ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ΤΜΗΜΑ ΑΓΡΟΤΙΚΗΣ ΟΙΚΟΝΟΜΙΑΣ ΚΑΙ ΑΝΑΠΤΥΞΗΣ

ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ

ΟΡΓΑΝΩΣΗ ΚΑΙ ΔΙΟΙΚΗΣΗ ΕΠΙΧΕΙΡΗΣΕΩΝ ΤΡΟΦΙΜΩΝ & ΓΕΩΡΓΙΑΣ

ΣΥΝΕΡΓΑΖΟΜΕΝΟ ΤΜΗΜΑ: ΕΠΙΣΤΗΜΗΣ & ΤΕΧΝΟΛΟΓΙΑΣ ΤΡΟΦΙΜΩΝ

ΜΕΤΑΠΤΥΧΙΑΚΗ ΕΡΕΥΝΗΤΙΚΗ ΕΡΓΑΣΙΑ

ΤΙΤΛΟΣ ΕΡΓΑΣΙΑΣ

Υπολογισμός ανθρακικού αποτυπώματος (carbon footprint) σε στόλο οχημάτων αστικών διανομών της εταιρείας ΑΒ Βασιλόπουλος

Αλέξανδρος Ντζούφας

ΕΞΕΤΑΣΤΙΚΗ ΕΠΙΤΡΟΠΗ:

Σ. Ροζάκης, Αναπλ. Καθηγητής ΓΠΑ (Επιβλέπων)
Α. Καμπάς, Επικ. Καθηγητής ΓΠΑ
Ε. Κλωνάρης, Επικ. Καθηγητής ΓΠΑ

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ΣΥΝΟΨΗ:

Ένας από τους κύριους στόχους σε παγκόσμιο επίπεδο, είναι η μείωση των περιβαλλοντικών επιπτώσεων των ανθρώπινων δραστηριοτήτων καθώς και η ελαχιστοποίηση των εκπομπών αερίων του θερμοκηπίου. Σύμφωνα με ton Διεθνής Οργανισμός Ενέργειας, ο τομέας των μεταφορών ευθύνεται για το ένα τρίτο περίπου των παγκόσμιων ενεργειακών εκπομπών (23%). Η Ευρωπαϊκή Ένωση, με σκοπό την προώθηση της βιωσιμότητας στον τομέα των μεταφορών, έχει υιοθετήσει μια σειρά από πρότυπα και κατευθυντήριες γραμμές για την προώθηση της πράσινων εμπορευματικών μεταφορών σε περιφερειακό, εθνικό, αλλά και τοπικό επίπεδο.

Οι αστικές περιοχές ιδίως, βιώνουν σε μεγαλύτερο βαθμό τις αρνητικές επιπτώσεις από τις δραστηριότητες μεταφοράς και διανομής των εμπορευμάτων. Οι πιο σημαντικές πτυχές των εμπορευματικών διανομών οι οποίες εκτελούνται σε καθημερινή βάση περιλαμβάνουν τις δραστηριότητες του λιανικού εμπορίου, τις ταχυδρομικές υπηρεσίες, καθώς και τη διαχείριση των απορριμμάτων. Οι αρνητικές επιπτώσεις που απορρέουν από τις δραστηριότητες των εμπορευματικών μεταφορών έχουν αντίκτυπό τόσο σε περιβαλλοντικό(π.χ. εκπομπές διοξειδίου του άνθρακα) και κοινωνικό(κυκλοφοριακή συμφόρηση και ατυχήματα) επίπεδο, όσο και σε οικονομικό (λειτουργικά έξοδα). Η υφιστάμενη κατάσταση επιβαρύνεται από την ραγδαία ανάπτυξη του ηλεκτρονικού εμπορίου και των κατ’ οίκον παραδόσεων (πόρτα-πόρτα) σε συνδυασμό με τις περιορισμένες υπάρχουσες υποδομές που συνήθως εντοπίζονται στα σύγχρονα αστικά περιβάλλοντα. Δεδομένου ότι η μείωση των εκπομπών αερίων του θερμοκηπίου είναι απαραίτητη, η Ευρωπαϊκή Ένωση έχει θέσει σε εφαρμογή προγράμματα, υλοποιώντας μια σειρά από στρατηγικές και έργα σε συνεργασία με τα κράτη μέλη, προωθώντας τις πράσινες και βιώσιμες εμπορευματικές μεταφορές, επίσης γνωστές ως «βέλτιστες πρακτικές».

Οι βέλτιστες πρακτικές μπορούν να υιοθετηθούν σε αστικές περιοχές σε επίπεδο παραλαβής και παράδοσης των προϊόντων, ενοποίησης και στρατηγικές συγκέντρωσης καθώς και σε επίπεδο τεχνολογίας του οχήματος. Αναφορικά με την τεχνολογία του οχήματος, η χρήση του φυσικού αερίου (CNG / LNG) καθώς επίσης υβριδικά και ηλεκτρικά οχήματα φαίνεται να είναι μια βιώσιμη προοπτική. Σε ό, τι αφορά τις στρατηγικές συγκέντρωσης, τα αστικά κέντρα ενοποίησης (UCC) και η πολιτική εφοδιαστικής συγκέντρωσης των μονάδων διαδραματίζουν κεντρικό ρόλο, καθώς ενισχύουν την βελτιστοποίηση του συντελεστή φόρτωσης των εμπορευματικών οχημάτων. Όσον αφορά τις πολιτικές παραλαβής και παράδοσης, οι στρατηγικές εφοδιαστικής αλυσίδας και τα πληροφοριακά συστήματα μπορούν να παίξουν σημαντικό ρόλο στη μείωση της κυκλοφοριακής συμφόρησης, της ρύπανσης και του θορύβου. Πιο συγκεκριμένα, περιλαμβάνονται οι νυχτερινές παραδόσεις, τα διόδια εντός πόλεων ,οι ζώνες ειδικής προστασίας (LEZs) και τα

ευφυή πληροφοριακά συστήματα μεταφορών (ITS). Οι προαναφερθείσες πρακτικές σκοπό έχουν να γίνουν πρότυπο υιοθέτησης από αστικές περιοχές προκειμένου να επιτευχθεί πράσινη και βιώσιμη λειτουργία των εμπορευματικών μεταφορών.

Ο κύριος σκοπός της παρούσας εργασίας είναι η ανασκόπηση και η ανάλυση των μεθόδων και εργαλείων για τον υπολογισμό του ανθρακικού αποτυπώματος στον τομέα των εμπορευματικών μεταφορών και η υιοθέτηση της πιο κατάλληλης μεθόδου για τον υπολογισμό των εκπομπών του διοξειδίου του άνθρακα του στόλου διανομών της ελληνικής εταιρείας λιανικού εμπορίου, ΑΒ Βασιλόπουλος. Πιο συγκεκριμένα, παρουσιάζονται οι διαφορετικές μεθοδολογίες, τα εργαλεία και οι βάσεις δεδομένων που χρησιμοποιούνται ευρέως για τον υπολογισμό του ανθρακικού αποτυπώματος. Οι τρεις πιο σημαντικές μεθοδολογίες για τον υπολογισμό του ανθρακικού αποτυπώματος πιο συγκεκριμένα είναι: α) η μέθοδος EMEP / EEA του Ευρωπαϊκού Οργανισμού Περιβάλλοντος, β) το ευρωπαϊκό πρότυπο EN 16258: 2012 και γ) η μεθοδολογία που προτείνεται από το Ευρωπαϊκό Συμβούλιο Χημικής Βιομηχανίας (CEFIC). Το πρότυπο EN 16258:2012 εφαρμόστηκε για τον υπολογισμό του ανθρακικού αποτυπώματος στη μελέτη περίπτωσης που ακολουθεί, διότι πρόκειται για την πιο ακριβή μέθοδο σε περιπτώσεις όπου δεδομένα κατανάλωσης καυσίμου είναι διαθέσιμα. Οι παράμετροι που λαμβάνονται υπόψη για τον υπολογισμό είναι: κατανάλωση καυσίμου, διανυθείσα απόσταση, μεταφερόμενο φορτίο, ωφέλιμο φορτίο οχήματος και επιστροφές προϊόντων.

Η ανάλυση των ευρημάτων, δείχνουν ότι οι πιο σημαντικοί παράγοντες που επηρεάζουν τις εκπομπές διοξειδίου του άνθρακα είναι ο συντελεστής φόρτωσης και η κατανάλωση καυσίμου του οχήματος. Πιο συγκεκριμένα, όσο συντελεστής φόρτωσης αυξάνεται, οι εκπομπές διοξειδίου του άνθρακα ανά τόνο-χιλιόμετρο μειώνονται. Αντίστοιχα, τα οχήματα με υψηλή κατανάλωση καυσίμου εκπέμπουν περισσότερες εκπομπές διοξειδίου του άνθρακα ανά τόνο-χιλιόμετρο. Ένας άλλος σημαντικός δείκτης που συνδυάζει τους ανωτέρω παράγοντες είναι η κατανάλωση καυσίμου σε αναλογία με το μεταφερόμενο φορτίο. Όσο η αναλογία αυτή αυξάνεται, οι εκπομπές διοξειδίου του άνθρακα ανά τόνο-χιλιόμετρο ακολουθούν παρομοίως αυξητική πορεία.

Τον υπολογισμό του ανθρακικού αποτυπώματος διαδέχεται μια σειρά από προτάσεις συμπεριλαμβανομένης της αξιολόγησης του στόλου των οχημάτων σύμφωνα με τις εκπομπές διοξειδίου του άνθρακα ανά τόνο-χιλιόμετρο που παράγουν καθώς επίσης και σενάρια δρομολόγησης με κριτήριο την κατανάλωση καυσίμου. Πράγματι, τα οχήματα που αξιολογήθηκαν ως τα πλέον αποδοτικά ήταν αυτά με τη χαμηλότερη μέση κατανάλωση καυσίμου σε αναλογία με το μέγιστο μεταφερόμενο φορτίο. Όσον αφορά τα σενάρια δρομολόγησης, διαπιστώνεται ότι αν η κατανάλωση καυσίμου ληφθεί υπόψη κατά την καθημερινή διαδικασία της δρομολόγησης, είναι δυνατόν να επιτευχθεί εξοικονόμηση της τάξεως του 5% στην κατανάλωση καυσίμου και τις εκπομπές διοξειδίου του άνθρακα αντίστοιχα. Τέλος, με μια τιμή πετρελαίου της τάξεως του 1,2 ευρώ, μπορεί να επιτευχθεί εξοικονόμηση χρημάτων της τάξεως των 30 χιλιάδων ευρώ ετησίως.

Ορισμένα μελλοντικά βήματα για περεταίρω έρευνα στον υπολογισμό του ανθρακικού αποτυπώματος περιγράφονται παρακάτω: α) υπολογισμός του συνολικού ανθρακικού αποτυπώματος των εμπορευματικών μεταφορών της επιχείρησης, β) εφαρμογή των προτάσεων που πραγματοποιήθηκαν για τη μείωση των εκπομπών διοξειδίου του άνθρακα με σκοπό την επαλήθευση των αποτελεσμάτων που παρουσιάζονται και γ) υπολογισμός του ανθρακικού αποτυπώματος κατά μήκος του κύκλου ζωής προϊόντων ιδιωτικής ετικέτας που εμπορεύεται η εν λόγω εταιρία.

Επιστημονική περιοχή:

Διοίκηση εφοδιαστικής αλυσίδας, Logistics, Μεταφορές

Λέξεις κλειδιά:

Πράσινες εμπορευματικές μεταφορές, Ανθρακικό αποτύπωμα, Αστικές διανομές, Εφοδιαστική αλυσίδα

Summary

One of the main goals, in global level, is the reduction of the environmental impact of the human activities - as well as the minimization of the GHG emissions. According to the IEA (International Energy Agency), the transport sector is responsible for about one third of global energy emissions (23%). The European Union, in order to promote sustainability in the transport sector, which comprises one of the most important economic sources in Europe, has adopted a series of standards and guidelines for the promotion of green freight transport in regional, national as well as in city level.

Urban areas especially are experiencing a greater degree of negative impacts from freight transport/delivery activities. Indeed, typical freight deliveries that are executed in a daily manner include retail products and goods, post services as well as waste management. The negative impact arising from the urban freight distribution deals with the environment(e.g. CO_2 emissions), the society(e.g. traffic nuisance and accident fatalities and economy (increased operating costs). The increase of e-commerce, last-mile deliveries coupled with the poor (usually) city's infrastructure charge make the existing situation more complex. As the reduction of GHG emissions is essential, the European Union has launched a series of programs and projects and implemented various strategies and projects in cooperation with member states, making recommendations for green and sustainable freight transport, also known as "best-practices".

The best practices can be adopted in urban areas in terms of product's pickup and delivery, consolidating and pooling strategies and vehicle's technology. In terms of vehicle's technology, alternative fuels such as CNG/LNG, as well as hybrid and electric powered vehicles seems to be a viable perspective. As far as consolidation and pooling strategies are concerned, Urban Consolidation Centers (UCC) and logistics pooling play a pivotal role as they support the optimization of load capacity of freight vehicles and the minimization of empty running miles. The pickup and delivery schemes include city logistics strategies as well as information technology systems that can support the reduction of traffic congestion and noise pollution including night deliveries, tolls, LEZs and ITS. The aforementioned best practices can be adopted by urban areas in order to achieve green and sustainable freight transport operation in city level.

Based on the aforementioned issues, the main scope of this thesis is the review and the analysis of methods and tools for the calculation of the carbon footprint in the freight transport sector (with emphasis on city logistics) and the adoption of the most suitable method for the calculation of the CO_2 emissions in the fleet of vehicles of a Greek retail company. More specifically, in the thesis, various techniques, methodologies and tools for the calculation of the carbon footprint are reviewed.

The three most well-known methods for calculating the carbon footprint for road freight transport are: a) the EMEP/EEA method of the European Environmental Agency, b) the European Standard EN 16258: 2012 and c) the methodology proposed by the European Chemical Industry Council (CEFIC) are presented in detail. For our case study we adopted the EN 16258:2012 standard, since it incorporates the energy based scheme (i.e. calculation of CO_2 emissions via fuel consumption), which is the most accurate way for calculating the carbon footprint of a fleet of vehicles. The specific standard was applied to the private owned delivery fleet of the retail company AB Vassilopoulos. The parameters taken into consideration were as follows: fuel consumption, distance travelled, cargo delivered, vehicle's payload, product returns and backhauling (where applicable).

The analysis of the findings, showed that the most important factors that affect CO_2 emissions are the loading factor and the vehicle's fuel consumption. More specifically, as the loading factor increases, the CO_2 emissions per tonne-kilometer decrease. Furthermore, vehicles with high fuel consumption emit more CO_2 emissions per tonne-kilometer. Another significant indicator that combines the aforementioned factors is the fuel consumptions in relation to the freight delivered. When this ratio increases, the CO_2 emission per tonne-kilometer is also increased.

Further to the analysis of the current status of the delivery fleet of AB Vassilopoulos, a series of recommendations were developed including the assessment of the fleet of vehicles according to their CO_2 emission per tonne-kilometer and new vehicle-routing schedules based on vehicle's fuel consumption (i.e. green routing). The assessment resulted in the efficiency of the fleet in terms of CO_2 emissions per tonne-kilometer. Indeed, the vehicles with the lower average fuel consumption in relation to their maximum payload were evaluated as the most efficient tucks. As far as the second recommendation is concerned, it is revealed that if fuel consumption is taken into consideration during the daily process of vehicle routing, it is possible to achieve savings of 5% in fuel consumption and CO2 emissions respectively. Finally, with the diesel price being around €1.2 /litre, savings of approximately 30K euros can be achieved.

Finally, future steps include the following: a) the calculation of the total carbon footprint of the overall freight transport operations of the company, b) the implementation of the recommendations made for CO_2 emission savings and verification of the results presented and c) calculation of the carbon footprint throughout their life cycle in private label products.

Scientific work Area:

Logistics, Supply chain management, Transportation

Keywords

City logistics, Carbon footprint, Green freight transportation, Urban distribution

Forward

This thesis owes its existence to the inspiring guidance of my supervisor, Dr. Vasileios Zeimpekis. I am deeply grateful and I owe him all the knowledge I gained during my thesis preparation. I would also like to express my gratitude to the representatives of AB Vasilopoulos, Babis Hatzoglou, Vaggelis Konstantonis, Dimitris Maniadakis, Nikos Tahtsis, for their assistance and availability, and for providing me with valuable material for my thesis

I would also like to thank my family, who gave me the opportunity to realize the postgraduate studies of my preference as well as the moral support they have shown me throughout this period. I also owe many thanks to the members of my friendly environment for their psychological support.

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1. Introduction

The first chapter provides initially the rational of this thesis that deals with freight transport operations and their impact on the environment. Then, the main scope and the objectives of the thesis are presented, followed by the methodology used for the elaboration of this work. The chapter concludes with the presentation of the structure of this thesis.

1.1. The environmental impact of freight transport operations

Freight transport is vital for modern societies, guarantying the flow of goods from production points to distribution points, making them accessible to consumers. In urban areas where usually none of the primarily essential goods are produced, freight transport is even more necessary. Indeed, cities present the highest demand in consumable goods, due to the large number of people that live in (European Commission, 2008).

The process of transportation includes the distribution and collection of goods and is considered as one of the most important supply chain functions (Ballou, 2004). This process is very costly since it represents approximately the one third of the total cost of logistics processes (Ballou, 2004). Road transport holds the 44.9% of the total transport, followed by sea transport with a percentage of 37.2% (EU Statistical Pocketbook 2014). The main reason of the road transport dominance is the efficiency of the delivery and the flexibility in terms of route selection, compared with other modes of transport. Additional benefits arising from road transport are door-to-door services and the accuracy in delivery times, without particular time fluctuations (Ballou, 2004).

However, various negative environmental impacts arise from road freight transportation. More specifically, the emission of CO_2 - and other greenhouse gases result in additional pollution of the environment, worldwide. At regional level they contribute in the creation of acid rain and photochemical smog while in local level they can contribute negatively to the appearance of high levels of nitrogen oxide (NO_x), hydrocarbons (HCs), ozone (O_3), carbon monoxide (CO) and sulfur dioxide (SO_2). Further negative impacts of road transport are the noise pollution, the traffic congestion and the accident fatalities.

According to recent EU statistics, road transport is responsible for 71.9% of the total greenhouse gas emissions produced by all modes of transport (EU Statistical Pocketbook 2014). Furthermore, according to the World Health Organization (WHO), road accidents ranked third out of the ten most frequent causes of death with a proportion of approximately 23%.

By taking into consideration the growing demand for goods between Member - States and the negative impact caused during transportation, the European Union has already adopted certain policies aimed at reinforcing and promoting environmental friendly freight transport operations. The main goal of the EU is the development of sustainable transport while protecting the environment and human health.

Further to the EU actions, nowadays, it is necessary for companies and organizations to turn into green freight transport in order to comply with European and global regulations for environmental protection and at the same time in order to reduce their dependence from conventional fuels (fossil fuels).

1.2. Scope and objectives of thesis

The scope of the thesis is to map and review the most significant methods and tools for the calculation of the carbon footprint in the freight transport sector and the adoption of the most suitable method for the calculation of the CO_2 emissions in the fleet of vehicles of a Greek retail company, AB Vasilopoulos.

The specific objectives of this thesis are as follows:

- Mapping of current status on green freight transportation
- Presentation of EU and national policies for adopting green freight transport in city level
- Presentation of best practices that refer to green city logistics
- Review of methodologies and techniques for CO_2 calculation. The standards will be that are analyzed in detail are as follows:
    - EMEP / EEA air pollutant emission method (European Environmental Agency)
    - EN 16258: 2012 Standard
    - CEFIC-European Chemical Industry Council
- Implementation of the most suitable method to a delivery fleet of vehciles (case study)
- Analysis of results and recommendations

1.3. Methodology

The methodology adopted for conducting the research in this theis is presented in Figure 1.1.

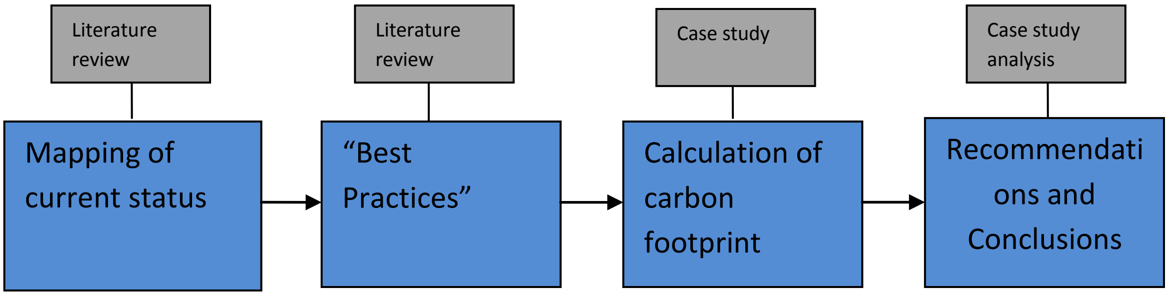

Fig. 1. 1: Thesis methodology followed

The first step involved the theoretical approach of green freight transport. There is a literature review according to the existing situation and the best practices in green freight transport using scientific articles, studies, books and the internet. The next step was the overview of the existing methods and standards for the calculation of carbon footprint in freight transport with particular emphasis on road freight transport, based on technical manuals. Three of the most important methodologies were selected to be examined for further analysis. The analysis was based on standards and directives of European Union as well as in technical manuals. Finally, the selection of the most appropriate method for the calculation of the carbon footprint (EN 16258:2012) follows. The latter was based on the evaluation of the available methods as well as according to the available primary data in order to achieve the desired level of accuracy.

The next step of this research included the calculation of the carbon footprint and the conclusions arisen from the aggregation of the results. For this reason, structured queries were created to record the distribution network. After recording the distribution network and collecting the necessary data (delivery trips, fuel consumption, vehicles used and cargo carried, returns and backhauling), data analysis and calculation of the carbon footprint follows. Afterwards, various scenarios were implemented targeting to reduce the CO_2 emissions of the company. Finally, the research concludes with the main findings according to the company's carbon footprint and the potential for further reduction.

1.4. Structure of dissertation

This dissertation consists of seven chapters and is its structure is as follows.

Chapter 1 briefly presented the main scope and objectives of this thesis followed by the methodology adopted to conduct the necessary research for the successful completion of the thesis.

Chapter 2 presents the literature review on issues related to green city logistics. The major types of urban freight distribution are described while the negative impacts that arise from urban deliveries are presented. Finally, recommendations of the European Commission for sustainable urban freight transport are given.

Chapter 3 presents a list of best practices where green strategies are adopted for urban freight transport. The chapter presents also a green logistics framework that comprises of three main pillars as follows: a) Green Technology (e.g. Vehicle technology), b) Green logistics (e.g. consolidating and pooling techniques, c) Green policies for pickup and delivery in urban environment.

Chapter 4 presents a classification of existing methods and techniques for the calculation of carbon footprint in freight transport. Three of the methods are described in detail, since they represent the most well-known methodologies for CO_2 calculation in road transport. The standard EN 16258:2012 is adapted for the calculation of the carbon footprint of the retail company since it was evaluated as the most appropriate due to the energy based data concerned(case study).

Chapter 5 presents the results from the calculation of CO_2 emissions of the privately owned fleet of vehicles of AB Vassilopoulos. The primary data used as well as the assumptions made for the calculation are described in detail. Subsequently, an analysis of the results is presented, followed by useful conclusions about the environmental performance of the fleet of vehicles.

Chapter 6 presents specific recommendations for the reduction of CO_2 emissions of the company’s fleet of vehicles. The recommendations are twofold. In first instance, an assessment of the fleet according to the CO_2 emissions is made. Then new vehicle routing schedules are proposed by taking into consideration the fuel consumption of each track. The chapter concludes with main findings arising from the recommendations.

