of:

- ground access (departure) and egress (arrival) time
- terminal ground side (departure) ie. terminal access time (parking, shuttle bus), check-in, security screening time, time to reach the gate
- airside (flight), flight time including boarding time
- belt baggage time

In the table below, the inbound air travel times for the domestic trips to the islands of the Aegean Archipelagos are analysed. The values presented here are based on assumptions considering the size of the mainland hubs and the size of the insular airports. From this analysis it is concluded that the average air-bound trip to these islands is approximately 3h, as the airside part of the trip is not varying significantly.

Table E29. Time categories for direct aviation trips and time estimations

DEPARTURE	**Terminal ground side access time**	1-2h Average 1.5h	Terminal access time (parking, shuttle bus)
			check-in and security screening time
			time to reach the gate area
			gate time
FLIGHT	**Airside**	40-70min Average 60min or 1h	Flight time, including boarding time and time to connect between flights at an intermediate airport
			unexpected flight delay
ARRIVAL	**Terminal ground side egress time**	10-60min Average 30min or 0.5h	Time to reach baggage claim or exit the terminal (if no checked bags)
			baggage claim wait time and time to exit the terminal with claimed bags
	Estimated total	**~ 3h**	

[1] *Passenger Value of Time, Benefit-Cost Analysis and Airport Capital Investment Decisions, Volume 1: Guidebook for Valuing User Time Savings in Airport Capital Investment Decision Analysis (2015), Chapter: 2.1 Value of Time Breakdown by Trip Segment, S.Landau, G.Weisbrod, G.Gosling, C.Williges, M.Pumphrey, and M.Fowler; Airport Cooperative Research Program; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine*

Table E30. SPSS analysis for aviation fares for domestic trips from the RP

SPSS Statistics

Fare for AIR MODE for domestic flights

		Statistic	Bootstrap[b] Bias	Std. Error	95% Confidence Interval Lower	Upper
N	Valid	112	0	0	112	112
	Missing	0	0	0	0	0
Mean		78.6875	-.2609	4.8451	69.1575	88.4881
Std. Error of Mean		5.01175				
Median		70.0000	-.2340	3.9950	60.0000	80.0000
Mode		80.00				
Std. Deviation		53.03934	-1.45765	8.69081	35.65687	69.42387
Variance		2813.172	-77.046	911.790	1271.412	4819.673
Range		375.00				
Minimum		5.00				
Maximum		380.00				

b. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

19.4.3. Limnos Samothraki 2020 connection

Three years after the survey was conducted, the new line Alexandroupoli-Samothraki-Limnos was introduced. According to the article on the official website of the Hellenic Broadcasting Corporation ERT for the northern Aegean. The article says:

“A new line starts on Monday, June 8 (2020) in the North Aegean. It is a ferry connection of Limnos with Samothraki and Alexandroupolis, which will be conducted with the ship "Adamantios Korais" of Zante Ferries, while there will be three routes per week until September 6. The route is under subsidy. The new ferry connection is a constant request of the institutions of both Limnos and Samothraki and Evros, as it is expected to contribute to the strengthening of the tourist traffic of the two islands. The operators of Samothraki, anticipate that the itineraries will be able to serve and the travelers who will disembark at the port of Limnos to be able to continue their journey to Lavrio.”

Source: https://voreioaigaio.ert.gr/aktoploia/xekina-8-ioynioy-i-nea-grammi-alexandroypoli-samothraki-limnos/

In the past a route has started with SAOS Ferries Lavrio-Limnos-Samothraki-Alexandroupoli but there were a lot of interruptions as the operator encountered technical problems in the implementation of the itinerary. *Source:* https://www.alexpolisonline.com/2017/05/13.html

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