The thesis concludes with Chapter 7 which summarizes the main findings of this thesis. Then, certain conclusions as well as a sum up of the recommendations - for reducing the carbon footprint of the delivery fleet are presented. The chapter concludes with directions for future actions.

2. Green City Logistics: Literature review and state-of-the-art

2.1. Introduction

In this chapter a literature review is performed in the field of freight transport operations in urban areas. In first instance, a categorization of urban areas takes place according to their population and geographical span. Then, major types of urban freight distribution are described coupled with the typical factors that affect the proper functioning of freight deliveries. The negative consequences of urban freight distribution are analyzed subsequently, indicating the effects on residents' lives. The chapter concludes with various recommendations of the European Commission for sustainable urban freight transport together with a list of European projects that are currently implementing those recommendations in cooperation with European countries and are indicated as best practices.

2.2. Categorization of Urban Areas

According to the United Nations, urban areas are defined as regions that have urban (i.e. built-up) land of 20 or more hectares that are less than 200 meters apart and linked to form a continuous built-up area. Below, a categorization of urban areas is performed according to their population and geographical span. Additionally, inefficiencies of freight distribution process that occurs in urban areas are also discussed respectively.

Metropolises

According to the United Nations, "metropolises" are identified as the largest European areas with a population of 3 million and over inhabitants. Apart from the population coverage, metropolises have a wide geographical range. Indeed, a metropolis consists of a central core city and a larger area around with the suburbs where inhabitants can commute to any sector of the city via underground, suburbian railway and bus networks. In metropolises, there are high concentrations of freight vehicle movements in contrast to the limited space available. This is why metropolises usually have significant problems regarding air quality and traffic flow. Local restrictions and infrastructure such as delivery time windows, low emission zones and pedestrianized zones are usually adopted in order to minimize traffic nuisance and noise so as to make them attractive for residents and visitors. Furthermore, in metropolises, there are usually logistic zones, located on the city's outskirts with access to rail or waterborne, combining warehousing, truck parking facilities and freight terminals. Based on a 3 million population threshold there are ten metropolises in Europe and, if ranked in terms of population, these cities are

London, Paris, Madrid, the Ruhr Area, Berlin, Barcelona, Athens, Rome, Hamburg and Milan(DG MOVE. 2012).

Other Large Urban Zones

According to the Eurostat definition, “Other Large Urban Zones**”** are urban areas with a population of 500.000 and over inhabitants, excluding metropolises as described above. These urban areas are usually retail and tourism centers and they face similar problems to metropolises, concerning poor air quality and high traffic congestion. Similar strategies are adopted by public authorities in terms of traffic management in order to improve freight transport and the living standards for residents. In terms of population, some of the cities that fall into this category are Bremen, Gothenburg, Krakow, Tallinn and Utrecht (DG MOVE, 2012).

Smaller Heritage Urban Areas

Although smaller heritage urban areas experience lower levels of traffic congestion and air pollution, they are also adopting various measures to minimize road traffic due to the importance of the city in cultural or heritage terms . An effective measure that is usually introduced in smaller heritage urban areas to regulate the aforementioned problems is delivery time windows for freight vehicles(e.g. early morning deliveries). Most Metropolises, Other Large Urban Zones and Smaller Heritage Cities in Europe have ring roads that provide the most suitable routes for long distance freight traffic (DG MOVE, 2012) Two European cities that belong in the category group are Ljubljana and Parma.

Other Smaller Urban Areas

These urban areas are relatively smaller in terms of population and geographic coverage. They may experience traffic congestion mainly during peak hours while they do not face significant problems in terms of air quality (DG MOVE, 2012). Freight vehicles can usually operate properly and this is why public authorities typically do not take any measures or restrictions to limit freight distribution.

2.3. Urban freight transport categorization and characteristics

Urban freight transport involves various stakeholders. On the one hand, those that are not directly involved such as residents, public authorities and visitors, and on the other hand the direct involved actors of the supply chain. Below there is a categorization of the major market sectors of urban freight transport.

Retail Market

Table 2. 1: Facilities of retail market

Retail Market Facilities	
Main Procedures	Collection
	Distribution
Secondary Procedures	Storage
	Packing
	Returns management

Retail market includes all those companies that deal with the sale of finished products to the end-user consumers. It is the link between bulk producers and final consumers (DG MOVE, 2012). Retail chain is characterized by unpredictability which means that both significant stocks and just-in-time deliveries of small quantities may be required according to the flow of demand. The main function that freight operators offer to the retailers are the collection and the distribution of the goods to the retail shops at specified time. Additionally there are further services that operators provide as it is the storage, packing and returns management in case of destroyed and out of date goods. In urban areas where the retail market is fragmented with a parallel fragmentation of supply chain (numerous suppliers which use their own vehicles for just-in-time deliveries), more freight deliveries with low load factor are required, increasing traffic congestion and costs (DG MOVE, 2012). Larger retail chains cooperating with logistics providers can increase their distribution efficiency by making better use of each vehicle's capacity and increasing the fill-rate. However, this contradicts the fact that consumers prefer small and medium-sized independent retail outlets due to the various choices that they provide (DG MOVE, 2012).

Express, Courier and Post deliveries

Express and courier transport services experience a significant development in urban areas. Express and parcel companies consolidate good flows destinated to the same urban sectors, reducing the total vehicle trip between regions. Courier operators use large or small to medium size vans for deliveries. Large vans are usually used to transfer goods between the regional depots while smaller good vehicles are used for inner deliveries. An express courier delivery tour can involve 70-90 deliveries, while a traditional parcel delivery tour serves about twenty receivers (DG MOVE, 2012). The efficiency of express and courier transport services is related to the local restrictions according to the freight vehicle’s access in the center of the city. Moreover, courier operators have to deal with time pressure and standardization of procedures, coming on their customers’ needs by collecting and delivering parcels in the same time windows.

Waste collection

Public authorities are responsible for waste harvesting in urban areas. In some cases they have their own fleet while others outsource their waste collection to private companies. Due to the increase of waste material, it is essential to follow new ways to deal with waste by aiming to recycling. With recycling, products are returning back to the original producers. This procedure requires specialized collection and transport and is considered as "reverse logistics"(OECD, 2003). Due to the high costs of collecting and transport, companies involved in reverse logistics need to achieve economies of scale in order to be cost efficient. Municipalities give high priority to waste collection and transport. Their optimization can make a significant contribution to the sustainability of cities by, for example, improving traffic flows through optimized fleet management and routing and by improving access to waste disposal facilities (e.g. collection points) (DG MOVE, 2012). According to Directive 2008/98/EC, authorities should implement additional measures to reduce the negative impacts on environment and human health involving waste production and management, as well as to make resource use more efficient. Waste management is an issue with plenty of potential, especially in urban areas and this is the reason that public authorities and private sector must cooperate.

Dangerous Goods transportation

Dangerous goods include hazardous waste, gasoline, gas cylinders (propane, acetylene, etc.) and chemicals. Transport of dangerous goods in urban areas has serious safety implications, and has become an increasingly important item on the political agenda (OECD, 2003). Vehicles that transfer "dangerous good" often meet restrictions of using designated bridges and tunnels, following alternative routes skipping crowded urban areas.

2.3. Challenges in urban freight distribution

The distribution of goods in urban areas is a necessary process for city's sustainability. Public space and infrastructure are used in a multiple way by citizens and business operators. Except from the factors that hinder the freight distribution which were described in the previous session, there are additional reasons that influence the efficiency of transportation. The significant increase of e-commerce and door-to-door services, the last-mile deliveries and the inefficient city's infrastructure are described below as the main factors that affect distribution's efficiency.

E-commerce

The explosive growth of the Internet use has led to a rapid development of e-commerce. It appears to be one of the fastest growing marketing channels for various products including both B2B and B2C transactions (OECD, 2003). In Europe more than four out of ten EU consumers (43%) have purchased goods and services over the Internet in 2011 (European Commission, 2012). The increasing success of e-commerce and home shopping has received growing attention in the literature because of its consequence for both private and freight traffic (Edwards *et al*., 2009). The impacts on traffic due to home delivery increase is a reference point for several authors (Braimaister, 2002;Weltevreden & Rotem-Mindali, 2009; TNO, 2010). On the one hand it is expected that home delivery will increase freight traffic while on the other hand less traffic related to shopping will take place as internet shopping will substitute physical shopping. However, the situation is more complicated as people tend to visit retail shops to try out the goods that are interested to purchase via internet. So they still making shopping trips but they buy less. According to the e-retailers, most of them do not have the necessary infrastructure to process e-commerce business, so they assign the logistics activities to express carries.

Last mile deliveries

A significant part of urban freight distribution is “last mile” deliveries. Gevaers *et al*., (2009) define as “last mile” “the final leg in a business-to-consumer delivery service whereby the consignment is delivered to the recipient, either at the recipient’s home or at a collection point”. Although rail, tram, underground and waterways can contribute in near “last mile” deliveries, road transport is the most significant mode due to its inherent flexibility. However, there are examples of alternative “last mile” deliveries in Europe as is the case of Utrecht where cargo boats make “last mile deliveries” to cafes and restaurants by using the inland waterways. Previous studies have shown that this last mile is responsible for greater emissions than the entire upstream process, which involves package collection, air freighting, and long-distance trucking (Edward *et al.*, 2010). For this reason, it is significant to focus on upgrading the vehicle’s engine technology from the diesel combustion to low and zero carbon technologies in urban areas. Electric and hybrid technology is a promising approach to reduce noise and CO_2 emissions.

Inefficient infrastructure

A common problem that is encountered in urban areas is the lack of road infrastructure which put barriers in freight vehicles to operate properly. A major issue is the lack of loading and unloading places for freight vehicles, both on-road and off-road. Even in some cases that a parking space for freight vehicles is available, it is often occupied by other unauthorized commercial or private vehicles. As result, freight vehicles are making round trips increasing road traffic and delivery costs as well as making double parks causing disruption to traffic and safety problems. (DG

MOVE, 2012). Additional problems that can arise from infrastructure limitations are height restrictions under elevated railways, roads or pedestrian crossing bridges.

Other factors that influence the efficiency of freight distribution are public restrictions and accident fatalities. Local authorities, especially in European cities, implement access restrictions to freight vehicles. The latter may differ according to various municipalities and include measures such as delivery time windows, vehicle's size or weight and vehicle's engine technology (DG MOVE, 2012). According to the accidents, when those are taking place on frequently used streets in urban areas, traffic jam and fatalities are created.

2.4. Operating factors that reduce the effectiveness of urban freight distribution

Inefficiency in distribution can also be derived from internal procedures of freight operators. The way that operators manage the vehicle's load factor, the number of total deliveries and the time spent in every single delivery, have direct impact on distribution's efficiency.

Low load factors

The load factor is the ratio of the average load to total vehicle freight capacity, in tones or volume (Adra *et al*., 2004). Load factor and empty running are the two main indicators of capacity utilization. Loading factors are generally far below the theoretical maximum but, in some market segments, this maximum is not reachable: certain goods (chemical products, milk) requires specialized vehicles that makes it impossible to find return loads (Madre *et al.*, 2010). The most effective way to incentivize the development of more sustainable UFT measures and practices (and reduce the amount of regulation) is to use the pricing mechanism i.e. through the internalization of external costs into the price of freight transport in urban areas and beyond (DG MOVE, 2012). Furthermore, other measures to optimize load factor is the consolidation and logistics pooling; Freight vehicles that operate in the same urban sector can share collection and delivery work, increasing their utilization and productivity. Finally, through investments in new technology (such as double-deck trailers or IT tools which facilitate load sharing and better route planning) can reduce empty and light running (Jensen & Boer, 2004). Low load factors are an issue of high importance due to the direct consequences to the traffic congestion, noise pollution and air quality.

Multiple deliveries

The optimization of distribution efficiency is a complex task (DG MOVE,2012). Inefficient distribution can arise from multiple deliveries to individual receivers with specific time windows. Retailers often establish time windows for receiving their deliveries. This may occur due to the type of the goods (perishable products) or to avoid conflict in sensitive urban environments between freight operators and pedestrians, making the market area more attractive. Another factor is the local restrictions which does not permit the entrance of freight vehicles to the inner city during peak hours. According to that, freight operators are required to perform all their deliveries at limited hours which lead to additional vehicle fleet, increasing the operating costs and making the distribution inefficient. Furthermore, when the retail market is fragmented, freight vehicles have to visit numerous urban sites to make just-in-time deliveries. In some cases, delivery frequency to retailers is, on average, higher than once a day as it happens in Rome which is indicative of poor distribution efficiency (DG MOVE, 2012).

Long service times

The time spent during loading/unloading coupled with the frequency of deliveries is an indicator of the delivery process efficiency. Different type of goods, according to the weight, value or frequency, can increase the service time of deliveries. Express courier operators which deliver small parcels and low weight documents with high value are making numerous deliveries with short service times to each single point. On the other hand, an 16.5 meter articulated HGV which is delivering ambient retail goods from a major supermarket to a single large retail outlet, requires more than one hour for loading/unloading (DG MOVE, 2012). Furthermore, long service times are usually made by the lack of parking availability for freight vehicles. The latter have to make round trips and finally double park in urban sectors where loading/unloading bays are not available.

2.5. Urban freight distribution impact

Urban freight transport is essential for the proper operation of urban areas. Some of the basic services that UFTs provides are the supply of retail shops with goods, parcels and documents deliveries to offices and waste remove from households. Nevertheless, we cannot neglect the negative impact of UFT in urban areas which are discriminated to environmental, social and economic.

According to the environmental consequences of urban freight transport, air quality and GHG emissions are the main factors examined.

Air Quality

Metropolises and large urban areas usually suffer from poor air quality (DG MOVE, 2012). City authorities are particularly interested in air quality issues, due to its impact on human health and to the European legislation. In case that they overcome the standards lay out in EU Directive, the penalties are significant. The majority of freight vehicles are diesel powered which produce high level of emissions. For that reason, electric and hybrid technology is the most promising alternative for reducing CO_2 emissions and improving air quality. Public authorities have introduced measures in order to improve air quality such as: a) low emission zones (LEZ) where diesel-powered vehicles are restricted and, b) congestion charges. Other measures that can contribute in the improvement of air quality are (Russo& Comi, 2012) are as follows:

- Tangible measures: sub-network, Urban Distribution Centre and Nearby Delivery Area
- Intangible measures: Intelligent Transportation System
- Measures that deal with infrastructure and equipment: sustainable performance and railway

GHG emissions

Freight vehicles involved in urban distribution emit various air pollutants and they are responsible for the 21% of CO_2 emissions (Schoemaker *et al.*, 2006). Although climate change is a matter of great attention, the result of GHG emissions is a worldwide issue with long term effects and this is why public authorities are aware. Urban areas have the largest share in polluting as they produce 80% of the total GHG emissions (ISPRA, 2009). In London during 2006 from the 9.6 million tons of carbon dioxide emitted by all forms of transport, some 23% was from freight vehicles (Endersbee, 2009). The European Commission Transport White Paper identifies a number of significant issues generated by transport, including the need to reduce GHG emissions to avoid significant climate change(European Commission, 2011). Low emission vehicles as electric, hybrid and CNG powered can contribute in reduction of GHG emissions.

The social impact of freight distribution in urban areas refers to the road congestion, the noise pollution and the intimidation and safety in respect of which there is a description below.

Road Congestion

As the population in urban areas increases, the requirements for freight distribution rise. Although passenger's vehicles have greater responsibility for urban road traffic, freight vehicles contribute to the existent road congestion. Freight vehicles typically represent 8-15% of total traffic flow in urban areas, while when they are processing deliveries outside designated parking spaces, the road capacity decreases with an instant increase in traffic jam (DG MOVE, 2013). Freight vehicles often have to operate in areas without loading or unloading bays or in some cases that those are available, they may be occupied by unauthorized vehicles. This results to illegal double parking and an increase in traffic congestion. Furthermore, the car users often are not aware of limitations and maneuverability of large freight vehicles. Thereby, traffic jam can occur due to the inability of those to stop or to change direction quickly. Local authorities, in order to deal with this major issue, introduce restrictions for freight vehicles according to their weight and size with the aim to avoid freight movements in central domains with high circulation.

Noise pollution

Another negative impact of urban freight transport is noise pollution. The increasing delivery of goods puts barriers on the tolerance of the residents and their ability to cope with urban freight transport. The main noise problems are caused by exhaust, engines, tires, doors and body rattle of freight vehicles and other freight equipment, *e.g.* forklifts (OECD, 2003). Additional problems indicated in residential areas is the nuisance produced by waste collection during night hours, the noise generated by freight vehicles during night deliveries and problems caused by the re-starting of engines of freight vehicles in early morning hours (OECD, 2003). In order to deal with the nuisance, freight operators have to make investments in low noise equipment, including all segments of distribution (driving, loading and unloading operations). Low emission vehicles, low noise equipment for loading and unloading and enclosed delivery bays inside stores can reduce noise pollution, making night distribution more sustainable. Various municipalities have established decibel (dB) indicators for acceptable noise levels.

Intimidation and Safety

With the increase of freight transport activity in urban areas, the problem of intimidation and safety is becoming more important for public authorities. It is considered that particularly HGVs are responsible for pedestrian's and cyclist's intimidation, due to their size. There is also a significant concern about the number of serious accidents involving freight vehicles and cyclists. According to Transport for London, the city's mobility agency, half of all cyclist fatalities in London are due to accidents involving freight vehicles (DG MOVE, 2012). Furthermore, in some cases of excessive demands in deliveries, strict delivery time windows and deadlines can lead to dangerous driving, causing accidents. For instance, when driver's salary is up to the number of deliveries accomplished, drivers may operate aggressively reaching the maximum deliveries.

The **economic** impact of UFT is significant, as the additional costs will pass into the final consumer. Although urban freight transport constitutes only a very small proportion in the total freight transport length, it represents a high proportion of the transport costs. This "last mile" in the transport chain accounts for 28% of total transport costs (Schoemaker *et al*., 2006). The economic impact of urban freight distribution affects the functional costs of freight operators. On the one hand, retailers are looking for upgraded customer services with the lowest possible price. On the other hand, freight operators have to deal with a significant number of restrictions which require making their deliveries in specific time windows with smaller and more modern vehicles. From the operators' side, there is a need for further investments in fleet which increases their operating costs. Additional delay costs can arise from congested traffic flow conditions caused by accidents as well as insurance costs associated with property damage, injuries and fatalities that may fortune.

2.6. Urban freight distribution and European Policy

As urban areas became overcrowded and the demand for goods increases, EU implements measures in order to make urban freight distribution sustainable. In order to use more energy-efficient modes of transport for distances greater than 300 km the key goal of European Commission was: 30% of road freight transport should shift to other modes as rail or waterborne transport by 2030, and this proportion should exceed 50% by 2050 (European Commission, 2011). Larger distances should be covered by combined transport such as rail and waterways and leave the last-mile deliveries for road transport. Moreover, in order to achieve the reduction in environmental pollution and the dependence on oil resources, it is necessary to improve the energy efficiency in all modes of transport as well as the development of sustainable fuels.

Modeled on the guidelines of the White Paper 2011, the transport plan by 2050 was created (Transport 2050). The project aims to the creation of a flexible and competitive network which will link road, rail, air and waterway infrastructure. The main objective is to increase mobility while reducing dependence on fossil fuels with an additional reduction of 60% in CO_2 emissions by 2050, compared to 1990 emission levels. In order to achieve the latter, it is recommended to: a) eliminate the conventional vehicles from urban areas until 2050, b) replace over 40% the existing aviation fuels to low carbon emission fuels, c) reduce at least 40% the CO_2 emissions in the shipping sector, and d) replace road to rail and waterborne transport by 50% (European Commission, 2011).

The vision of EU for urban freight transport that was set out in the White Paper (March 2012) describes a situation where freight deliveries in European urban areas are both economically and environmentally efficient in the future. The vision includes (DG MOVE,2012) :

- Minimizing the number of freight movements and the distances required
- Using low emission vehicles for freight deliveries
- Making maximum use of Intelligent Transport Systems (ITS) in order to increase the efficiency of freight deliveries;
- Reducing noise pollution from freight movements, so that road infrastructure could be used more efficiently, encouraging night deliveries and avoiding deliveries during peak periods.

EU has established European programs with the cooperation of European cities' authorities and private sector, implementing recommendations for sustainable freight distribution. Some of the most significant European projects are described below.

CIVITAS

CIVITAS ('City-Vitality-Sustainability') is a large European Commission co-funded program which aims to support sustainable urban mobility (Rooijen& Quak, 2014). The fundamental aim of CIVITAS, which started in 2002, is to contribute to a change towards sustainable urban mobility by (Lindt & Emmert, 2013):

- promoting and implementing sustainable, clean and (energy) efficient urban transport measures;
- implementing integrated packages of technology and policy measures;
- building up critical mass and markets for innovation;
- overcome barriers for implementation of innovative and ambitious measures and policies by experimental testing combined with targeted research.

CIVITAS initiative contained several edition during the last decades, CIVITAS I, CIVITAS II, CIVITAS PLUS and CIVITAS PLUS II. The cities that participated in CIVITAS initiative are shown in the map below (Fig. 2.1).

Fig. 2. 1: The CIVITAS demonstration cities(civitas.eu, 2012)

In any addition of CIVITAS initiative, a large variety of measures were implemented according to clean fuels and vehicles, collective passenger transport, demand management strategies, mobility management, safety and security, car independent lifestyles, urban freight logistics and transport telematics (Rooijen, Quak, 2014). CIVITAS succeeded in raising awareness for sustainable freight mobility in Europe while other cities copied many measures that have been implemented successfully. Concerning the measures for urban freight logistics, they were unfortunately less successful than those of other clusters. This outcome can be explained by the necessity of partnerships with private sector actors to implement an urban logistics measure for urban freight logistics while in the other clusters were implemented by cities themselves.

CITYMOVE

CITYMOVE is a European collaborative project which started in 2012 and is co-funded by the European Commission, part of the UE 7th Framework Programme for sustainable surface transport. CITYMOVE is coordinated by Centro Ricerche Fiat and it involves 13 partners in 6 different European countries, including industries, research institutes, associations and freight operators (Citymoveproject, 2007). CITYMOVE project goal is to increase the efficiency and the sustainability of urban freight transport through innovative vehicle solutions and better management of auxiliaries and services. Some of the issues that have been considered by CITYMOVE are the following (European Commission, 2012):

- New vehicle architectures, with optimized layout to reduce congestion and facilitate movements in narrow city streets.
- Compatible and interoperable vehicle bodies and goods containers.
- Special attention to CO_2 emissions and fuel consumption, in line with the Kyoto Protocol.

The development of these solutions requires the involvement of all parties. The purpose of CITYMOVE project is the development of an innovative vehicle concept for urban freight transport services by introducing new technologies with a high chance to be applied in the future (Aimo Boot & Burzio, 2010).

BESTUFS:

BESTUFS (Best Urban Freight Solutions) started in 2000 addressing urban freight transport for 4 years. BESTUFS II followed as a Coordination Action and was carried out from 2004 until 2008. BESTUFS follows the Green Paper in general and recognizes that many urban freight transport oriented arguments are already directly addressed by the document.

The main objective is to identify, describe and disseminate best practices, success criteria and bottlenecks of urban freight transport solutions. Furthermore, BESTUFS aims to maintain and expand an open European network between urban freight experts, user groups/associations, ongoing projects, the relevant European Commission Directorates and representatives of national, regional and local transport administrations and transport operators (Schoemaker, 2011).

BESTUFS II was considered as a follow up project to the successful project BESTUFS. BESTUFS II aim was to achieve a broader geographic coverage of the existing BESTUFS network on urban freight while to take off the language barriers, especially in small and medium sized cities. Furthermore, another perspective was to quantify the contribution of urban freight solutions to EU policy objectives and examine urban freight transport models and data structures.(BESTUFS, 2014). Overall, BESTUFS's II aim was to identify the problems and the requirements of the cities as well as of all private actors involved in urban freight and maintain the environment for establishing policy as well as research recommendations.

STRAIGHTSOL

STRAIGHTSOL (Strategies and measures for smarter urban freight solutions) is a 3 year EU-funded project, comprising seven innovative cutting edge urban freight demonstrations. The main objectives of STRAIGHTSOL are to (EVGI, 2014):

- Develop a new impact assessment framework for measures applied to urban-interurban freight transport interfaces
- Support a set of innovative field demonstrations showing latest developments in freight operating practices in Europe
- Apply the impact assessment framework to the live demonstrations and develop specific recommendations for future freight measures.

The demonstrations represent cutting edge initiatives from leading stakeholders like DHL, Kuehne+Nagel and TNT, and cover Brussels, Barcelona, Thessaloniki, Utrecht, Lisbon, Oslo and England.

Apart from the European programs which have a wider framework and purpose, European projects are targeted to implement specific practices in cooperation with public and private sector. The results of those projects are of great importance and can be applied to the rest European countries.

CO3(Collaboration Concepts for Co-modality)

According to a study by the World Economic Forum (2009), the average capacity utilization of the European logistics network hardly reaches 43%. This means that 1 out of every 4 vehicles drives empty and the average loading factor of the other 3 is less than 60%(CO3, 2014). Horizontal collaboration can play a significant role in maximizing loading factors. It requires the interruption of a neutral third party which in the CO3 case, this party is called a network orchestrator or “trustee”. A “trustee” is necessary for the collaborating shippers in terms of dealing with confidential data or operating in competing markets, for redistributing synergy gains and for synchronizing daily operations. The aim of CO3 is to encourage horizontal collaboration between European shippers in terms of European logistics’ competitiveness and sustainability. The main objectives of the CO3 project are to:

- Develop a European legal framework and remove managerial barriers for horizontal collaboration
- Facilitate, launch, and coordinate test cases
- Organize workshops and seminars to educate trustees, shippers and logistics service providers

Horizontal collaboration can lead to the improvement of the utilization rate of transport fleet. This can be translated into a reduction of 20-40% of carbon footprint emissions per freight movement.

COFRET

Climate change is a significant issue of global interest. According to the White Paper (2011) and Transport 2050, it is necessary to reduce GHG emissions. In order to achieve that, transparency of energy consumption and emissions is required. A wide range of different methodologies for the calculation of GHG emissions are applied by various parties which leads to different indicators that are not compatible. A global standardization in calculating GHG emissions will contribute to such a transparency. For supporting the efforts for reducing emissions, the EU launched COFRET (Carbon Footprint of Freight Transport) in 2011. COFRET is a co-financed project by the European Commission, part of the 7th Framework Program, with the aim to develop a complete methodology for the determination of GHG emissions for complex logistics and transport chains. COFRET’s main objective is to review the existing methodologies for the calculation of carbon footprint and evaluate their compatibility with the European Standard EN 16258 :2012 in freight transport and logistics. The added value of COFRET is that it provides suggestions to achieve global harmonization of calculation GHG emissions and give the opportunity to logistic operators that use all modes of transport (road, rail, maritime and aviation) to calculate and reduce their emissions.

E-SAVE (Energy Efficiency in the Supply Chain through Collaboration, Advanced Decision Support and Automatic Sensing)

According to the climate change consequences, an imperative need for energy resources management is required. The E-SAVE project aims to develop the information support tools in order to improve operations and supply chain management decisions where environmental Key Performance Indicators (KPIs) are taken into consideration. Furthermore, the project will support efficient information sharing and collaboration among supply chain partners. The goal is the cooperation of supply chain in an energy-efficient way, by providing the system, services, collaboration platform and management tools that will give the opportunity to companies to monitor, manage and share energy use and carbon footprint data in order to support the decision making and the strategy followed. Supply chain partners can make changes into their daily operations (e.g. vehicle routing, replenishment schedules etc.), monitoring the energy efficiency and carbon footprint across the supply chain, optimizing their emissions and energy consumption (E-SAVE, 2012).

2.7. Conclusion

In this chapter, there was a description of green city logistics in term of urban freight distribution. Urban areas, according to their population and geographical span face various problems which in a particular base, the larger a city the more intense problems encountered. The most important aspects in urban freight distribution are the retail, the post services and the waste management. While these procedures are necessary for city’s function, they have negative impact in terms of environment, society and operating costs. The existing compromised situation is enhanced by the development of e-commerce and last-mile deliveries and the limited city’s infrastructure. Additionally, various operating factors affect the efficiency of freight distribution with the most important to be the low load factor. According to the EU policy, the reduction of GHG emissions is essential. In this direction, European programs and projects implement recommendations for green and sustainable freight transport in cooperation with member states, leaving a “best-practices” legacy for further use by the rest European countries.

3. Green City Logistics and Best Practices in UFT

3.1. Introduction

The third chapter's aim is twofold: It describes a framework related to green city logistics operations and presents a series of best practices for freight transport in urban areas. The framework presented is based on three main pillars namely vehicle technology, consolidation and pooling strategy and pickup and delivery schemes. Initially, there is a description of the technological features of freight vehicles according to engine's technology, the efficiency and the GHG emissions produced in any case as well as factors that can affect vehicle's performance. The second pillar describes the market in corporate level, offering proposals for sustainable urban freight transport through consolidation in terms of urban consolidation centers and logistics pooling. The third pillar refers to the pickup and delivery schemes regarding the policies and the information technology systems established in order to increase sustainability in urban areas. These solutions are indicated as best practices and they are models of potential adaption by other European cities.

3.2. Green city Logistics framework

The green city logistics framework consists of three main pillars; The vehicle technology, consolidation and pooling strategy and pickup and delivery schemes.

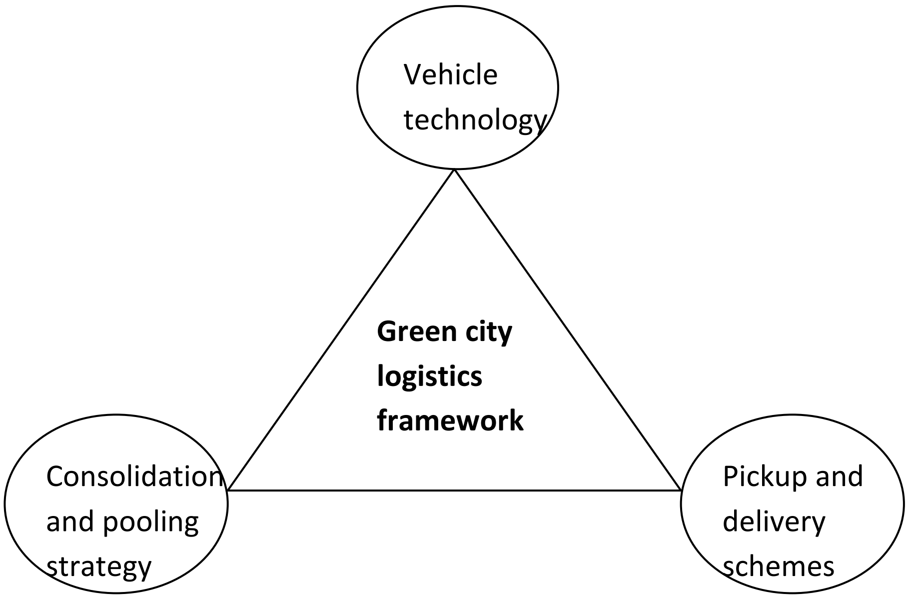

Fig. 3. 1: Green city logistics framework

The first pillar refers to the freight vehicle's technology. A lot of surveys have been carried out for the development of vehicle's engine technology both for alternative fuels and for the improvement of diesel engine combustion. As the vehicle's technology improves, the GHG and noise emissions that a freight vehicle produces are decreased. Low emission vehicles not only produce less GHG emissions, but also can be used for night deliveries, reducing the traffic congestion during day-times. In this way, the vehicle's technology can significantly contribute in green city's logistics development.

The second pillar is related to the consolidation and pooling strategies. The main features of the second pillar are the Urban Consolidation Centers(or Construction Consolidation Center according to the use sector), logistics pooling and Collecting Delivery Points(CDP). Through consolidation and logistics pooling, optimization of load factor can be achieved. This leads to less freight vehicle needed for the existing good's distribution capacity. With the implementation of CDPs, the phenomenon of missed first-time home deliveries is decreasing, reducing the required freight deliveries. These practices have a positive impact on traffic congestion and air pollution, as a lower number of freight vehicles have to operate in order to cover distribution's requirements. So, the development of the above strategies can improve the efficiency of green city logistics.

Finally the third pillar refers to the pickup and delivery schemes, regarding the policies established and the development of information technology systems. Public authorities in various cities have introduced night deliveries, tolls, LEZs and co-mobility. These practices have lead to the reduction of road congestion and GHG and noise pollution, produced by the freight vehicles. Furthermore, there is a lot of potential in the development of ITS in urban freight transport which triggers the equal results in traffic congestion and air quality. Green city logistics can take advantage of these practices in order to improve sustainability and environment quality.

3.2.1. Pickup and delivery schemes in urban freight distribution

Freight transport is a vital function for urban area's existence. While cities became overcrowded, existing infrastructure is hard to be extended. This is why public authorities are introducing measures and restrictions, some of which contradict with the operation of freight distribution. The aim of these policies is to make the urban environment more attractive and sustainable for their inhabitants and freight transport. Some of the main measures are discussed below:

Table 3. 1: Green city logistics policies/measures

Policy/Measure	Action
Time based access deliveries	• Time windows for day deliveries • Night deliveries
Tolls	• Congestion charging
Low Emission Zones(LEZ)	• Limited access in freight vehicles
Co-modality	• Cooperation of railway and waterborne for urban distribution

Time based access deliveries

There are two basic categories in time based access deliveries in urban areas: a) Time windows for freight transport in urban areas during the day and b) night deliveries.

The time windows during the day were introduced in order to reduce the traffic congestion, the GHG emissions and the conflict between pedestrians (visitors, residents) and freight vehicles (DG MOVE, 2012). Deliveries take place in a specific urban sector for freight vehicles in certain times of the day, such as between 07.00 and 09.00 in the morning and 18.00 and 20.00 in the evening. In this way, freight vehicles are not loading and unloading during the peak hours, creating an attractive environment for shoppers and tourists (DG MOVE, 2012). Time windows are usually effective in reducing traffic congestion in urban areas while the freight vehicles access is controlled by some form of physical barriers or number plate recognition cameras. Nonetheless, time windows might increase the distribution costs due to the need for delivering freight in shorter time which may lead to additional investments in vehicle fleet. (DG MOVE, 2012)

Night deliveries include distribution in retail shops, restaurants and offices at night time and those early in the morning by avoiding morning and afternoon peak traffic periods (DG MOVE, 2012). Comparing with the deliveries during the day, night deliveries have multiplied benefits. The round trip journeys and the vehicle turnaround times are reduced. The time spent in stationery, idling in traffic congestion shrinks and this leads to an increase in drivers' productivity while the fuel consumption diminishes (Browne, 2005). Another positive impact of night deliveries is the limitation of conflict between vehicle drivers and customers as well as the reduction of car accidents. The shops became more productive with positive effect on sales. On the other hand the night deliveries in urban areas have to deal with the negative reactions of the residents. The loading and unloading activities of freight vehicles might disturb the resident's sleep. Low noise equipment, such as electric or hybrid vehicles and quiet materials, are required. The costs and the benefits have to be measured in any case of adaption night delivering. The replacement of freight transport fleet has an additional cost while new infrastructure in buildings should be established with loading and unloading bays including controlling access.

Tolls

It is estimated that traffic congestion costs around 1,1% of EU GDP per year (Russo&Comi, 2012). Tolling is a common measure that an increasingly number of EU cities follows. By charging the use of infrastructure, traffic congestion is relieved and alongside financing for developing new road facilities is available. London introduced an urban toll system while Germany followed the Maut motorway charge for commercial vehicles. European Commission promotes electronic smart road charging systems for heavy good vehicles, calculating and collecting road use charges without disrupting the traffic flow (slow down or stop, restrict to a designated line). The use of tolls had a positive impact in traffic congestion while there was lot of opposition by retailers and freight operators regarding the economic impact of the additional costs. (DG MOVE, 2012; Geroliminis&Daganzo, 2005)

Low Emission Zones (LEZ)

LEZs are specific geographic urban sectors where the access is limited in freight vehicles that meet certain emission standards. LEZs are usually located in metropolises and other large urban areas where the air quality is a matter of major focus. Poor air quality is an urgent issue and this is the reason that LEZs are becoming increasingly introduced by major European Countries which want to meet emission European standards. LEZs are effective in improving the air quality with a significant reduce in Particulate Matter (PM), Nitrogen Oxides (NO_x) and Carbon Oxide (CO) but with limited impact on CO_2 emissions. The results in air quality are more encouraged when the restrictions apply not only to the heavy good vehicles but to any categories of vehicles. A PwC/ISIS study in 2010 for the European Commission on Access Restrictions Schemes (ARS) reported that 91% of LEZs were introduced for environmental reasons, while 36% were also introduced to reduce road congestion and 18% for “other” reasons (DG MOVE, 2012).

Freight operators are encouraged to replace their transport fleet, for instance diesel engines with hybrid or electric ones. Due to harmonization with the LEZ policy, freight operators have to invest in new technology which implies additional compliance costs. Adverse impact of LEZs is the additional costs of the freight transport which ultimately pass onto customers. Before implementing such a measure, it is essential to offset the positive effects in air quality with the additional costs in infrastructure, as in any case the balance differs. (DG MOVE, 2012; Leonardi *et al.*, 2012)

Co-modality

Due to the expansion of cities and the formation of major urban areas, intermodal transport (Co-modality) is encouraged for long distance freight transport, leaving the “last mile” deliveries to road vehicles. Trans-European Transport Network (TNT-N) supports the development of sustainable UFT in 83 urban areas, promoting the intermodal freight interchanges within or close to urban nodes. Logistics zones are located on the outskirts of cities, often combining warehousing and freight can be transferred over medium and long distances by rail and waterborne transport. The TEN-T “project of common interest” would also concern the development of re-fuelling infrastructure for Low Emission Vehicles (LEVs) and the establishment of ITS in urban areas. (DG MOVE, 2012),

Rail Freight Transport

In the past, the use of railway had a significant impact in urban freight transport. Nowadays the role of train has been declining, replaced by the road transport with the high flexibility and the ability to offer door-to-door services (DG MOVE, 2012). Making a retrospect to the European countries which implemented the rail way services in urban areas, goods are consolidated in a center located outside the urban area. Afterwards they are delivered to a distribution center which is in the center of the city where low emission road vehicles are undertaking the final delivery to their destination.

The use of tramways is another perspective in urban good distribution. While the freight transport can be based on existing rail infrastructure, the use of cargo trams is insignificant. Tramways are mainly designed to link passengers’ destinations rather than connecting distribution centers with inner retail shops. As a result, there are practical issues that put barriers in tram freight distribution such as the loading bays. Nonetheless, the tram distribution offers significant advantages due to zero emissions that expose with the additional impact in traffic relief (Diziain *et al*., 2014). Zurich and Dresden have introduced the cargo-trams for the waste disposal in order to avoid lorry traffic within the city.

Finally, another sustainable option that can reduce traffic congestion and environmental pollution is the use of underground for freight distribution. However the use of underground was abandoned through the significant costs compared with the road freight transport.

Waterborne Freight Transport

Infrastructure for waterborne freight transport is often available to cities that have rivers or canals passing through them such as Amsterdam and Paris. Although waterborne facilities are not used for last-mile deliveries, Utrect is an exception to the rule where there are restaurants and hotels that have direct access to the canals receiving catering products and beverage by electrically powered “beer-boats” which delivers goods from a distribution center to the inner city. Inland waterways can be effective for construction material and high value material transport especially when urban areas are directly linked with major sea harbors by an inland waterway. (DG MOVE, 2012; Diziain *et al.*, 2014)

ICT

ICT is mainly applied in the commercial vehicles for urban freight transport. The aim is to expedite deliveries, improve operational efficiency, decrease operational costs and improve incident response (DG MOVE, 2012). Nevertheless, ICT applications are mainly used by third party logistics companies with large fleets than by low potential operators. The table below contains the basic features of ICT which are subsequently described.

Table 3. 2: ICT policies and measures

Policy/Measure	Action
Traffic management systems	• Loading/Unloading information, access control
Traffic Safety Information Services	• Incidents information
Electronic road tolling	• Automatic charging systems

Traffic management systems

The efficiency of freight distribution can be improved by integrating the ICT of the freight operators with the ITS solutions of traffic management that public authorities provide (DG MOVE, 2012). This is a sector with plenty of potential enforcement improvements. By ITS a freight operator can make a reservation of a parking space for loading and unloading, checking the availability by completing his wished time and place of operation. Additional information that an ICT system can provide is the access control, regulations for specific locations, traffic congestion and incidents. With the cooperation of both sides, freight operators will be able to improve their deliveries while at the same time road users will benefit. Integrated traffic management would also have positive impact in incident prevention of dangerous goods transport (DG MOVE, 2012).

The ITS Directive of the European Union (Directive 2010/40/EU) in cooperation with the subsequent Action Plan (Action Plan for the Deployment of ITS in Europe, COM(2008)886) focus on the continuity of traffic and freight management including all parties. The aim of the Action Plan is to benchmark and standardize the information flows between the relevant traffic centers and different stakeholders. (DG MOVE, 2012)

Traffic Safety Information Services

Traffic safety information related to incidents must be available to any road user without charge. Until now, the information about safety is spread by radio stations. The ITS Action Plan is looking to develop free minimum information across the EU, improving road safety by providing wider and easier access to safety-related information such as danger warnings for objects on the road and scenes of accidents (European Commission,2011; DG MOVE, 2012)

Variable Message Signs (VMS) are electronic traffic signs which are usually used in motorways in order to inform road users about various incidents. According to safety information, VMS can inform road users to slow down in case of a crass happens (including vehicle spin-out or rollover), as a preventative measure for reducing secondary accidents. Furthermore, information about traffic congestion, road-work zones, extensible weather conditions (fog) and speed limits can be indicated by VMS in order to draw the user's attention. In urban areas, VMS often provide information about available parking spaces, alternative routes, traffic conditions, etc.

Electronic road tolling

According to the Directive 2004/52/EC, European countries are requested to implement an interoperable system of toll charge called European Electronic Toll Service (EETS). The road user will be able to pay the tolls easily throughout the whole of the EU due to one subscription contract with one service provider and one single onboard unit without having to slow down or stop, disrupting the traffic flow.(European Commission,2011)

3.2.2. Vehicle Technology for Green Urban Distribution

Freight transport growth brings changes to the fuel consumption and the GHG emissions. The purpose of European Commission that is described in the European White paper is to reduce the dependence on oil which will result in a reduction of GHG emissions (European Commission, 2011). The technology of light and heavy duty vehicles was strongly influenced by the emission limit values (Euro standards). The air quality and the air pollution control in transport was a major issue at a national and European level. The control on the quality of diesel and gasoline with a following introduction of exhaust gas limits (Euro Standards) by the European Commission, resulted to a reduction in GHG emissions of the individual vehicle classes (Table 3.3).

Table 3. 3: LDV/HDV classes and semi-trailer trucks in Germany in 1 January 2010(KBA,2010)

	Type	Max Gross Weight	Typical use area
	Light Duty Vehicle (LDV)	Bellow 3.5 tons	Service and delivery transport
	Light Heavy Duty Vehicle (HDV)	3.5 up to 7.5 tones	Delivery and short distance transport
	Middle Heavy Duty Vehicle (HDV)	7.5 up to 12 tons	Delivery, regional transport and transport of line and voluminous goods

	Big Heavy Duty Vehicle (HDV)	Above 12 tons	Regular trucks plus trailer for long road haulage and single trucks for delivery(e.g. heavy commodities)
	Semi-trailer truck	Regular up to 40 or 44 tons	Long road haulage

In 2008 the European commercial vehicle fleet was amounted to 33 million vehicles, with France, Spain and Italy having the biggest vehicle fleet, following by UK, Poland and Germany (Fig3.2). (Litschke&Knitschky, 2012)

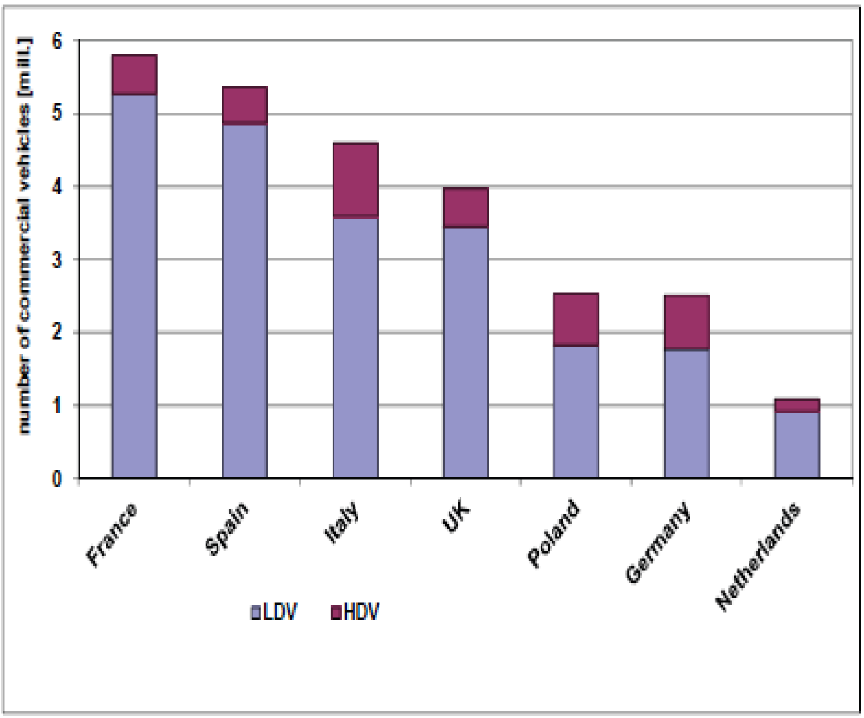

Fig. 3. 2: Commercial vehicle fleets in some EU countries(ACEA,2009)

Diesel power

The majority of freight vehicles in Europe are moving with diesel power. It is expected that diesel technology of commercial vehicle fleet will dominant in this and the next decade until the alternative technology replace it (Litschke& Knitschky, 2012). Diesel power can afford additional improvement both in the field of efficiency and service life and in the field of exhaust gas limits. Significant techniques were the introduction of direct injection, four-valve technology, engine supercharging and electronically controlled high pressure injection that improved the efficiency and environmental compatibility (VDA, 2008; VDA 2009). Potential changes in diesel engines could lead to 10% fuel savings that means 3 liters/100km less fuel consumption for semi-trailer trucks, by improving the drive train or achieving higher injection pressures and optimizing engine control (Litschke& Knitschky, 2012).

Biodiesel is non-petroleum based, non-toxic, biodegradable fuel made from a variety of vegetable oils, or animal fats, such as recycled cooking grease and it can be used in any diesel engine when mixed with mineral diesel. (Transport Canada, 2005). Biodiesel is the most common biofuel in Europe. Pure biodiesel (B100) currently reduces emissions with up to 60% compared to fossil diesel. By 2020, the EU intends to impose a minimum proportion of 10% of biodiesel either pure (B100) or mixed with conventional diesel. While the use of biodiesel is specified by regulations, tax policy and vehicle technology, conflicts with other purposes such as heat generation, food production or use as row materials. As battery densities are not currently suitable for longer distance road freight, biodiesel is a potential fuel which reduces the CO_2 emissions and the dependency on fossil energy.

Liquefied Natural Gas-LNG

Liquefied natural gas (LNG) has the potential to offer significant fuel cost savings compared to conventional diesel. It can also reduce greenhouse gas emissions, from production to use, compared to conventional diesel and bio-diesel in new engines. LNG use helps reduce CO_2 emissions by around 25% in comparison with heavy fuel oil (HFO). LNG-fuelled trucks can operate for longer where noise restrictions apply, for example in urban areas. Despite its advantages, the use of natural gas vehicles faces several limitations, including fuel storage and infrastructure available for delivery and distribution at fueling stations.

CNG-Compressed Natural Gas

CNG is a gaseous fuel that freight vehicles carry on board in pressure tanks and requires modified combustion engines. Although CNG has been available for many years in the market, the number of LDV and HDV supporting CNG technology is insignificant (Litschke& Knitschky, 2012). This is due to various barriers such as taxation and lack of refilling stations. However some trucks are currently operating in EU countries. There are also some hundred HDV with CNG technology in municipal fleet that are used for waste collection.

In contrast with the diesel combustion, CNG is a very clean fuel as regards the CO_2 emissions. CNG powered vehicles can release up to 10% less CO_2 emissions than comparable diesel engines (Pucher, 2005). Any engine without modification can operate by using CNG with high share of biogas while a natural gas vehicle filled with biogas allows operation with 60% - 90% lower CO_2 emissions than using diesel fuel depending on the greenhouse gases created during the biogas generation [DENA, 2010]. The corresponding decrease of NO_x and SO_2 emissions during CNG combustion is insignificant. Another positive impact of CNG use is the lower level of nuisance comparing with a diesel engine which amounts to 50%.

The use of CNG power is recommended in urban areas with light and medium commercial vehicles due to the lower CO_2 and noise emissions with the proviso that there is sufficient network of refilling stations. (Litschke& Knitschky, 2012; DG MOVE, 2012)

Demand for natural gas in the transportation sector is already strong. Currently, there are close to 18 million natural gas vehicles (NGVs) in the world, with 1.5 million of them in Europe. In 2012, the demand for the "blue fuel" in transport reached 30 billion cubic meters, and 21,000 compressed natural gas (CNG) filling stations were operating worldwide. (Bluecorridor, 2014). The EU project "Blue Corridors" is a co-funded project by the European Commission involving 27 partners from 11 countries. The aim of the project is to establish natural gas as a real alternative for medium & long distance transport- first as a complementary fuel and later as an adequate substitute for diesel. To accomplish its objective, a roadmap of natural gas refueling points along four corridors has been defined, covering the Atlantic area, the Mediterranean region and connecting Europe's South with the North and its West and East accordingly(Fig. 3.3)(Ngvaeurope, 2014).

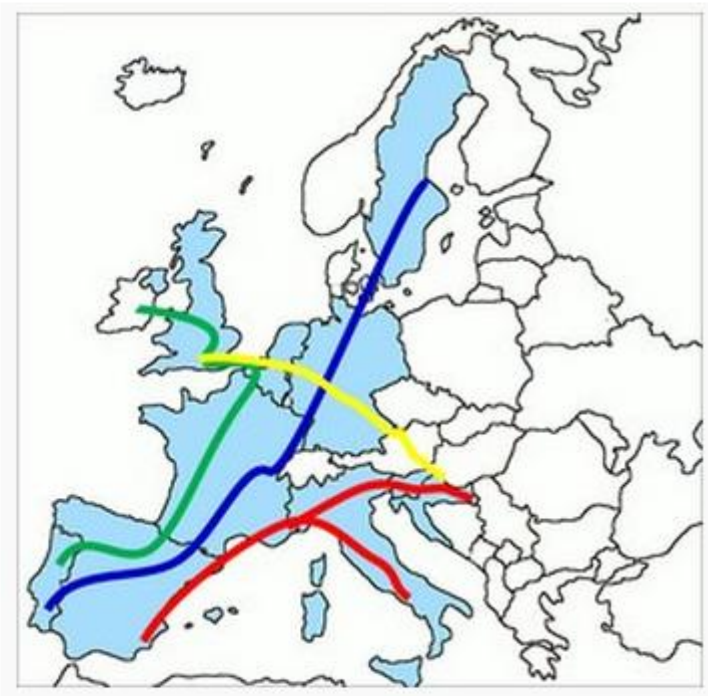

Fig. 3. 3: Corridors map(NGVA Europe)

LPG- Liquefied Petroleum Gas

Liquefied Petroleum Gas (LPG) is a liquid mixture of butane and propane, which is produced as a byproduct of refinery process. LPG is a pure fuel which can be used by modified petrol engines which can operate in both petrol and LPG power. While a few vehicle manufactures argue that LPG transmits lower CO_2 emissions, the actual CO_2 emissions vary according to the engine technology used. (Litschke, Knitschky, 2012).

Hybrid and Electric Technology

Electrification and hybridization is a choice that most car manufacturers follow by developing and producing electric and hybrid models. Both electric and hybrid vehicles have lower CO_2 emissions (tank to wheel) compared with the diesel engines. The cost of acquiring of electric and hybrid vehicles is comparatively higher than that with diesel power since the manufactures have not achieved economies of scales due to low demand.

H**ybrid** engines designed for saving fuel and giving sufficient use of energy. The hybrid vehicles can be divided in two categories; On the one hand according to the combination of electric and combustion engines into series, parallel and mixed hybrids and on the other according to the efficiency of the electric engine, into micro, mild, full and plug-in hybrids (Litschke&Knitschky, 2012). While hybrid vehicles have the benefit of extending the range of operability, they don't produce zero emissions at the point of use comparing with the electric vehicles. For urban distribution the average saving potential compared to conventional diesel is about 5% for automatic start-up, 20-30% for full hybrid vehicles and up to 40% for plug-in hybrid vehicles (Ricardo, 2009).

Electric vehicles are producing zero emissions at the point of use while they can take advantage of the existing electric supply infrastructure. Regarding the operating costs, the latter have lower costs in contrast to the diesel power vehicles due to the lower fuel costs, the fewer moving parts and the lower costs for maintenance. Electric vehicles are operating with an electric engine while having a battery for energy storage. The drawback arising from electric powered function is the self-reliance of the batteries (DG MOVE, 2012). While the charging technology is progressively meliorating, some freight vehicles in the UK need to be charged every 4 hours of operation. Even if some existing technologies offer theoretically 200 km self-reliance with a single charge , the real range may vary less than 50% in urban freight transport while is almost impossible to operate in areas with significant gradients (DG MOVE, 2012). This is because a battery charge is strongly influenced by the weather conditions (high and low temperatures) as well as the driving behavior. Another point is the fact that the additional weight of batteries can classify a small van to a HGV that requires more qualified drivers which increases the transportation costs. Another issue arising from the low noise pollution that electric cars produce is that pedestrians are less aware of their presence, engaging risks for their safety. (Litschke&Knitschky, 2012)

Vehicle Aerodynamic Technology

Except from the different types of engines based on their fuel use, there is still potential for additional improvement in order to reduce the CO_2 emissions. The most significant factor for improving is the reduction of driving resistance. As the driving resistance increases, more energy is required to be consumed in order to reach a particular speed. The most various components of driving resistance are the air resistance, the rolling resistance and the mechanical losses through friction.

The **air resistance** can be reduced by improving the aerodynamics. Aerodynamics depends on the regulations of vehicle size and the carrier's demand for maximum load space volumes. Small improvement, such as roof and side spoilers and cladding the vehicle chassis have lead to positive but insignificant results in fuel saving on HDV and semi-trailer trucks.

Rolling resistance is another important factor which contributes to higher fuel consumption. Rolling resistance may be derived from the deformation of the tires on road contact, the tire diameter, the material properties and the road surface. Rolling resistance is responsible for the one third of the total fuel consumption in HDVs. Low rolling resistance tires and an automatic control system that optimizes the tires air pressure are two methods of reducing rolling resistance and finally fuel consumption.

Furthermore, driving resistance is associated with the vehicle's weight. The reduction of vehicle's weight by creating lightweight construction will initially lead to energy save and afterwards to an increased payload. Lightweight constructions in freight vehicles can be achieved by using aluminum and composite materials. (Litschke & Knitschky, 2012)

Other type of vehicle categories for low/zero emission

Cybercars are small vehicles fully automated which can transfer limited goods and passengers. Cybercars does not need any human interaction while it can be fully autonomous by using information from a traffic control center, from infrastructure or from other road users. Furthermore, they can be used for last-mile deliveries in houses or offices and also they can be used for the transportation of "problem goods" such as cash to banks and post offices and urban waste (DG MOVE, 2012).

Personal Rapid Transport (PRT) vehicles are used for the passenger transport. They are automatic vehicles that are moving in dedicated tracks. PRT vehicles can be beneficial for freight transport connecting logistics nodes between inland and port terminals with urban areas. They have the advantage of the reduction of driver's cost due to the automation (DG MOVE, 2012).

High-Tech Lorries are vehicles whose technology resembles the traditional trolley busses. They have rubber wheels, using part of the route on gateways. While High-Tech Lorries have automated systems for navigation and drivers assistance, a driver is necessary for increasing productivity and safety. For freight transport, High-Tech Lorries are advantaged compared with the PRT vehicles and Cybercars due to the larger size that increases the loading capacity. Ideally, High-Tech Lorries can transfer goods between logistics nodes and urban areas (DG MOVE, 2012).

Dual-Mode Vehicles have common features with cybercars but they can also be driven manually. They can move autonomously on a dedicated line or can be moved in a platoon with a single driver. Dual-Mode Vehicles can be useful for last-mile deliveries and just-in-time deliveries in zones where the access is limited such as historic city centers or airports. (DG MOVE, 2012)

Cargo cycles

Deliveries of low volume and weight goods that can be accomplished by bicycles or tricycles, is not an innovative solution but it has dominated in the postal transport. "Last mile" deliveries by cargo cycles require the transfer of goods from large vehicles to very small vehicles which greatly increases the cost of transportation. These additional costs may be covered by state subvention or by customers who are looking for sustainable solutions in their deliveries (DG MOVE, 2012).

3.2.3. Consolidation and pooling strategy

Another perspective for reducing traffic congestion and GHG emissions in corporate level is the consolidation of freight deliveries. This can be achieved through the Urban consolidation Centers and Logistics pooling.

Urban Consolidation Center-UCC

Urban freight transport planning was traditionally undertaken by the private operating companies. Due to the problems that were coming up in urban areas such as traffic congestion, nuisance, air pollutions and conflicts between pedestrians and freight vehicles, public authorities started getting involved in order to identify a viable solution in these major issues. As a result, Urban Consolidation Centers (UCCs) were introduced. The latter can be defined as distribution centers located close to the center of urban areas where deliveries from freight operators with low loading capacity and various customers can be consolidated in order to optimize both route and road utilization. The final transportation is usually carried out by environmental friendly vehicles such as gas powered vehicles, electric and electrically-assisted tricycles (Zanni & Bristow 2010).

There are three different types of Urban Consolidation Centers: Urban Consolidation Center (UCC) for retail market, Construction Consolidation Center(CCC) and Vehicle Reception Points(VRP):

- **Retail Consolidation Centers:** The UCCs in retail market are beneficial where the market is fragmented. The large chains already have sufficient volumes to support full truck loads, in contrast with the small to medium retailers with proportionately less demand and wide variety. The purpose of UCC is to increase the loading factor of the freight vehicles so fewer vehicles are needed. As a result it will be a reduction in total distance travelled which leads to lower CO_2 emissions and traffic congestion. Through consolidation, the total kerbside space and time for loading and unloading can be reduced (Gonzalez-Feliu,2011). The freight companies can take advantage of UCC by avoiding the traffic congestion of the inner city gaining costs and time. UCC can also offer logistics and retail value added services for their customers such as off-site stockholding, preparation of product for display and price labeling, assembly and disassembly and consignment unpacking. The services that a UCC provides are competing with the services of the rest freight operators. The additional costs that a UCC has to deal with, such as the cost of transferring the goods from an in-coming vehicle to a UCC vehicle and the cost capture of the UCC's building, will finally pass to the customer. A private logistics provider or a public authority must be interested in promoting the UCC. Additional direct or indirect subsidy will reduce the cost of function giving advantage over the private freight operators. It is preferred the retail activity to be concentrated in a small zone so the critical freight can be consolidated in individual vehicles while the added value services will make deliveries more beneficial (Gonzalez-Feliu,2011).

- **Construction Consolidation Center (CCC):** The CCCs are widely used the recent years for reducing traffic and waste in urban areas by offering services as consolidating deliveries to construction sites. CCCs are distribution centers located close to urban areas where different transport operators deposit raw materials. The CCC vehicles consolidate them in full track loads to individual customer making just-in-time deliveries. The benefits coming from the CCC is the reduction of the transport vehicles which have to visit an individual construction site. In London, as a result of CCC establishment there was a reduction up to 70% of the operating vehicles which led to a 75% decrease in GHG emissions **(**Zanni&Bristow, 2010). Additional benefits that come up from the existence of CCC in London include just-in-time deliveries to sites with restricted space, improvement of productivity and decrease of the industrial accidents. Due to the short distance between the CCC and the construction site the delivery performance and accuracy improved while the total payments of London Congestion Charge decreased.

- **Vehicle Reception Points(VRP):** Additional reduction in GHG emission can be achieved with the establishment of VRPs(Zanni&Bristow 2010). These regions are located in a specific area of the town, smaller in size than UCCs, where drivers are instructed in parking their vehicles and unloading. The final goods delivery is carried out on foot by using handling equipment. The use of VRPs is usually utilized by small retail shops where goods to be delivered are normally smaller and can be transferred by light equipment. VRPs are usually established by private business operators in cooperation with public authorities. These centers are making their way in various cities in France and in some cases achieved CO_2 emissions reduction of up to 80% (Patier, 2007).

European UCCS and government subsides

The operation of the UCCs has a positive impact in reduction of GHG emission and traffic congestion. Perhaps this is the reason that UCCs were always subsided by the public authorities. The first UCCs were private or semi-private initiatives, following economic and optimization interests (Dablanc & Massé, 1996). Later, environmental and social issues made public administrations to develop such systems for urban goods distribution (Gonzalez-Feliu, 2008). From the 75 UCCs that were operating in Europe only a 40% of the total are still operational supported by public authorities on financing and on organizational supporting.

Italy is the most typical case with the most numerous UCC infrastructures. The main UCCs in Italy are related to medium-sized cities, i.e. cities between 100.000 and 500.000 inhabitants, like Bologna, Genova, Ferrara, Padova,Parma, Siena, Venezia-Mestre and Vicenza, among others (Browne *et al.*, 2005; Gonzalez-Feliu, 2008; Spinedi, 2008). In the last 5 years, other small cities (from 10.000 to 50.000 inhabitants), like Frosinone or Aosta have started to develop such systems (Trentini *et al*.,2011). The only application cases in big cities are those of Milan, where the public transport operator ATM used their bus depots and other facilities to propose an urban freight delivery system and that of Naples, which made a pilot of a urban-regional rail distribution system(Gonzalez-Feliu, 2008). The majority of Italian UCCs were receiving direct financing by regional, national and European authorities (DG MOVE, 2012).

France ranks second in UCC operation. We can distinguish two types of UCC: a) The ones that are close to an entire city or historical center (La Rochelle and Monaco are the two that remain still functional) or near neighborhoods (Bordeaux, Paris, Rouen) and b) the private UCCs as those of Chronopost and Samada-Monoprix (Paris), Colizen and La Petite Reine.

The German case is interesting from the view point that UCCs were developed by private consortiums without public support even if in some cases received research and development funds. This resulted in a limited success of German UCCs in contrast to the Italian and French but with a stronger connection to the market.

As regards Netherlands and United Kingdom, an insignificant number of UCCs are still operational even though they received support from the public authorities. Limited success for the UCCs of Sweden and Switzerland is detected which had similar operation mode with those of UK and Netherlands. Lastly, the remaining south-west Europe countries such as Spain, Portugal and Greece are still in a primary phase, following the Italian and French model but with the inability to secure funding (DG MOVE, 2012).

Below are listed examples of direct and indirect subsidies of UCCs in Europe. In Bremen, a UCC that was founded in 1994, received EU funding for purchasing low emission vehicles and develop ICT system in order to make deliveries more efficient. Indirect subsidies are frequently offered to UCC as a supplementary assistance by allowing wider time windows to UCC’s freight vehicles. In some cases these vehicles are not required to pay congestion access charges or in the case of Vicenza in Italy the UCC vehicle have monopolistic access to the city center. In Bristol, the public authorities allowed the UCC’s freight vehicles to operate at the Broadmead Shopping

Center when at the same time the rest freight vehicles were banned. In the case of Ferrara which was supported from the ECOPORTO project, 51 UCC methane-powered vehicles delivering perishable goods were allowed to make deliveries at anytime between 06.00 and 17.30 (the other freight vehicles were operating from 06.00 to 11.00 and from 15.30 to 17.30) and also had a 80% reduction in congestion access charge (Gonzalez-Feliu, 2011).

From past experience, it appears that the UCCs need an important investment in infrastructure. In some case, the subsidies by the public authorities are not always enough as the operational costs cannot be covered by the UCC's income. However, a UCC that manages to be sustainable must be based on entrepreneurial initiative of operators (offering consolidated deliveries and added value services) and not in direct financing by the public authorities. Additional indirect assistance that can be granted by the public authorities is the extended time windows, privileged use of priority lines and exception from access charging systems (DG MOVE, 2012).

Collecting Delivery Points (CDP)

The development of e-commerce brought consequences to private and freight traffic. Simulation studies have shown that the net gain between the reduced number of car journeys and the increased number of van deliveries could result in a reduction of vehicle/km of up to 70–80% (Cairns, 2005; McLeod *et al.*, 2006). A variety of measures have been introduced in high populated urban areas with the aim to reduce the traffic congestion and the GHG emissions. One of them was the establishment of CDPs which were designed to reduce the traffic which was coming from the increasing trend for internet purchases. CDPs are attended or unattended locations where couriers can leave a parcel when the recipient is not able to receive it. It can be a delivery box in a shopping district in the case of unattended deliveries or a petrol station, a post office or a supermarket in the case of attended deliveries. CDP is an effective solution to tackle the growing phenomenon of missed first-time home deliveries. (Zanni&Bristow, 2010)

Logistics Pooling

Logistics sharing and logistics pooling are specific forms of resource sharing (Gonzalez-Feliu *et al.*, 2010). The term sharing may comprise in material and immaterial resources as well as in the processes of dividing and distributing. While operational decisions are taken by the users, strategic and tactical decisions which are taken by groups with different formalities can be divided in three categories. a) The "non-collaborative sharing" where the involved actors are sharing infrastructure or vehicles for accomplishing their deliveries but without simultaneously sharing them. B)In "Collaborative sharing with hierarchical decision making" the infrastructure and vehicle management is made by the involved actors while there is a manager or a small group of stakeholders that are taking the main decisions. c)Finally, in "Collaborative sharing with non-hierarchical decision making" all stakeholders are taking part in decision making even if there is a third party that has been assigned to manage(Gonzalez-Feliu, 2011).

For freight transport, sharing consists of three parts; Vehicle sharing, infrastructure sharing and route sharing. Concerning vehicle sharing, the logistics organization is similar to that of car sharing or bike sharing systems for people transportation (Katzev, 2003; SUGAR project, 2010). For freight transport, each user can utilize a vehicle to make a delivery by booking on the vehicle's sharing system. The second issue, infrastructure sharing refers to the platform sharing (Rakotonarivo *et al.*, 2010), without necessarily a collaboration between users. The third approach, the route sharing is related to logistics pooling.

Logistics pooling can be defined by analogy to car pooling (De La Morsanglière *et al.*, 1982; Gärlinga *et al.*, 2000). In freight logistics pooling, the decisions are taken by a single stakeholder but all the parties involved in transportation are aware and have a direct action on decisions. As happens on car pooling (De La Morsanglière *et al.*, 1982), a freight transport pooling involves deliveries having a common trip chain in their overall path, and follows the same principles of multi-echelon transport with cross-docking (Gonzalez-Feliu, 2011).

3.3. Best practices for green urban distribution operations

Various policies were implemented in different urban areas for reducing traffic congestion and air pollution. Best practices, as defined, can be adopted by other cities in order to make freight transport more sustainable and upgrade the urban environment. Some of the best practices are described below:

Table 3. 4: Best practices policies and measures

City	Policy/Measure
UK	• Low Emission Zones (LEZ)
Rotterdam	• Electric Vehicle City Distribution System
Barcelona	• Multiply Use Lanes
Barcelona	• Night Deliveries
Germany	• Truck Toll System
France	• Multimodal Freight Transport
Japan	• Multimodal Freight Transport

UK-Low Emission Zones (LEZ)

A Low Emission Zone is a specific area where the access for the freight vehicles is limited depending on the vehicle's technology. Clean and low emission vehicles who comply with the Euro standards are allowed to have access while older vehicle are prohibited to operate inside the LEZ. Although LEZs does not always relieve traffic congestion, the air quality improves as a higher number of clean vehicles are travelling inside (Geroliminis&Daganzo, 2005). The operating companies with aged vehicles have an incentive to replace their existing fleet with cleaner and technologically advanced vehicles. LEZs were firstly established in Sweden as environmental zones where freight vehicles over 3.5 tones were prohibited to enter unless they comply with the Euro emission standards.

In London, freight vehicles which do not meet the emission standards have to pay a daily charge in order to operate in the LEZ. The Congestion Charge applies between 07:00-18:00 from Monday to Friday, excluding public and Bank Holidays (TFL,2014). The emission criteria for trucks, busses and coaches are according to the European emission standards and the Reduced Pollution Certificate (RPC). Between 2002 and 2007 the number of freight vans operating in the charging zone decreased by 13% and for HGVs by 5%. In 2005 an increase in lorries entering the LEZ was detected. Although between 2006 and 2007 traffic figures concerning vehicles/km stabilized, the travelled distance of lorries inside the LEZ increased by 9%. This can be explained by the fact that lorries which pay the daily charge, do maximum deliveries before leaving LEZ. (Zanni&Bristow, 2010)

Rotterdam-Electric Vehicle City Distribution System

Rotterdam, with a population of 600.000 inhabitants, is the most important harbor in Europe concerning the goods distribution. Due to the large volume of goods transport, the public authorities pursued an environmental friendly policy. ELCIDIS (ELectric vehicle CIty DIstribution System) was a project that was coordinated by Public Works Department of Rotterdam and was introduced in further 6 European cities with the aim of supporting cleaner and more efficient freight distribution. The vehicles that were used for freight distribution were hybrid or electric (load capacity of 1-1.5 ton, loading volume 12-16 m^3 and range 75-90 km) replacing the diesel powered vehicles. Electric vehicles offer a very clean alternative to the diesel engine vehicles and are very suitable for the short trips and many stops, characteristic for urban distribution vehicles (Vermie, 2002). Another action adopted was the introduction of an Urban Consolidation Center (UCC) in the edge of Rotterdam which reduced the number of deliveries by heavy duty vehicles, making the freight distribution more efficient. The long distance deliveries were operated by large trucks while vans and small trucks were used for inner city deliveries. Despite the difficulties encountered by vehicle breakdowns, the results were encouraging similar cases exist in Osaka with the electric vans and Zurich with cargo tram (Geroliminis&Daganzo, 2005).

Barcelona-Multiply Use Lanes

The total commercial fleet that operates in Barcelona amounts to 41000 freight vehicles which constitute the 9% of total vehicles and 16% of total trips. There are 6200 loading and unloading points in the city center with significant traffic congestion mainly in the morning. The public authorities introduced the multiple use lanes dividing it in three time periods; Open to traffic from 8 am to 10 am and 5 pm to 9 pm, for loading and unloading from 10 am to 5 pm and for resident parking from

9 pm to 8 am. Furthermore, two different kind of signaling were established; A vertical information panel with the lane use, depending on the corresponding time and a horizontal marker informing freight vehicles for parking availability. Finally a website was created (BCN, 2014) to inform users about the regulations and also enables the user to make a freight reservation for loading and unloading space.

Barcelona - Night Deliveries

Night deliveries came to deal with the phenomenon of traffic congestion in populated urban areas during peak day hours and the public regulations of limited access for freight vehicles. The advantages of night deliveries are the higher road speeds in combination with the lower traffic congestion which result in a lower fuel consumption. Nevertheless, the problems linked with night deliveries are the noise for the residents, as well as theft and security for both drivers and goods. In Barcelona a pilot program called "silent night delivery trial" introduced where freight vehicles equipped with low noise vehicles (low noise equipment, CNG etc) and larger trucks acquired access to the city, where they were restricted during the day time. The lorries were making delivery processes between 23.00h and 24.00h in the night and between 5.00h and 6.00h in the morning (Niches, 2014). The project completed successfully since the two night trips saved 7 day trips in peak hours.

Germany- Truck Toll System

A truck toll system was introduced in Germany to obtain financing for investments in road and environmental infrastructures required due to the significantly increasing freight transport. A distance-based truck toll system was established where trucks with total weight of 12 tones and over were charged with an average of 0,12 € per kilometer (Geroliminis&Daganzo, 2005). The toll system was able to calculate the total distance travelled without creating traffic congestion by slowing down or make vehicles waiting in a designated line. The toll system was operating both manually and automatically in order to verify that all drivers can use it. The automatic toll system was working via automatic telecommunication technology and a satellite-based GPS. The satellite could detect the truck's position, counting the distance travelled while calculating and transmitting the amount of toll charge to the Toll Collect computer center (TOLL-COLLECT,2014).

Urban Waterways in France - Multimodal Freight Transport

While in the past waterway deliveries were continuously decreasing, between 1997 and 2010 an increase of 30% in waterway traffic has been indicated (Diziain *et al.*, 2014). In October 2010 a new service established that deal with waste and recycle goods, which were collected by a barge, covering a range of 20 km in the western part of the Paris region (Hautsde-Seine department). In 2011 the barge transported 300.000 tons of waste while it is estimated that led to 30% reduction in CO_2 emissions comparing with road transport (Diziain *et al.,* 2014).

In 2012, a “warehouse barge” called Vokoli was established on the Seine river assisted by electrically cargo cycles(Fig. 3.4). Ten docks have been created across the river and 4000 parcels are delivered in a daily base. Vokoli is delivering a variety of goods such as office supplies, cosmetics and pharmaceuticals.

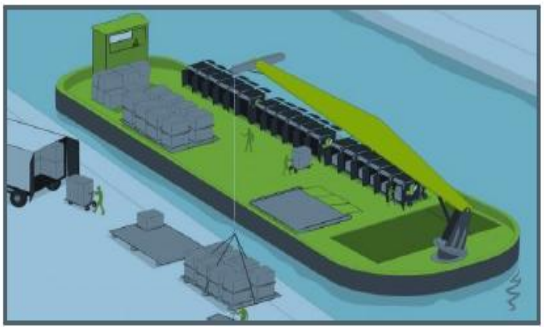

Fig. 3. 4: Vokoli barge and cargocycle (Source: courtesy of Vokoli)

While waterway transport gained a lot of attention due to the increasingly road congestion, there are factors that must be taken into consideration such as the total cost of the single delivery, technical suitability (river depth), natural conditions(floods, typhoons) and requirements for new infrastructure(docks and storage).

Urban Railways in Japan - Multimodal Freight Transport

A waste material service by railway was introduced in 1995 in Kawasaki City which is located south west of Tokyo. The waste, with a daily capacity of 900 tons, was delivered to Ukishima’s waste disposing center, an area 23 km south. The existing rail infrastructure were used for the delivery of residential waste, large residential waste, incinerated ashes, cans and bottles while new properly made containers were developed(Diziain *et al*., 2014). Although railway transport is effective for distances over 500 km, the Kawasaki case was efficient due to the existing railway lines, the subsidies from the Ministry of Environment and the tendency of Japan Railway Freight Company for rail activities.

Another case is the Yamamoto transport company which introduced rail transport between Kyoto and Arashiyama, a tourist area located 10 km to the west. Yamamoto used the Keifuku Electric Railroad, an existing railway line for passengers’ transportation, due to the high road congestion during the peak tourist season. The parcels were travelling before the busy hour for passengers, accompanied by the supporting staff of the company and delivered to their final destination by electric bicycles (Diziain *et al*., 2014).

3.4. Conclusion

In this Chapter, there was mainly a analysis of the best practices for freight transport that can be adopted in an urban area in terms of pickup and delivery schemes, consolidating and pooling and vehicle's technology. According to the vehicle's technology, hybrid and electric powered vehicles seems to be a viable perspective as it can play a significant role in the reduction of GHG and noise emissions. Regarding the market consolidation and pooling strategies, Urban Consolidation Centers (UCC) and logistics polling offer a valuable alternative by optimizing the load capacity of freight vehicles which result to fewer delivery trips. Despite that, there are economic barriers that undermine the development of UCCs with the main reason being the lack of funding. The actions implemented according to the pickup and delivery schemes, are the policies and information technology systems that can contribute to the reduction of traffic congestion and noise pollution. Night deliveries, tolls, LEZs and co-modality are measures that have proved their effectiveness while ITS is a sector with a lot of potential for further development regarding urban freight transport. All the above measures, or in other words best practices, are models that the rest European urban areas can adapt in order to achieve green and sustainable freight transport.

4. Methods and techniques for the calculation of carbon footprint in freight transport

4.1. Introduction

The need for measuring GHG emissions in freight transport operations has resulted in the development of various methods and techniques focusing on the calculation of carbon footprint. In this chapter, we present a list of well known and widely accepted methodologies and techniques for calculating CO_2 emissions adopted in European and global level. A detailed analysis is made to the EN 16258:2012 standard, which is the only one available(in European level) for the calculation of carbon dioxide emission in the transport sector. Furthermore, the chapter also describes a series of tools and databases that provide emission factors based on the type of the vehicle, the vehicle technology and the fuel used. The chapter concludes with classification of all methodologies and tools presented above indicating their characteristics and in which cases are applicable.

4.2. Methodologies and standards for carbon footprint calculation in freight transport

The methodologies and standards that are presented below are widely used for the calculation of carbon footprint. More specifically, EMEP/EEA, CEN 16258:2012, Cefic, Bilan Carbon and NTM are presented.

4.2.1. EMEP/EEA (European Monitoring and Evaluation Programme/ European Environmental Agency)

The European Environmental Agency (EEA) aims to inform the countries - members in order to protect the environment and promote sustainability. In 2009, an updated guide called EMEP / EEA emission inventory guidebook (based on EMEP CORINAIR emission inventory guidebook) was published which provided guidance for calculating emissions from anthropogenic and natural sources(EEA, 2009). In order to calculate the carbon footprint of freight transport, vehicles are classified into categories based on the type and size of vehicle as well as the type of fuel used.

This methodology includes passenger vehicles, motorized scooters, lorries, buses, motorcycles and mopeds. The engine technologies that are included are the conventional, EURO I, II, III, IV, V, VI.

The calculation of GHG emissions can be done by three different methodologies (Tier I, Tier II, Tier III). The choice of the method depends on the available data and the accuracy of calculations desired. The following figure shows the procedure that should be followed for the selection of the most appropriate method in each case.

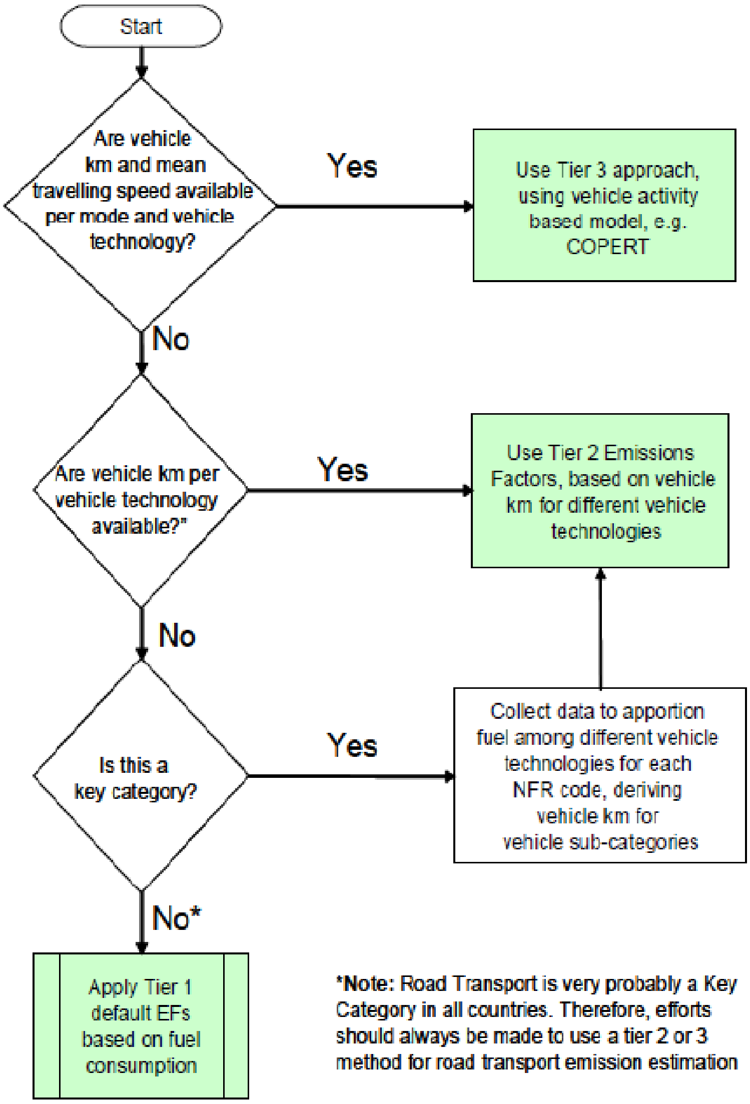

Fig. 4. 1: Decision tree for the choice of the method followed in road transport(EMEP, 2009)

As seen from the figure above, the simplest method for calculating the carbon footprint is the Tier I, which uses only fuel consumption figures. It is noted that it should be used only if there is a lack of statistical data on the transport sector for the specific country. In case that there are available data for the distance travelled for any vehicle category, the method Tier II is proposed. Finally, if there is additional data available as the vehicle's speed, method Tier III is the appropriate. It should be noted that the more detailed and accurate method for emissions' calculation is the Tier III, since it takes into account more parameters.

Tier I

The equation for calculating emissions is:

$$E_i = \sum_j \left(\sum_m \left(FC_{j,m} \times EF_{i,j,m} \right) \right) \quad \text{(Eq. 1)}$$

Where:

E_i emissions of pollutant i, [gr]

$FC_{j,m}$ the fuel consumption of vehicle category j for fuel m, [kg]

$EF_{i,j,m}$ the emission factor of pollutant i for the vehicle category j and fuel m, [g / kg]

The fuels which are included are petrol, diesel, LPG and natural gas. The emission factors are given in gr / kg and they have been calculated with the method Tier III. However, for countries with a fleet consisting of vehicles EURO class II and above, differences may be arise in the results of the Tier I compared with methods II and III. This happens because the tables of emission factors of Tier I do not take into account all advanced vehicle technologies.

Tier II

The equation for calculating emissions is:

$$E_{i,j} = \sum_k \left(\langle M_{j,k} \rangle \times EF_{i,j,k} \right) \quad \text{(Eq.2)}$$

Or

$$E_{i,j} = \sum_k \left(N_{j,k} \times M_{j,k} \times E_{f,j,k} \right) \quad \text{(Eq. 3)}$$

Where:

$\langle M_{j,k} \rangle$ the total distance traveled by all vehicles of category j and technology k, [veh-km]

$EF_{i,j,k}$ the emission factor of pollutant i for vehicle category j and technology k, [gr / veh-km]

$M_{j,k}$ the average annual distance travelled for vehicle category j and technology k, [km / veh]

$N_{j,k}$ the number of vehicles of category j and technology k in national level

The emission factors are given in gr / veh-km and they have been calculated by the method Tier III, taking into account parameters such as speed, ambient temperatures and the type of network (urban, rural, highway). As regards the calculation of emissions compared to Tier I and III, the Tier II method provides more accurate results than the Tier I but not than Tier III. Especially for vehicles with technologies EURO I and higher, the results may vary in relation to the Tier III , as the data of emission factors in gr / veh-km are given for two vehicle categories. The first category includes conventional vehicles while the second includes vehicles with EURO I technology and more, without making separation among EURO I, II, III, IV, V, VI. So, differences in emissions from vehicles complying with stricter rules are not really taken into account.

Tier III

Tier III is the most accurate method for the calculation of GHG emissions, taking into account more parameters that affect the amount of emissions from road transport. According to the Tier III method, the total emissions from road transport are all "hot emissions" including those generated when the vehicle is moving and the " cold-start emissions" including those generated from the transition state of the vehicle engine. It should be noted that the distinction between hot and cold-start emissions is necessary since in the latter case there are larger amounts of emissions due to the change in engine's temperature.

Furthermore, this method takes into account the amount of emissions depending on driving conditions and the type of road network that the vehicle operates. For this reason, emissions are calculated separately for highway, rural and urban network. According to the highway and rural network, the amount of emissions are lower than in the urban network since in the latter the vehicles stop and start several times which leads to greater cold-start emissions.

The calculation of the GHG emissions is made according to the following equations:

$$E_{TOTAL} = E_{HOT} + E_{COLD} \quad \text{(Eq. 4)}$$

And

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY} \quad \text{(Eq. 5)}$$

Where:

E_{TOTAL} total emissions of any pollutant, [gr]

E_{HOT} emissions during vehicle movement, [gr]

E_{COLD} emissions during the transition state of the engine, [gr]

E_{URBAN}, E_{RURAL}, $E_{HIGHWAY}$ emissions in urban, rural and highway road network respectively, [gr]

4.2.2. CEN 16258: 2012

The EN 16258:2012 standard was created by the European Technical Committee and is an internationally recognized standard for the calculation of emissions and energy consumption of freight and passenger transport. The model aims to the transport companies (freight or passenger), the stakeholders and the users of freight transport and transport services.

The data used for the calculation of carbon footprint according to the EN 16258: 2012 are the amount(lt) and the type of fuel, the distance traveled, the fuel consumption, the freight delivered, the loading factor, the payload and the empty running kilometers. These data may be derived from specific measurements or from default values. In case of measured values, the data are provided by the operator or the owner of the fleet of vehicles. Regarding the default values, they should be derived from valid published data (preferably the most recent available).

The three main steps as well as the different phases for the calculation of energy consumption and emissions are the following:

- Step 1: Define the different transport legs
- Step 2: Calculation of energy consumption and GHG emissions for each leg
- Step 2.1: Determination of the Vehicle Operation System (VOS) of each vehicle in this leg
- Stage 2.2: Quantification of total fuel consumption of the VOS
- Step 2.3: Calculation of the energy consumption and GHG emissions of the VOS
- Step 2.4: Allocation of Step 2.3 results throughout the leg

- Step 3: Calculation of total results for each leg

For the calculation of the energy consumption and emissions, firstly the operating system of each leg should be selected, especially the type and the number of vehicles as well as the time period that operated. The next step is the quantification of the total fuel consumption for the selected operating system. In case that vehicles use different fuel types, the calculation of fuel consumption should be done for each type of fuel separately. In Step 2.3 the conversion of fuel consumption to energy consumption and emissions of the vehicle operating system is taking place. The calculation is performed in two separate stages, a) the first includes the procedure from the production of fuel until the distribution and the use from vehicles (Well-to-wheels) and b) secondly only fuel use of the vehicle (Tank- to-wheels). The formulas used for this purpose are given below:

- For well-to-wheels energy consumption of the VOS:
  $E_w(VOS) = F(VOS) \times e_w$ (Eq. 6)

- For well-to-wheels GHG emissions for the VOS:
  $G_w(VOS) = F(VOS) \times g_w$ (Eq. 7)

- For tank-to-wheels energy consumption of the VOS:
  $E_t(VOS) = F(VOS) \times e_t$ (Eq. 8)

- For tank-to-wheel GHG emissions of the VOS:
  $G_t(VOS) = F(VOS) \times g_t$ (Eq. 9)

Where:
$F(VOS)$: the total fuel consumption used for the VOS, [lt]

e_w: the well-to-wheels energy factor for the fuel used, [MJ/kg] or [MJ/lt]

g_w: the well-to-wheel GHG emission factor for the fuel used , [gr CO_2e/MJ] or [kgr CO_2e/kg] or [gr CO_2e/lt]

e_t: the tank to wheel energy factor for the fuel used, [MJ/kg] or [MJ/lt]

g_t: the tank-to-wheel GHG emission factor for the fuel used, [gr CO_2e/MJ] or [kgr CO_2e/kg] or [gr CO_2e/lt]

In the following table, energy and emission factors for the most commonly used types of fuel are indicated.

Table 4. 1: Density and energy rates for different types of fuels (CEN 16285: 2012)

		ENERGY FACTOR			
	Density	**Tank-to-wheels (et)**		**Well-to-wheels (ew)**	
Fuel type description	**kg/l**	**MJ/kg**	**MJ/J**	**MJ/kg**	**MJ/J**
Gasoline	0,745	43,2	32,2	50,5	37,7
Ethanol	0,794	26,8	21,3	65,7	52,1
Gasoline/Ethanol blend 95/5	0,747	42,4	31,7	21,4	38,4
Diesel	0,832	43,1	35,9	51,3	42,7
Bio-Diesel	0,89	36,8	32,8	76,9	68,5
Diesel/Bio-Diesel blend 95/5	0,835	42,8	35,7	52,7	44
Liquified Petroleum Gas (LPG)	0,55	46	25,3	51,5	28,3
Compressed Natural Gas (CNG)		45,1		50,5	
Aviation Gasoline (AvGas)	0,8	44,3	35,4	51,8	41,5
Jet Gasoline (Jet B)	0,8	44,3	35,4	51,8	41,5
Jet Kerosine (Jet A1 and Jet A)	0,8	44,1	35,3	52,5	42
Heavy Fuel oil (HFO)	0,97	40,5	39,3	44,1	42,7
Marine Diesel Oil (MDO)	0,9	43	38,7	51,2	46,1
Marine Gas Oil (MGO)	0,89	43	38,3	51,2	45,5
Aviation Gasoline (AvGas)	0,8	44,3	35,4	51,8	41,5

Table 4. 2: Density and GHG emission factors for various fuel types (CEN 16285: 2012)

		GHG EMISSION FACTOR					
	Density	**Tank-to-wheels (et)**			**Well-to-wheels (ew)**		
Fuel type description	**kg/l**	**gCO_2e/ MJ**	**$kgCO_2e$/ kg**	**$kgCO_2e$ /l**	**gCO_2e/ MJ**	**$kgCO_2e$/ kg**	**$kgCO_2e$ /l**
Gasoline	0,745	75,2	3,25	2,42	89,4	3,86	2,88
Ethanol	0,794	0	0	0	58,1	1,56	1,24
Gasoline/Ethanol blend 95/5	0,747	72,6	3,08	2,3	88,4	3,74	2,8
Diesel	0,832	74,5	3,21	2,67	90,4	3,9	3,24
Bio-Diesel	0,89	0	0	0	58,8	2,16	1,92
Diesel/Bio-Diesel blend 95/5	0,835	71	3,04	2,54	88,8	3,8	3,17
Liquified Petroleum Gas (LPG)	0,55	67,3	3,1	1,7	75,3	3,46	1,9
Compressed Natural Gas (CNG)		59,4	2,68		68,1	3,07	
Aviation Gasoline (AvGas)	0,8	70,6	3,13	2,5	84,8	3,76	3,01
Jet Gasoline (Jet B)	0,8	70,6	3,13	2,5	84,8	3,76	3,01
Jet Kerosine (Jet A1 and Jet A)	0,8	72,1	3,18	2,54	88	3,88	3,1
Heavy Fuel oil (HFO)	0,97	77,7	3,15	3,05	84,3	3,41	3,31
Marine Diesel Oil (MDO)	0,9	75,3	3,24	2,92	91,2	3,92	3,53
Marine Gas Oil (MGO)	0,89	75,3	3,24	2,88	91,2	3,92	3,49

After calculating the energy consumption and total emissions in the selected operating system, the share of those that belong to this leg should be calculated in Step 2.4. The formulas used in this section are the following:

- $S(leg) = T(leg) \div T(VOS)$ (Eq. 10)
- $E_w(leg) = E_w(VOS) \times S(leg)$ (Eq. 11)
- $G_w(leg) = G_w(VOS) \times S(leg)$ (Eq. 12)
- $E_t(leg) = E_t(VOS) \times S(leg)$ (Eq. 13)

- $G_t(leg) = G_t(VOS) \times S(leg)$ (Eq. 14)

Where:

$S(leg)$: the factor used to calculate the share of the VOS's energy and emissions which is allocated to a transform service for the leg. This share is based on relative proportions of transport activity for the leg and for the associated VOS.

$T(leg)$: the transport service's transport activity for the leg, [tn-km].

$T(VOS)$: the transport activity of the VOS which is related to the leg, [tn-km].

The transport activity can be calculated by multiplying the freight delivered to the distance traveled. According to the freight delivered, the amount of freight as well as the packaging, handling and transport material should be included. Finally, in Step 3, the total emissions and energy consumption are calculated by adding the relevant results from the different modes of transport, in case that exists.

The EN 16258: 2012 standard was selected for the calculation of the carbon footprint in the case study that is discussed in chapter 5, as it is a globally recognized standard for measuring GHG emissions, giving accurate result in cases where fuel consumption data are available. More detailed description will take place in chapter 5.

4.2.3 European Chemical Industry Council (Cefic)

The methodologies that are discussed in this section have been proposed by the organization of Cefic, in an effort to find ways to measure and reduce the carbon footprint of the transport activity on the chemical industry. According to the survey results, the calculation of GHG emissions from road transport can be based on the fuel consumption of vehicles (energy based), or on the transport activity (activity based) (Cefic, 2011).

Energy Based:

The calculation of carbon footprint in this case is made by multiplying the fuel consumption with the conversion factor corresponding to the particular fuel. The equation for emissions calculation is:

$$CO_2(kg) = \text{fuel consumption(lt)} \times \text{conversion factor}\left(\text{kg} \times \frac{CO_2 =}{lt}\right)$$ (Eq. 15)

According to the equation above, there are tables with specific conversion factors in accordance with the different type of fuel. The fuel consumption data can be derived from fuel receipts showing the quantity and the type of fuel purchased or by direct measurement of fuel gaugers and fuel storage tanks. Alternatively, if there are economic data of fuel costs, there can be a fuel conversion based on the average selling fuel price. Many companies have outsourced the transport of products to third parties, which makes the access to these data difficult (McKinnon et al., 2010).

Activity Based

In the absence of fuel consumption data, the proposed method for estimating GHG emissions is the activity based. The equation for calculating emissions is:

$$CO_2(kg) = \text{tones transported} \times \text{distance travelled(km)} \times \text{conversion factor}\left(\text{kg} \times \frac{CO_2}{tn-km}\right)$$

(Eq. 16)

The emission factors are given in tables and depend on the gross weight of the vehicle and the loading factor during the trip. According to the equation given above for carbon footprint calculation, data of vehicle activity for each vehicle type is required. The data of the freight and the distance traveled in each case can be derived from information systems or delivery certificates.

4.2.4 Bilan Carbone

Bilan Carbone is both a methodology and a tool. It developed at national level for the calculation of carbon footprint and is widely used in France. It was created by the French Agency for Environment and Energy Management (ADEME). The organization is composed of public and private entities which promote sustainability and provide consulting services to businesses, local authorities and citizens, aiming at the optimization of environmental management. Direct and indirect emissions can be calculated with Billan Carbone methodology. The main purpose is to take into account all the physical flows which are necessary for the operation and link them with the GHG emissions that they produce. Some of the main features that are taken into account are the space heating, the combustion in case of manufacture process, the freight shippers, the passengers travel, the raw production and the waste management. It is an easy accessible methodology, providing specialized guidance to industrial, tertiary businesses and local authorities for the calculation of GHG emissions (ADEME, 2010).

4.2.5 Network for Transport and Environment (NTM)

NTM is another important methodology that has been developed in Sweden by the Network for Transport and Environment (NTM). The latter is a non-profit organization with experience in creating databases and methodologies for effective measuring of the environmental impact in the transport sector. The calculation tool created by NTM was the result of the collaboration between NTM organization, industrial members, academic groups and other transport stakeholders. For the case of road transport, vehicles are classified into 13 categories and the calculation of GHG emissions is based on vehicle's loading factor including distances traveled without payload (empty running). The methodology includes the calculation of the following emissions: CO, HC, NO_x, PM, CH_4, SO_2, CO_2 as well data of energy consumption (NTM, 2013). However, parameters such as weather conditions, driving style and the type of engine are not taken into account, making emission results looking more as indicators rather than accurate information. Finally, it is considered to be an important tool, as it was used for the creation of the internationally recognized standard EN:16258:2012(NTM,2014).

4.2.6 Comparative analysis of current methods and standards

The following table presents a classification of methods for calculating the carbon footprint in the transport sector.

Table 4. 3: Methods for calculating the carbon footprint

Methodology	Level	Modes of Transport	Type	Availability
EN 16258		All modes of transport	Energy based	Public
CEFIC		All modes of transport	Energy based/ Activity based	Public
EMEP/EEA	TIER I	Road transport	Energy based	Public
	TIER II		Activity based	
	TIER III		Activity based	
Bilan Carbon		All modes of transport	Activity based	Public
NTM		All modes of transport	Activity based/ Energy based	Partly public

Green Freight Transport	All modes of transport	Activity based	Public

The table above classifies the specific tools according to certain criteria such as the modes of transport, the type of data entry and the access by the user. As we observe, most of the methodologies cover a wide range of transport. There are methodologies that cover both activity and energy based data while others are specialized. Lastly, almost all methodologies permit free access to the user.

4.3 Tools and applications for carbon footprint calculation in freight transport

4.3.1. EcoTransIT

Ecological Transport Information Tool (EcoTransIT) is one of the most recognized tools for the carbon footprint calculation in all modes of transportation worldwide. EcoTransIT is a free online tool for calculating the energy consumption and GHG emissions from the freight sector. The calculation of emissions can be made in two levels. The first level (standard) provides a primary estimation of emissions, while the second level (extended) offers a more detailed and accurate calculation of emissions, by using more parameters. The parameters used are the means of transport, the quantity and type of goods, the freight delivered, the loading factor, the empty trips and the point of departure and arrival.

4.3.2. Cenex

In the United Kingdom, the Cenex organization (the Centre of Excellence for low carbon and fuel cell technologies) created another tool for calculating the carbon footprint, specialized in emissions produced by road freight transport. The tool supports fleet managers and vehicle operators, providing information in two related fields; Firstly to reduce their emissions for environmental reasons and secondly to reduce their fuel consumption for financial reasons. The information focuses on the technical measures that can be used as part of decarbonising a fleet. The Cenex guidance presents step-by-step the procedures for calculating the current vehicles' emissions of the fleet. In addition, the guide enables the user to estimate the reduction of emissions by using various fuel types and technologies in order to find the most viable option (Cenex, 2010).

4.3.2. Copert

COPERT (Computer Programme to calculate Emissions from Road Transport) is a software tool used for the calculation of air pollutants and greenhouse gas emissions produced by road transport worldwide. COPERT 4 is the latest updated version of COPERT which is based on the methodology EMEP / EEA Inventory Guidebook - Tier III - as defined by the EU. Copert 4 was created by the Laboratory of Applied Thermodynamics of Aristotle University of Thessaloniki (EMISIA) and is recognized by the European Environment Agency (EEA) and the European Topic Centre for Air Pollution and Climate Change Mitigation (EMISIA, 2013). It enables the calculation of GHG emissions according to the distance travelled the type of the vehicle and fuel used including parameters such as the type of the road(urban, rural, highway), the vehicle speed and the loading factor (Gkatzoflias D et al., 2007). The effects of carbon dioxide emissions are given in kg CO_2 per trip.

4.3.4. Carbon Footprint for Metro Group Logistics

Apart from the tools mentioned which are accessible to the public, there are private companies which have developed in-house tools. Metro Group Logistic company created in collaboration with the consulting company Bearing Point, the Carbon Footprint tool for Metro Group Logistics. The tool aim is to calculate the carbon footprint of the Metro Group Logistics supply chain by focusing on the transport operations of the company. The calculation of the carbon footprint is based on suppliers' data and the actual distribution network. The results of the emission can be per customer-supplier or per shipment (Bearing Point, 2013).

4.3.5. Comparative analysis of current tools and applications

The table below presents a classification of tools for calculating the carbon footprint in the transport sector.

Table 4. 4: Tools for calculating the carbon footprint

Tools /Applications	Emissions Covered	Transport Mode	Availability
EcoTransIT World	CO_2,CH_4,Nox,SO_2	All modes of transport	Public
Cenex	Green House Gases	Road transport	Public
COPERT 4	CO, VOC, NMVOC, CH4, NOx, NO, NO_2, N_2O, CO_2	Road transport	Public
Carbon Footprint for Metro Group	CO_2, CH_4, N_2O, CO	Road transport	In-house stakeholders

The table above classifies the specific tools according to certain criteria. These are the emissions and the modes of transport that they cover as well the ability to be accessed by the user. As we observe, the majority of the aforementioned tools cover a wide range of emissions and are specialized in road transport while the last tool is targeted to all modes of transport. Finally, almost all databases allow free access to the user. The above mentioned categorization is useful for the users in order to be able to choose the appropriate tool according to their specific needs for the calculation of carbon footprint.

4.4. Databases for carbon footprint calculation in freight transport

In this section, a description of the available databases used to calculate the carbon footprint in freight transport is presented. The main primary data that can be found in these databases are mainly the emission factors of greenhouse gas emissions based on the vehicle type, vehicle technology and the fuel type used.

4.4.1. CORINAIR

The database of the European Union (EMEP / EEA), formerly known as CORINAIR, contains emission factors that can be used for the emissions calculation in the European Union. This database holds data concerning road transport, where vehicles are grouped by type (cars, trucks scooters, lorries, buses, motorcycles, etc.), fuel used (petrol, diesel, etc.), vehicle technology (conventional, EURO I, II, III, etc.) and finally the size of the vehicle (EEA, 2009).

4.4.2. HBEFA

In commercial terms, one of the most significant databases is the HBEFA (Handbook Emission Factors Road Transport) which deals exclusively with road transport. This database was created by taking into account different driving conditions, considering 44 cars technology EURO II and EURO III in different driving conditions and different roads (De Haan & Keller, 2004).

4.4.3. JEC

Another important database created by JEC which resulted from the collaboration of JRC / IES (the Institute for Environment and Sustainability of the EU Commission's Centre), EUCAR (the European Council for Automotive R & D) and CONCAWE (the oil companies' European association for environment, health and safety in refining and distribution). This database is available online, free of charge and gives the emission factors in gr / km depending on the type of fuel and engine, offering a choice between compatible and alternative technologies and fuels. (JEC, 2008)

4.4.4. LIPASTO

In 2011 in Finland, the database LIPASTO was created by the Technical Research Centre (VTT), covering all modes of transport. The database is available for free via internet and offers information on energy consumption and emission factors. (LIPASTO,2014).

4.4.5 ARTEMIS

Under the 5th European Development Programme for Sustainable Mobility, ARTEMIS project (Assessment and Reliability of Transport Emissions Models and Inventory Systems) created a database for emission factors including all modes of transport. The database provides all necessary data for the calculation of emissions including the amount of 'hot and cold emissions' and exhausts for road transport (André *et al.*, 2008).

4.4.6. Comparative analysis of current databases

The following table presents a classification of databases for calculating the carbon footprint in the transport sector.

Table 4. 5: Databases for the calculation of carbon footprint

Database	Emissions Covered	Modes of Transport	Availability
EMEP/EEA (CORINAIR)	CO, NOx, NMVOC, CH_4, CO_2, N_2O, NH_3, SOx, PM, PAHs, dioxins and furans, heavy metals contained in fuels	All modes of transport	Public

HBEFA	CO, CO_2, FC, HC, NOx, PM	Road transport	Commercial use
JEC	CO_2, CH_4, N_2O and CO_2 equivalents	Road transport	Public
LIPASTO	CO, HC, NOx, PM, CH_4, N_2O, SO_2, Pb, CO_2, CO_2 equivalent, energy consumption	All modes of transport	Public
ARTEMIS	CO, HC, NO_x, PM, Pb, SO2, CO_2, methane, ammonia, benzene, tolyene, xylene, polycylic aromatic hydrocarbons, PM , 1.3-butadiene, acetaldehyde, acrolein, benzopyrene, ethylbenzene, formaldehyde, hexane	All modes of transport	Public

The table above classifies the specific tools according to certain criteria such us the emissions and the modes of transport that they cover as well as the ability to be accessed by the user. As we observe, the majority of the abovementioned databases cover a wide range of emissions. Furthermore there are databases that are specialized in the road transport while other are targeting to all modes of transport. Finally most of the databases allow free access to the user.

4.5. Conclusion

In this Chapter there was a detailed presentation of three main methods for the calculation of carbon footprint. The first was the Tier I, II, III of the European Environmental Agency, followed by the Council of the European Chemical Industry methodologies (Cefic) and finally the standard EN 16258: 2012 which was selected for the calculation of the carbon footprint in the case study presented in Chapters 5. Furthermore, there was a brief analysis of tools and databases used in recent years for the calculation of carbon footprint in the supply chain and more specifically in freight transport. Finally, the chapter concludes with pivot tables presenting summarized data according to the methodologies, tools and databases that were analyzed above.

5. Calculation of carbon footprint in a retail company with privately owned fleet: The case of AB Vassilopoulos

5.1. Introduction

This chapter presents the results from the calculation of carbon footprint in the privately owned fleet of the retail company AB Vasilopoulos for the freight distribution network located in the area of Attica. In first instance, the historical data that were collected from the retail company are described, followed by the assumptions that were made for the calculation of the carbon footprint. Then, the results of the calculation are presented(in monthly and semester level) while an analysis of the vehicles' efficiency in terms of CO_2 emissions per tonne-kilometer takes place in order to assess the environmental efficiency of the fleet. The chapter concludes with a summary of the main findings.

5.2 Company profile

AB Vassilopoulos SA was founded on December 1969 by Gerasimos and Charalambos Vassilopoulos. The company operates in the food retail sector and is one of the biggest companies in Greece. AB Vassilopoulos belongs from 1992 to the Delhaize group, the leading Belgian retail company. The branch network of AB Vassilopoulos consists of 308 retail shops while the availability of goods' variety reaches the amount of 26,600 active SKUs. It is the most significant company in retail market while is now among the largest employers in Greece, with a staff of 11.000 employees approximately, and the fifth largest commercial enterprise in the country. The company has three central warehouses located in major geographical nodes. The central warehouse that is taken into consideration in this project is located in Mandra (Attica region) while the rest of the warehouses are located in Oinofita and Sindos, which belong to the prefecture of Voiotia and Thessaloniki, respectively. The company has adopted a centralized system for goods storage and distribution that is why most of the goods are stored in the central warehouses and then delivered to the supermarkets. The distribution of the goods to the retail stores is taking place mainly by using the private fleet of the company. In some cases specific type of products are directly distributed by suppliers' fleet of vehicles.

5.3. Methodology and assumptions for the calculation of the carbon footprint

For the calculation of the carbon footprint, a specific methodology was followed that consists of certain steps as shown in Figure 5.1:

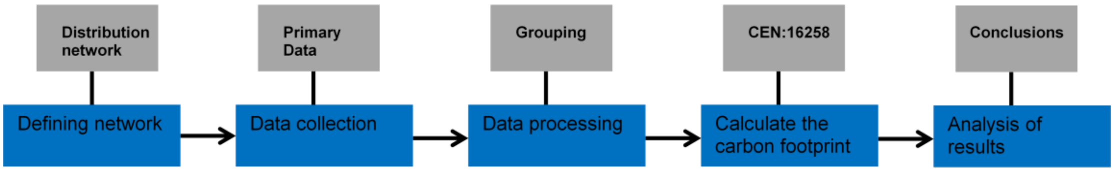

Fig. 5. 1: Process followed for the calculation of carbon footprint

Initially, the network was defined according to the distribution process of the company. Then, the data collection took place where the primary data were collected for further analysis. The next step was the data processing where the data were grouped in monthly and semi-annual basis. Subsequently, the calculation of carbon footprint followed where the EN:16258:2012 standard was used, taking into account as a main factor the fuel consumption of each vehicle. Finally the analysis or the results took place where the main findings were described.

The above steps are described in detail below.

Defining network and data collection

Initially the distribution network that would be taken into consideration was identified. More specifically, the calculation was focused on the distribution network in the Attica region. The distribution center (i.e. initial and ending point of the vehicles) of the retail company is located in Mandra (Attica region). The vehicles are executing deliveries from Mandra to the supermarkets located throughout Attica . The fleet of AB Vassilopoulos consists of sixty seven (67) vehicles with various loading capacities and engine technologies. Furthermore, for the calculation of the carbon footprint we took into consideration both the goods distribution after a normal delivery and the return trip. During the return trip, the vehicle was carrying product returns or executing backhauling. Backhauling is the procedure where the vehicle is carrying freight form a supplier's premises during the return trip. The primary data that were required for the calculation of carbon footprint is shown in Table 5.1.

Table 5. 1: Type of primary data for the calculation of the carbon footprint

Data Type	Data Elements
Date of data collection	First half of 2014 (1/1/2014-30/6/2014)
Total distance travelled per trip	Km
Total payload per trip	Kg
Total fuel consumption per trip	Lt
Total number of points visited (per trip)	Number of supermarkets per trip
Area of the supermarket	Urban
Zip Code of the supermarket	e.g. 16345
Pallets transferred per trip	Numbers of pallets delivered
Gross weight	tn
Payload	tn
Vehicle's fuel	Diesel
Vehicle's engine technology	Euro II, III, IV, V, VI
Returns and Backhauling	Kg/pallets

The data acquired by the company included the vehicles' routes, vehicle's technical description and the backhauling. Table 5.2, shows the type of data acquired.

Table 5. 2: Primary data for the vehicle's routes

PRIMARY DATA FOR THE CALCULATION OF CARBON FOOTPRINT					
Period of data collection:	January-June 2014				
Vehicle's plate	YPO 2951				
Vehicle's type (e.g. Articulated 34-40Tn):	....	**Gross weight (Tn):**	19000	**Payload (Tn):**	8570
Engine's technology (e.g. EURO III):	III				
Type of network:	100% Urban	........**% rural**	.... **% highway**		

Date of Delivery	Total distance travelled (klm)	Total fuel consumption per delivery (lt)	Points visited (per trip)	Region	Zip Code	Pallets
3/1/2014	114.251	27.79	2	ILIOUPOLI;PAPAGOS	163 45;156 69	16.8
4/1/2014	113.225	27.69	1	ALIMOS	174 55	18
4/1/2014	77.165	34.19	1	N.MAKRI	190 05	18
7/1/2014	114.305	33.88	1	MARKOPOULO	190 03	16
7/1/2014	106.113	23.09	3	RADIO CITY;MENIDII 2;LIKOVRISI	112 53;136 71;141 23	18
7/1/2014	35.41	34.20	1	KALIVIA(AGORA)	190 10	14
7/1/2014	74.687	31.75	1	GLIFADA NEO	166 74	18
9/1/2014	91.372	10.60	1	CHAIDARI	124 61	18
9/1/2014	41.813	22.35	1	GLIKA NERA 2	153 51	18
9/1/2014	56.122	27.34	1	KOROPI	190 02	12

The data that have been used for the calculation of the carbon footprint are the fuel consumption, the distance travelled and the freight delivered.

Table 5.3 presents a description of the technical characteristics of the fleet of vehicles. For each vehicle typical information include: manufacturer, model, engine technology, gross weight and payload.

Table 5. 3: Technical characteristics of the vehicles

Vehicle's Plate	Make	Model	Euro	Gross Weight	Payload
YXO8516	VOLVO	FL10	II	18.000	7.562
YZY8315	MERCEDES	1317	II	13.000	5.680
YXX2653	MERCEDES	2540	II	26.000	14.540
YXX2654	MERCEDES	1317	II	13.500	6.906
YXX2655	MERCEDES	1317	II	13.500	6.926
YXX9181	MERCEDES	1317	II	13.500	5.950
ZYN2882	VOLVO	FL6	III	19.000	9.322
ZYN2883	VOLVO	FL6	III	19.000	9.322
YPO2951	VOLVO	FL6	III	19.000	8.570
YPO9198	IVECO	ML 180 E 24	III	18.000	8.432
YPO9199	VOLVO	FL6	III	19.000	8.512
YPO9200	VOLVO	FL6	III	19.000	8.470

Finally, Table 5.4 shows the amount of cargo transferred by certain vehicles during their return trip (backhauling).

Table 5. 4: Data concerning backhauling operations

Date	Supplier	Vehicle's Plate	Payload(pallets)	Backhauling(pallets)
03/01/2014	MELISSOS	YPO 9199	18	13
03/01/2014	BDF	YXX 9206	35	28
03/01/2014	COLGATE	YXO 8516	35	32
03/01/2014	SCA	ZXN 1851	35	33
03/01/2014	SCA	ZXN 1850	35	33
03/01/2014	SCA	YTA 9372	35	33
03/01/2014	COLGATE	ZXH 3901	15	15
07/01/2014	NESTLE	ZXN 1850	35	32
07/01/2014	COLGATE	ZXH 9873	18	10
07/01/2014	SCA	YXX 9206	35	33
07/01/2014	NESTLE	YXO 8516	35	32

The table above includes data related to the date of the cargo collection, the supplier visited, the vehicle used per case, its payload and last but not least the amount of cargo carried per vehicle (backhauling).

Data processing

After collecting the necessary data, the next step was the data processing. The latter took place in a daily base for every single delivery trip. After that, a grouping in monthly and semester level took place for each vehicle. The main aim of this step(i.e. data processing) was the calculation of the total CO_2 emissions(per vehicle, per fleet, per month). Nevertheless, various key performance indicators were additionally calculated such as the tonne-kilometers, the CO_2 emissions per tonne-kilometers(gr) as well as the loading factors per truck.

Calculation of carbon footprint

For the calculation of the carbon footprint the standard EN 16258: 2012 was applied (CEN,2012). The latter is the sole European standard that uses fuel consumption(energy-based methodology) as a basis for the calculation of the CO_2 emissions of a vehicle (COFRET,2011).

In our case, the data used were the amount (lt) and the type of fuel used. For the specific type of fuel (diesel) there is a unique emission factor which equals to 2,67 based on the CEN 16258:2014 prototype. The calculation concerns the tank-to-wheels procedure.

The equation used for the calculation of carbon footprint of the vehicle operation system (VOS) is:

$G_t(\mathrm{VOS}) = \mathrm{F}(\mathrm{VOS}) \times g_t$ (Eq. 1)

Where:

F(VOS): the total fuel consumption used for the VOS, [lt]
g_t: the tank-to-wheel GHG emission factor for the fuel used, [gr CO_2e/MJ] or [kgr CO_2e/kg] or [gr CO_2e/lt]

For the calculation of the tonne-kilometers, the route was divided in two legs. The first leg included the route of the vehicle from the distribution center to the points of delivery (i.e. supermarket stores). The second leg included the reverse route, where each vehicle carried returns or provided backhauling services. The following equation was used for the calculation of tonne-kilometers:

$$\mathrm{tn-km} = \frac{freight\ transfered\ to\ supermarket \times distance\ travelled}{2} + \frac{\text{returns and backhauling} \times \text{distance travelled}}{2} \quad \text{(Eq. 2)}$$

Another significant indicator is the CO_2 emissions per tonne-kilometer. Its usefulness lies on the fact that it can display how efficient a vehicle is. It is resulting from the division of the total CO_2 emissions to the total tonne-kilometers during a route, as described from the following equation:

$$\frac{\mathrm{gr}\ CO_2}{tn-km} = \frac{G_t\,(vos)}{total\ tn-km} \quad \text{(Eq. 3)}$$

Loading Factor-Assumptions for the calculation of the carbon footprint

For the calculation of the loading factor, it was necessary to define the cargo travelled during the trip. Initially, the average weight per pallet was considered to be 450 kg. This assumption is based to the type of the goods that the company distributes as well as according to the load capacity of the fleet of vehicles. Furthermore the trip was divided in two legs: a) from the distribution center to the points of delivery and b) the return trip.

As concerns the initial trip, the calculation included the cargo travelled from the distribution center to the points of delivery (i.e. supermarkets) according to the primary data given by the company. Figure 5.2 describes the calculation of the loading factor during the initial trip.

$$LF = \frac{\text{Freight Transferd}}{\text{Payload}} \times 100\%$$

Fig. 5. 2: Calculation of the loading factor during the first leg

During the return trip, the freight vehicles may carry: a) product returns (destroyed and out of date items) and returning transit equipment (roll cage cover), b) freight from supplier's premises (backhauling), c) return empty. In order to define the cargo traveled, an assumption was carried out where the vehicles during their return trip are making backhauling or they are carrying returns equal to 15% of the average load per trip.

The average load per trip was calculated by summing up all the freight delivered during the semester and dividing it with the total number of the trips. Line with the above, the average load amounts to 6.943 kg.

The backhauling during the semester corresponds to 1.130 routes. The total cargo delivered from backhauling was isomerized into the total trips (20.335 trips) and amounts to 550,67 kg per trip. For the rest of the trips (19.205 trips) there was an assumption that each vehicle carries 15% of the average load (6.943 kg). This load was also isomerized to the total trips (20.335 trips) and amounts to 983,57kg per trip. By summing up the product returns and backhauling, every vehicle carries during the return trip on average 1534 kg. Figure 5.3 describes the calculation of the loading factor during the return trip.

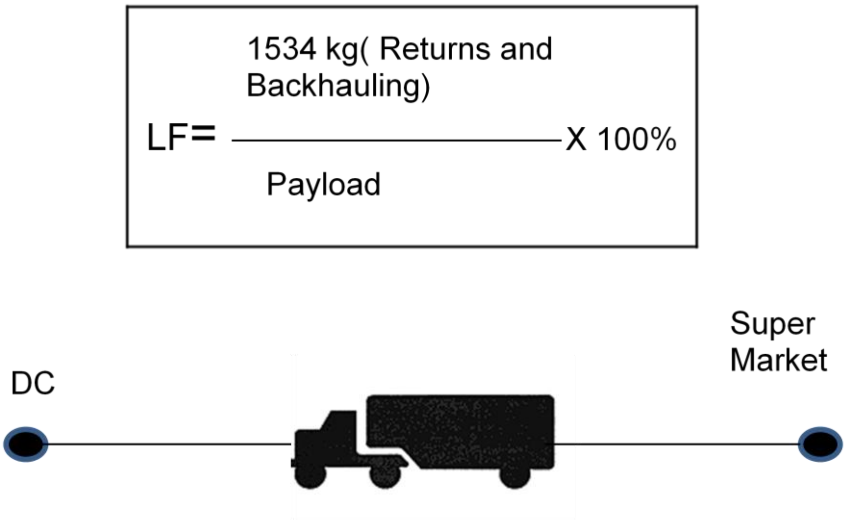

Fig. 5. 3: Calculation of the loading factor during the return trip

Overall, for the calculation of the loading factor, the following equation was used:

$$\text{Loading Factor} = \left(\frac{\mathit{Cargo\ to\ Supermarket}}{\mathit{Load\ Capacity}} + \frac{\text{Returns and Backhauling}}{\mathit{Load\ Capacity}}\right) \div 2 \quad \text{(Eq. 4)}$$

5.4 Monthly and semi-annual results from the calculation of the carbon footprint

Figure 5.4 shows the total CO_2 emissions per month of the fleet of under consideration. The measuring unit is in tones.

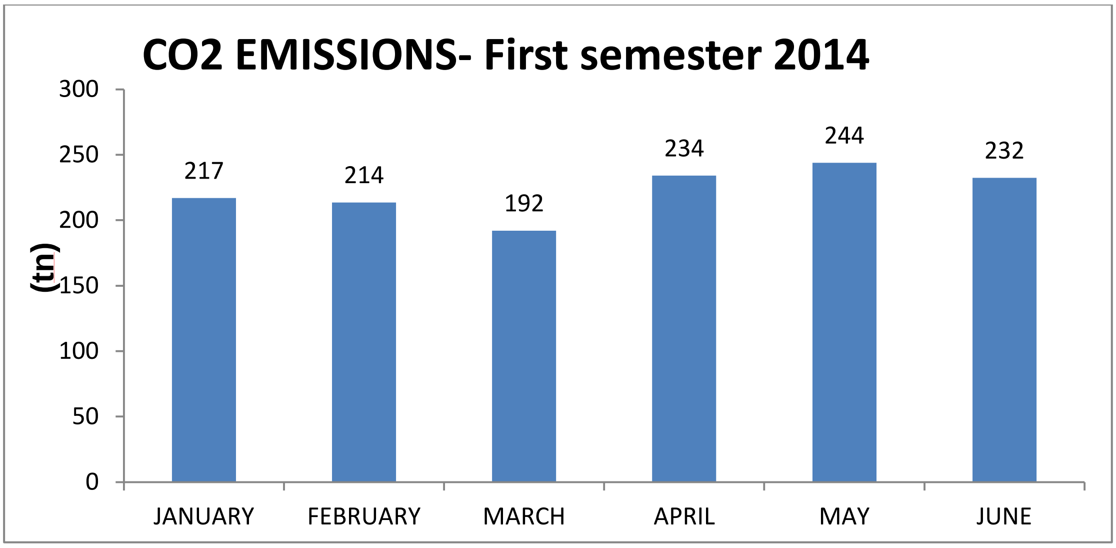

Fig. 5. 4: Monthly CO_2 emission of fleet of vehicles

According to the Figure 5.4, it seems that April and May exhibit the highest total emissions when compared to the other months. This is due to the fact that during the end of April the celebration of Easter took place and the need for product replenishment in the retail stores increased significantly.

Figure 5.5 shows the loading factor of the delivery vehicles per month.

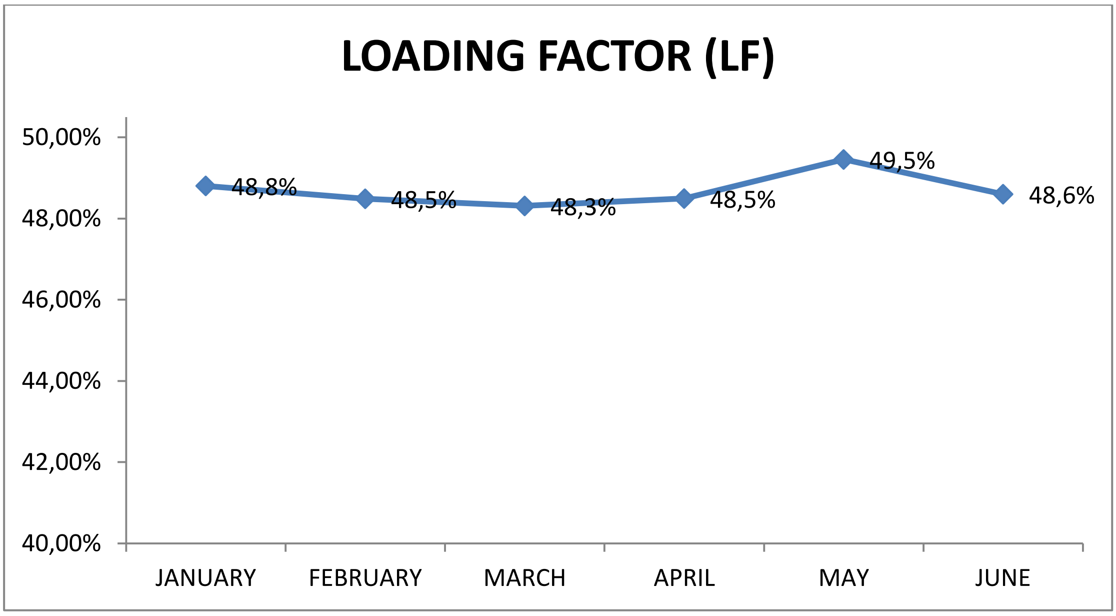

Fig. 5. 5: Monthly loading factor of fleet of vehicles

From the figure above, we can notice that May has the highest loading factor in contrast with March which has the lowest one. The average loading factor is 48,7% while all the months are showing a slight deviation from the average.

Figure 5.6 shows the CO_2 emissions per tonne-kilometer. It is a significant indicator since it enables us to decide how efficient a vehicle is. The measuring unit is in grams.

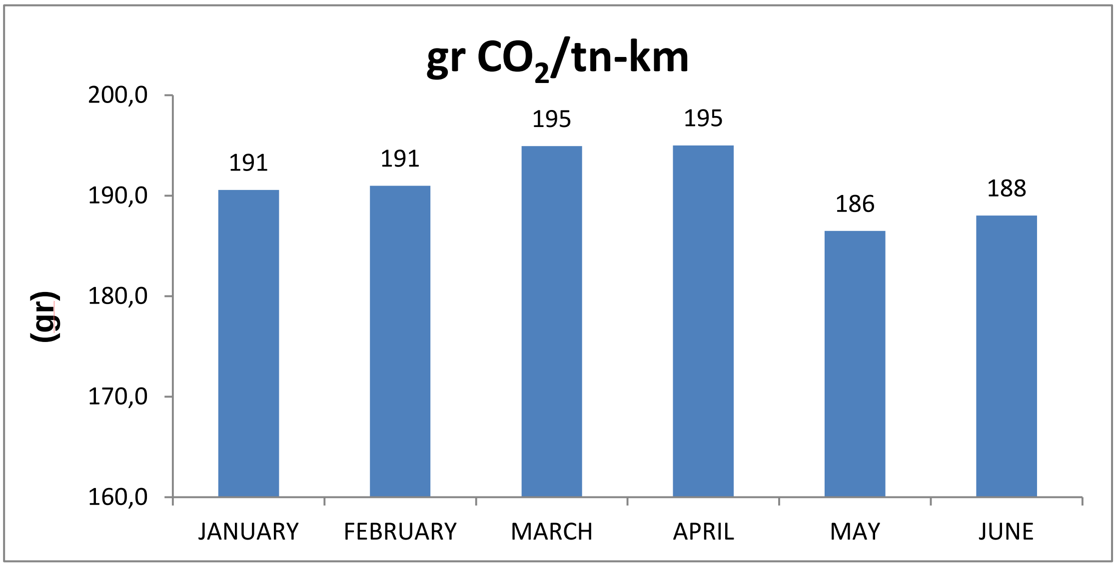

Fig. 5. 6: Monthly CO_2 emissions per tonne-kilometer

From the figure above it appears that, although May has the highest total emissions, it is the most efficient month in terms of CO_2 emissions per tonne-kilometer. Furthermore, May has the highest loading factor which equals to 49,5%. In contrast, March and April are the less efficient months in terms of CO_2 emissions per tonne-kilometer where the lower loading factors are identified.

Below there is a figure of the total kilometers travelled per month.

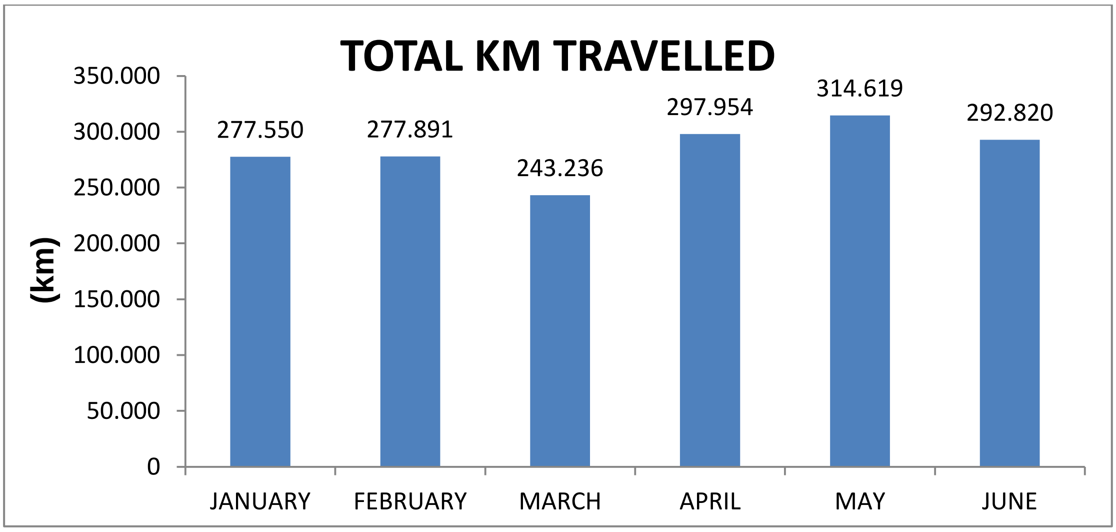

Fig. 5. 7: Monthly kilometers traveled (km**)**

According to the Fig 5.7, we can notice that May has the highest kilometers travelled which is consistent with the highest CO_2 emissions of the given month. On the other hand, March has the fewest kilometers travelled while it displays the lowest CO_2 emissions.

Bellow there is a figure with the total tonne-kilometers per month.

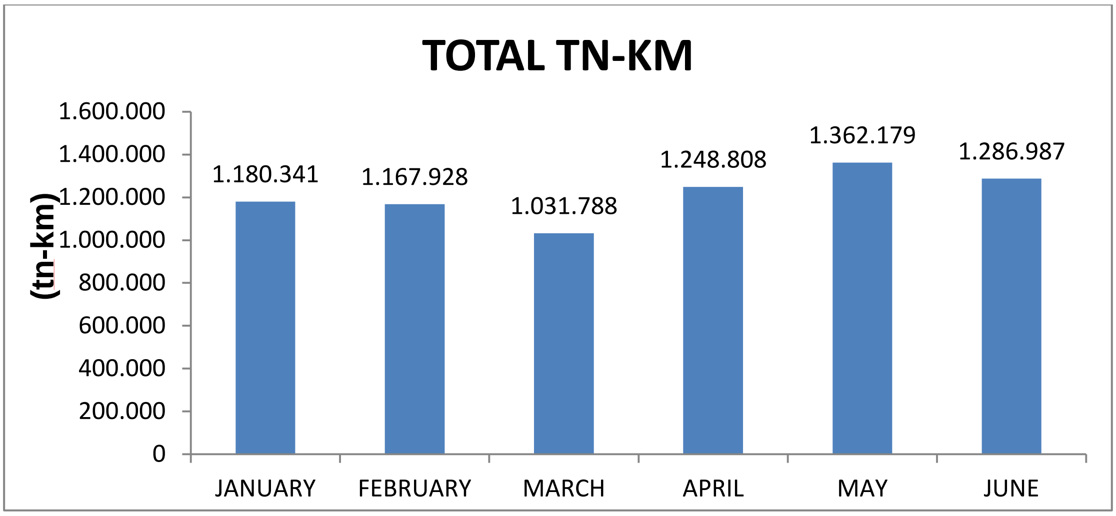

Fig. 5. 8: Monthly tonne-kilometers travelled

As it appears from the figure above, the total tonne-kilometers are consistent with the total kilometers. May has the highest kilometers and tonne-kilometers while March has the lowest ones.

Below there is a figure with the amount of freight delivered per month during the specific semester. It includes only the freight that the company distributed to the delivery points without taking into account product returns and backhauling.

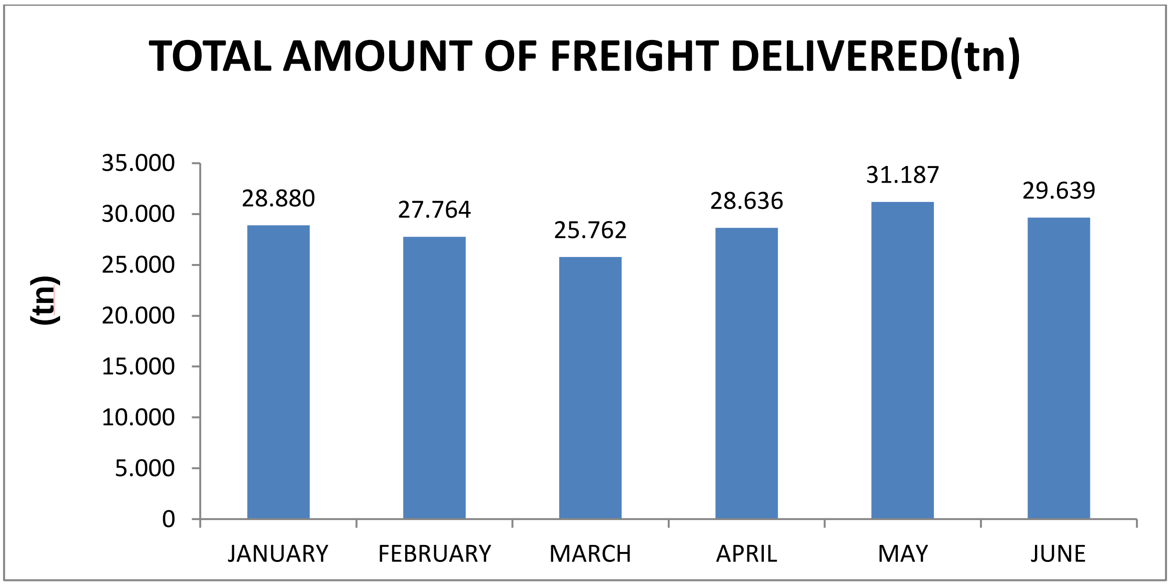

Fig. 5. 9: Amount of freight delivered (per month)

As arises from the Fig 5.9, the total freight travelled per month follows a similar trend with the total distance travelled which is described in the figure 5.7. and it can be explained from the fact that the loading factor follows a similar pattern.

Below there is a figure with the total fuel consumption per month. The fuel that the fleet of vehicles use is the diesel. Fuel consumption is an indicator of high importance since the CO_2 emissions are produced as a consequence of the diesel combustion.

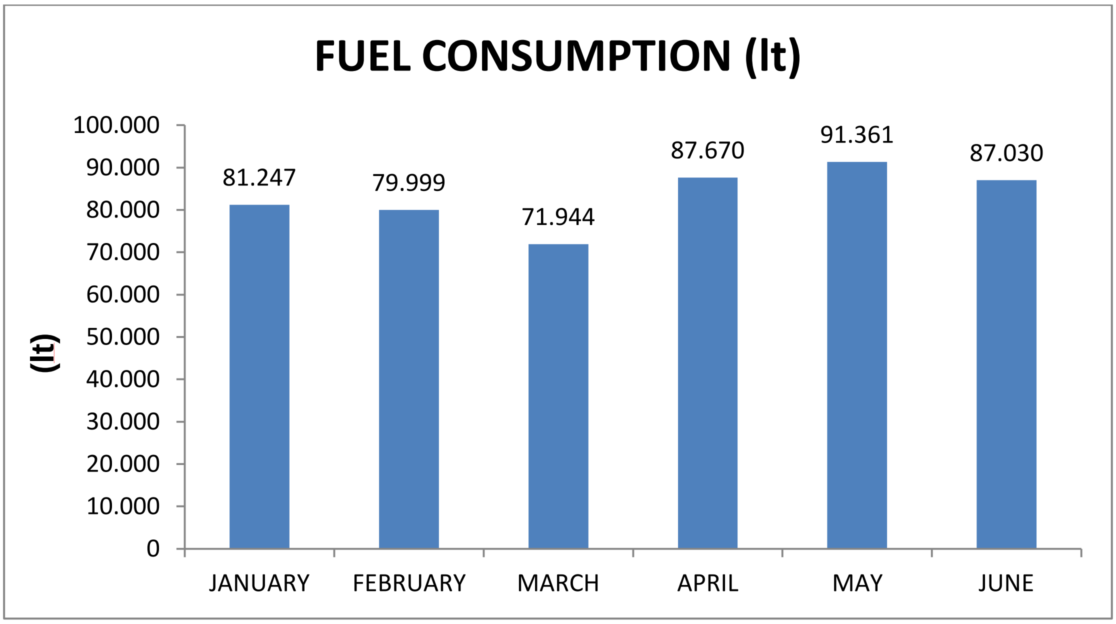

Fig. 5. 10: Monthly fuel consumption

As it appears from the figure above, the fuel consumption follows a similar trend with the total distance travelled. This is reasonable since the more distance is travelled by a vehicle, the higher the fuel consumption is.

The table below describes the total results of the fleet of vehicles that we examine during the semester. The total results concern the total distance travelled, the amount of freight delivered, the total tonne-kilometers, the total fuel consumption, the average fuel consumption, the total CO_2 emissions, the average loading factor and the average CO_2 emissions per tonne-kilomter.

Table 5. 5: Total results of fleet operation during semester

Total distance travelled	Amount of freight delivered	Total tn-km	Total fuel consumption	Average fuel consumption	Total CO_2 emissions	Average loading factor	Average gr CO_2/tn-km

1.704.070 km	141.185 tn	7.278.030 tn-km	499.277 tn	30lt/100 km	1.333 tn	48,7%	191 gr

Analysis of results per month

The aim of the monthly analysis for the fleet of vehicles is to assess the monthly CO_2 emissions per tonne-kilometer for each vehicle and provide o monthly benchmarking of the fleet's efficiency. The figure below provides information about the average CO_2 emissions per tonne-kilometer of the fleet of vehicles during January as well as the allocation of any single vehicle's CO_2 emissions per tonne-kilometer. According to that, the performance of all vehicles is presented giving the opportunity to evaluate the efficiency of the fleet in terms of CO_2 emissions per tonne-kilometer.

The figure below presents the average CO_2 emission per tonne-kilometer for each vehicle during January

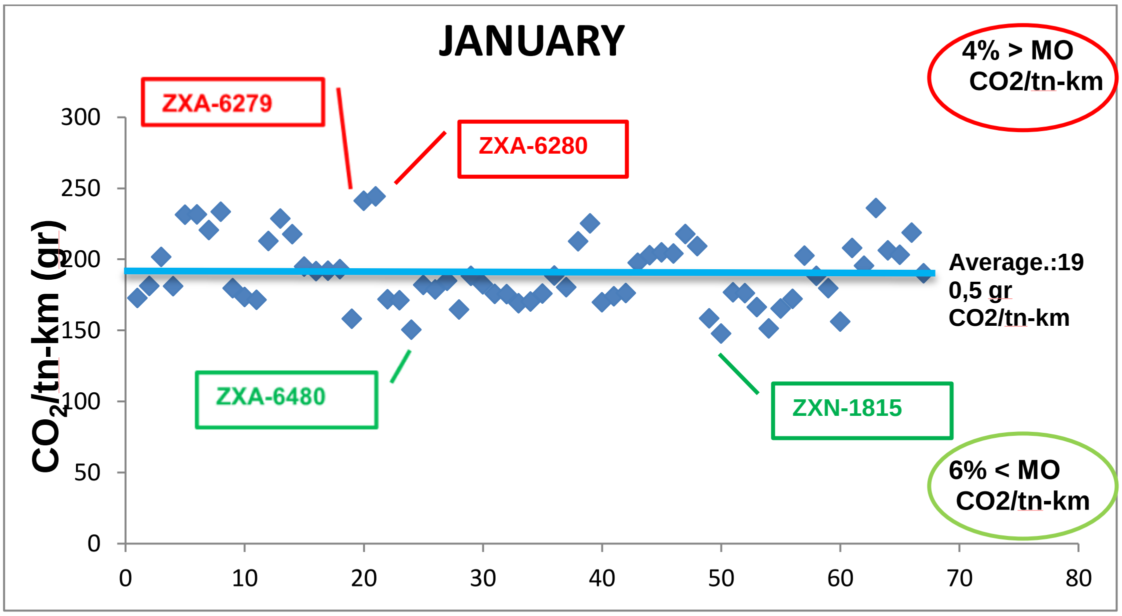

Fig. 5. 11: CO_2 emissions per tonne-kilometer in January

For the investigation of vehicle's efficiency, additional data for two couples of vehicles are presented. The further information of the outliners examined are related to the payload, the average freight delivered, the loading factor, the average fuel consumption and the areas visited. According to the payload, there are articulated trucks having different payloads in terms of the trailer use. Furthermore, the areas visited were examined since the central regions face higher traffic congestion problems in contrast with those located in the suburbs, which is a factor of higher fuel consumption. As it is described in more detail later, NSA represents the north sector of Attica ,SSA the south sector of Attica, ESA the east sector of Attica, WSA the west sector of Attica, CSA the central sector of Attica, EA the east Attica, WA the west Attica and P the Peiraius.

Below there is a table with the additional data for the two couples of vehicles during January.

Table 5. 6: Comparative data of outliers during January

Vehicle	**ZXA-6280**	**ZXA-6279**	**ZXA-6480**	**ZXN-1815**
CO_2/tn-km	244 gr	241 gr	150,6 gr	147,9 gr
Payload	5,47 tn	5,48 tn	11,95/19,95 tn	7,72 tn
Average amount of freight delivered	5,95 tn	5,58 tn	14,83 tn	7,85 tn
Loading Factor	54,4 %	50,9 %	38,2 %	49,4%
Average fuel consumption	26,5 lt/100 km	24,4 lt/100 km	38,9 lt/100km	21,5 lt/ 100 km
Area of delivery	NSA,CSA, P,WSA, EA, SSA	NSA,CSA,EA,WSA,P	SSA,P,EA,,	NSA,WSA,SSA,EA,P

Although the vehicles ZXA-6280 and ZXA-6279 have quite high loading factor, they also exhibit high average consumption compared to the average payload which results in high CO_2 emissions per tonne-kilometer. Another point worth noticing is that the vehicle ZXN-1815 has lower fuel consumption than the vehicle ZXA-6279 while transferring on average 2,3 tonnes additional freight.

The figure below shows the allocation of the fleet of vehicles according to their CO_2 emissions per tonne-kilometer during February.

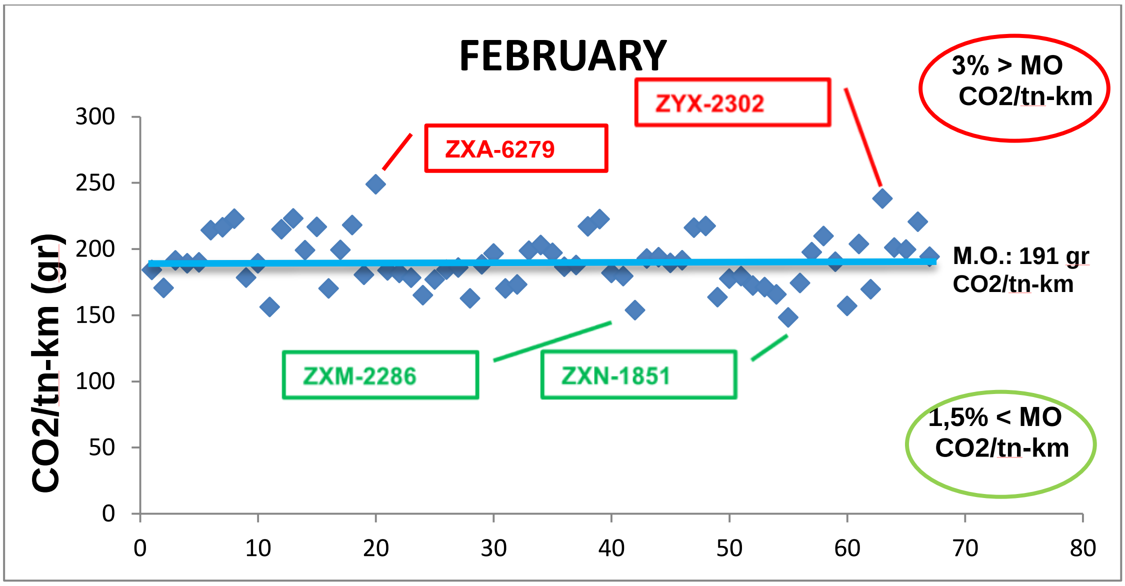

Fig. 5. 12: CO_2 emissions per tonne-kilometer in February

There are two couples of outliers; Firstly the vehicles ZXA-6279 and ZYX-2302 with the highest CO_2 emissions per tonne-kilometer and thereafter the vehicles ZXM-2286 and ZXN-1851 with the lowest CO_2 emissions per tonne-kilometer. Moreover, it worth mentioning that there is slight fluctuation among the remarks with the majority of those to be close to the average. In more detail, there are 3% of the vehicles that are over the average while there are 1,5% of the vehicles that are under the average. The average CO_2 emissions per tonne-kilometer during February equivalents to 191 gr.

Below, a table with additional information concerning the couples of outliers is presented.

Table 5. 7: Comparative data of outliers during February

Vehicle	ZXA-6279	ZYX-2302	ZXM-2286	ZXN-1851
CO_2/tn-km	249gr	238,2 gr	153,9 gr	148,4 gr
Payload	5,48 tn	7,45 tn	9,64 tn	11,13/18,45 tn
Average amount of freight delivered	5,59 tn	5,7 tn	9,12 tn	14,36 tn
Loading Factor	51 %	38,3 %	47,3 %	43 %

Average fuel consumption	25,6 lt/100 km	24,8 lt/100 km	26,1 lt/100km	37,3 lt/ 100 km
Area of delivery	EA,CSA,P,SSA, NSA,WSA	CSA,WSA,P,EA, SSA, WA,NSA	NSA,EA,WSA,CSA, SSA	EA,WSA,WA,NSA

The vehicle ZXA-6279 was repeated during January, having the highest CO_2 emissions per tonne-kilometer. The ZXM-2286 has almost the same fuel consumption with the vehicle ZXA-6279 but carrying on average 3,5 tonnes higher load. Furthermore, while the vehicle ZXN-1851 has a 50% higher fuel consumption than the vehicle ZYX-2302, it transfers on average 1,5 further load.

Fig. 5.13 presents the CO_2 emission per tonne-kilometer for the fleet of vehicles in March.

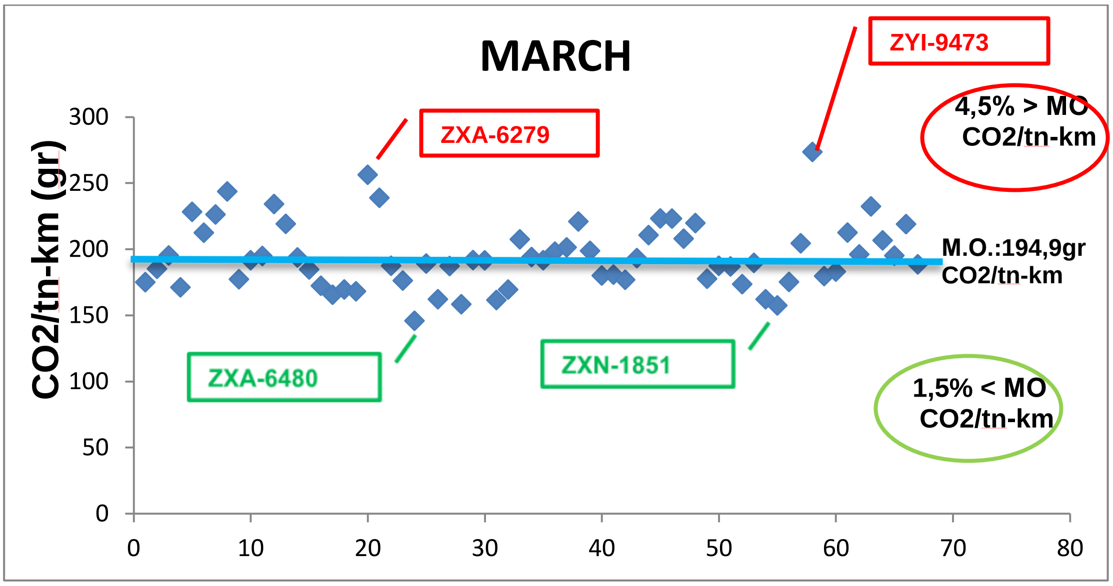

Fig. 5. 13: CO_2 emissions per tonne-kilometer in March.

The vehicles ZXA-6279 and ZYI-9473 have the highest CO_2 emissions per tonne-kilometer while the vehicles ZXA-6480 and ZXN -1851 have the lowest CO_2 emissions per tonne-kilometer. The majority of the remarks are located close to the average, with 4,5% of the them to be over the average and 1,5% of them to be under the average. The average CO_2 emissions per tonne-kilometer during March equivalents to 194.9 gr.

Below, a table with additional data for the two couples of vehicles follows.

Table 5. 8: Comparative data of outliers during March

Vehicle	ZYI-9473	ZXA-6279	ZXN-1851	ZXA-6480
CO_2/tn-km	273,7 gr	256,3 gr	157,5 gr	145,9 gr
Payload	5,96 tn	5,48 tn	11,13/18,45 tn	11,95/19,95 tn
Average amount of freight delivered	6,87 tn	5,74 tn	13,4 tn	15,09 tn
Loading Factor	57,6 %	52,2 %	42,7 %	37,8 %
Average amount of freight delivered	34,4 lt/100 km	26,7 lt/100 km	37 lt/100km	39,4 lt/ 100 km
Area of delivery	WA,NSA,EA,SSA,P, SSA	WSA,CSA,NSA,P,EA	EA,WSA,NSA,SSA	SSA,P,EA,

The vehicles ZXA-6279 and ZXN-1851 are repeated during January and February while the vehicle ZZA-6480 is repeated in January. Although the vehicle ZXN-1851 has almost the same average fuel consumption with the vehicle ZYI-9473, it is carrying twice the average load.

The figure below shows the allocation of the fleet of vehicles according to their CO_2 emissions per tonne-kilometer in April.

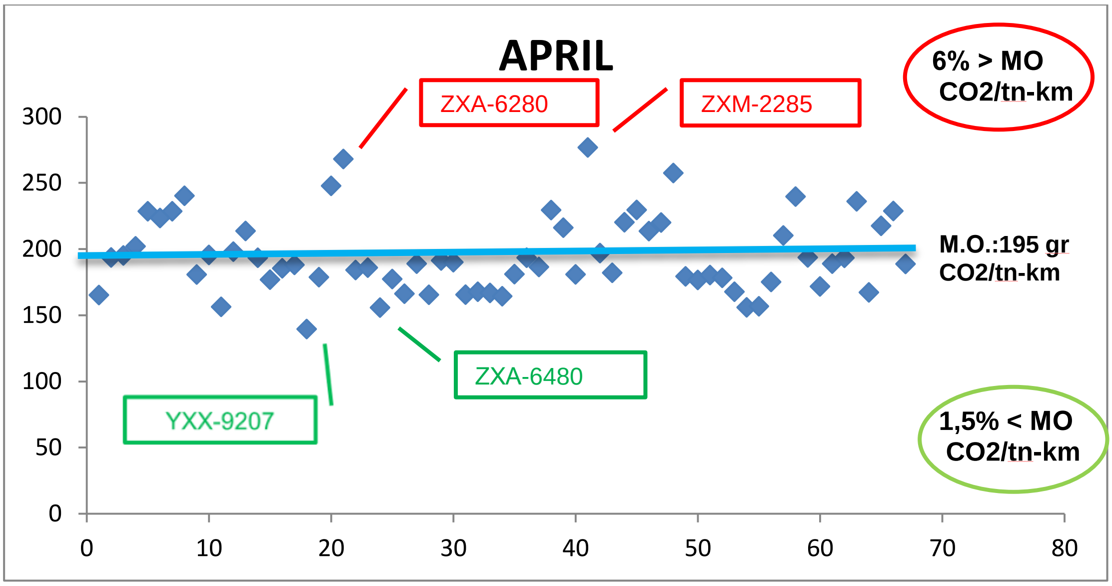

Fig. 5. 14: CO_2 emissions per tonne-kilometer in April

The vehicles ZXA-6280 and ZXM-2285 have the highest CO_2 emissions per tonne-kilometer in contrast with the vehicles ZXA-6480 and YXX-9207 which have the lowest CO_2 emissions per tonne-kilometer. The majority of the remarks are located close to the average, with 6% of the them to be over the average and 1,5% of them to be under the average. The average CO_2 emissions per tonne-kilometer during April equivalents to 195 gr.

Table 5.9 presents additional information about those couple of vehicles.

Table 5. 9: Comparative data of outliers during April

Vehicle	ZXM-2285	ZXA-6280	ZXA-6480	YXX-9207
CO_2/tn-km	276,9 gr	268,1 gr	155,8 gr	139,7gr
Payload	9,64 tn	5,47 tn	11,95/19,95 tn	13,66/19,41 tn
Average amount of freight delivered	8,48 tn	5,83 tn	15,49 tn	16,51 tn
Loading Factor	44 %	53,2 %	39,4 %	42,5 %

Average fuel consumption	35,5 lt/100 km	28,6 lt/100 km	43 lt/ 100 km	43 lt/ 100 km
Area of delivery	CSA,NSA,WSA,WA,SSA,EA,	CSA,EA,P,WSA,NSA, WA	SSA,P,EA,	SSA,P,EA,NSA

The vehicle ZXA-6280 is repeated in January while ZXA-6480 is repeated during January and March. Although the vehicle YXX-9207 has 7,5 lt higher average fuel consumption than the vehicle ZXM-2285, it is carrying 8 tons higher load. Even though the vehicle ZXA-6280 has high loading factor (53,2%), the quite high fuel consumption in contrast with the average load delivered classifies it as the second most non-efficient vehicle during April.

The figure below shows the allocation of the fleet according to the CO_2 emissions per tonne-kilometer in May.

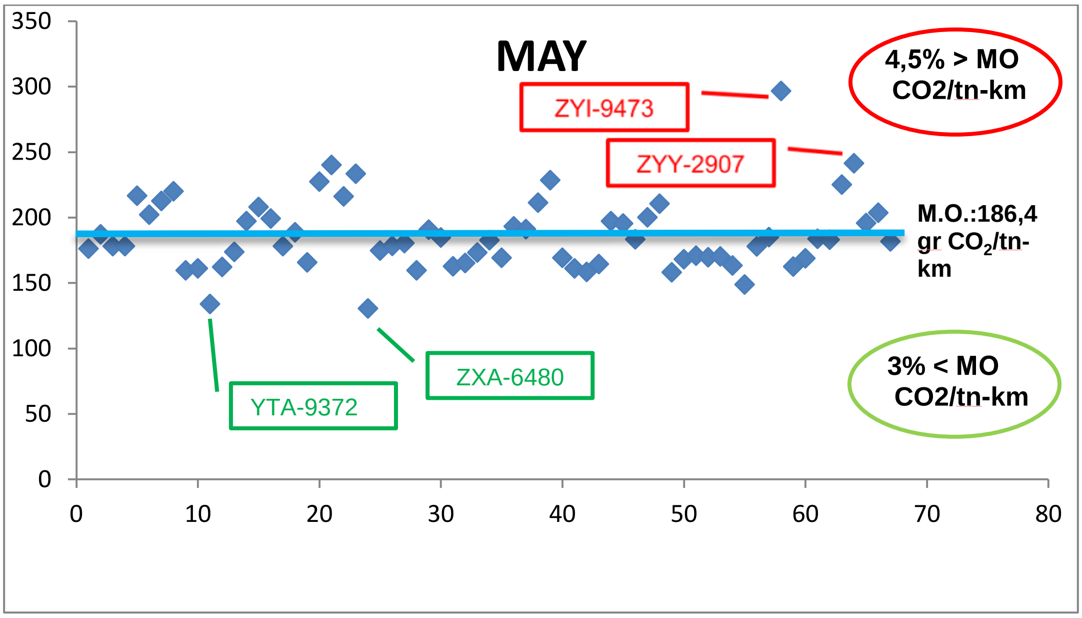

Fig. 5. 15: CO_2 emissions per tonne-kilometer in May

The vehicles ZYI-9473 and ZYY-2907 have the highest CO_2 emissions per tonne-kilometer while the vehicles ZXA-6480 and YTA-9372 have the lowest CO_2 emissions per tonne-kilometer. The majority of the remarks are located close to the average, with 4,5% of the them to be over the average and 3% of them to be under the average. The average CO_2 emissions per tonne-kilometer during May equivalents to 186,4 gr.

Below, a table with additional information about those couple of vehicles follows.

Table 5. 10: Comparative data of outliers during May

Vehicle	ZYI-9473	ZYY-2907	YTA-9372	ZXA-6480
CO_2/tn-km	296,7 gr	241,5 gr	134 gr	130,6 gr
Payload	5,96 tn	6,74 tn	13,16/20,37 tn	11,95/19,95 tn
Average amount of freight delivered	7,22 tn	7,81 tn	15,21 tn	15,73 tn
Loading Factor	60,6 %	57,8 %	39,5%	41,79 %
Average fuel consumption	39 lt/100 km	35 lt/100 km	36,6 lt/100km	37 lt/ 100 km
Area of delivery	SSA,NSA,P,CSA, SSA,WA	SSA,P.NSA,CSA,EA, WSA,WA	WA,EA,NSA	SSA,EA,P,WA,CSA

The vehicle ZYI-9473 is repeated in March while ZXA-6480 is repeated during January, March and April. It is worth noting that although the examined vehicles have similar average fuel consumptions, the vehicles YTA-9372 and ZXA-6480 carry twice average load than the vehicles ZYI-9473 and ZYY-2907. Even if the vehicles ZYI-9473 and ZYY-2907 have rather high loading factor, the high ratio of the average fuel consumption in combination with the freight delivered classified them as the most inefficient vehicles during May in terms of CO_2 emissions per tonne-kilometer.

Figure 5.16 presents the average CO_2 emission per tonne-kilometer for the fleet of vehicles during June.

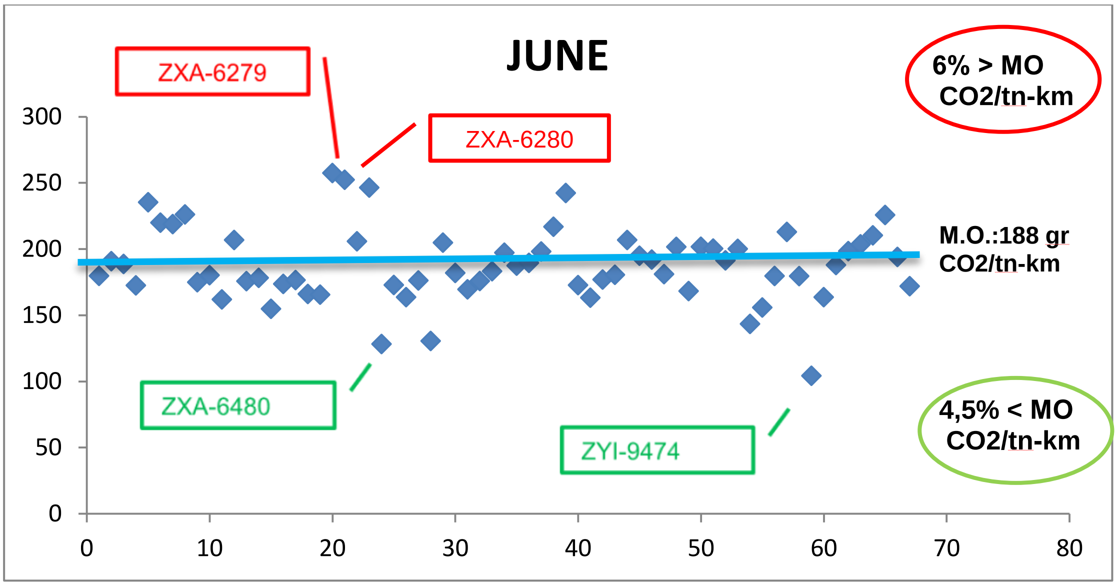

Fig. 5. 16: CO_2 emissions per tonne-kilometer in June

The vehicles ZXA-6279 and ZXA-6280 have the highest CO_2 emissions per tonne-kilometer while the vehicles ZXA-6480 and ZYI-9474 have the lowest CO_2 emissions per tonne-kilometer. The majority of the remarks are located close to the average, with 6% of the them to be over the average and 4,5% of them to be under the average. The average CO_2 emissions per tonne-kilometer during June equivalents to 188 gr.

Below, a table with additional information of the outlier vehicles follows.

Table 5. 11: Comparative data of outliers during June

Vehicle	ZXA-6279	ZXA-6280	ZXA-6480	ZYI-9474
CO_2/tn-km	257,5 gr	252,4 gr	128,3 gr	104,3gr
Payload	5,48 tn	5,47 tn	11,95/19,95 tn	6,06 tn
Average amount of freight delivered	5,67 tn	5,77 tn	16,73 tn	7,36 tn
Loading Factor	51,8 %	52,7 %	41,93 %	60,7%
Average fuel	27lt/100 km	27 lt/100 km	40lt/100km	14 lt/ 100 km

consumptio n				
Area of delivery	CSA,WSA,NSA,SSA , EA,P,	EA,WSA,P.CSA,SSA,NSA,W A	WA,WSA,CS A	WA,BTA,SSA,WSA , CSA

The vehicles ZXA-6279 is repeated during January, February and March. The vehicle ZXA-6280 is repeated in January and April while the vehicle ZXA-6480 is repeated during January, March, April and May. Although the vehicle ZXA-6480 has 33% higher fuel consumption than the vehicle ZXA-6279, it is carrying 2 times further load.

Fig. 5.17 presents the total CO_2 emission per tonne-kilometer for the fleet of vehicles during the semester.

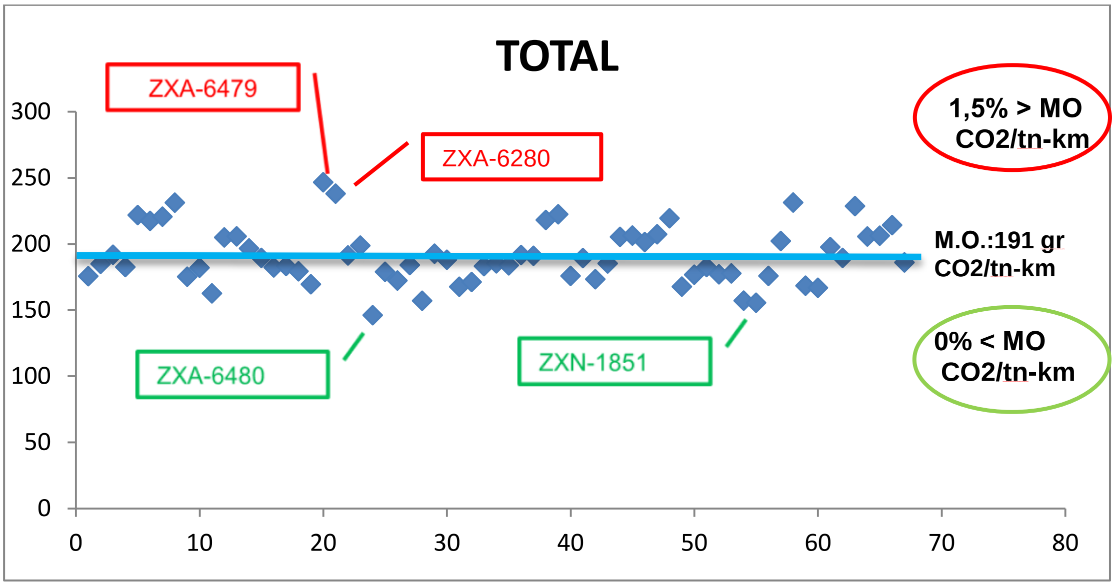

Fig. 5. 17: Total CO_2 emissions per tonne-kilometer during semester

The vehicles ZXA-6479 and ZXA-6280 have the highest CO_2 emissions per tonne-kilometer while the vehicles ZXA-6480 and ZXN-1851 have the lowest CO_2 emissions per tonne-kilometer. The majority of the remarks are located close to the average, with 1,5% of the them to be over the average and 0% of them to be under the average.

Below, a table with additional information about those couple of vehicles follows.

Table 5. 12: Comparative data of outliers during June

Vehicle	**ZXA-6279**	**ZXA-6280**	**ZXN-1851**	**ZXA-6480**

CO_2/tn-km	246,6 gr	238 gr	155,5 gr	146,1gr
Payload	5,48 tn	5,47 tn	11,13/18,45 tn	11,95/19,95 tn
Average amount of freight delivered	5,74 tn	5,89 tn	13,8 tn	15,43 tn
Loading Factor	52,3 %	53,8 %	42,3 %	39,5%
Average fuel consumption	25,8 l/100 km	25,7 lt/100 km	37,2 lt/100km	39,5 lt/ 100 km
Region of delivery	EA,CSA,WSA,NSA ,SSA,P,	EA,WSA,P.CSA,SSA,NSA,WA	EA,WSA,NSA,SSA	NSA,EA,CSA,WSA, WA, P

According to the total results, the vehicles ZXA-6279 is repeated during January, February, March and June, the vehicle ZXA-6280 in January, April and June, the vehicle ZXN-1851 is repeated during January, February and March and April and the vehicle ZXA-6480 in January, March , April, May and June. Although the green vehicles have lower loading factor than the red ones, the sufficiently higher average freight delivered in contrast with the average fuel consumption classifies them as the most efficient vehicles.

Allocation of total CO_2 emissions to the geographical sectors of Attica

As mentioned previously, the fleet of vehicles under examination is serving retail stores that are located in the Attica region. Figure 5.18 shows a map with the allocation of the total CO_2 emission to every geographical sectors of Attica. Since in most of the cases, each truck delivered in retail stores that belong to different sectors, we assumed that the total emissions of each trip should be “charged” to the sector that the first delivery point belongs. This assumption was made since it was difficult to distribute the total CO_2 emission of a delivery trip to each delivery point.

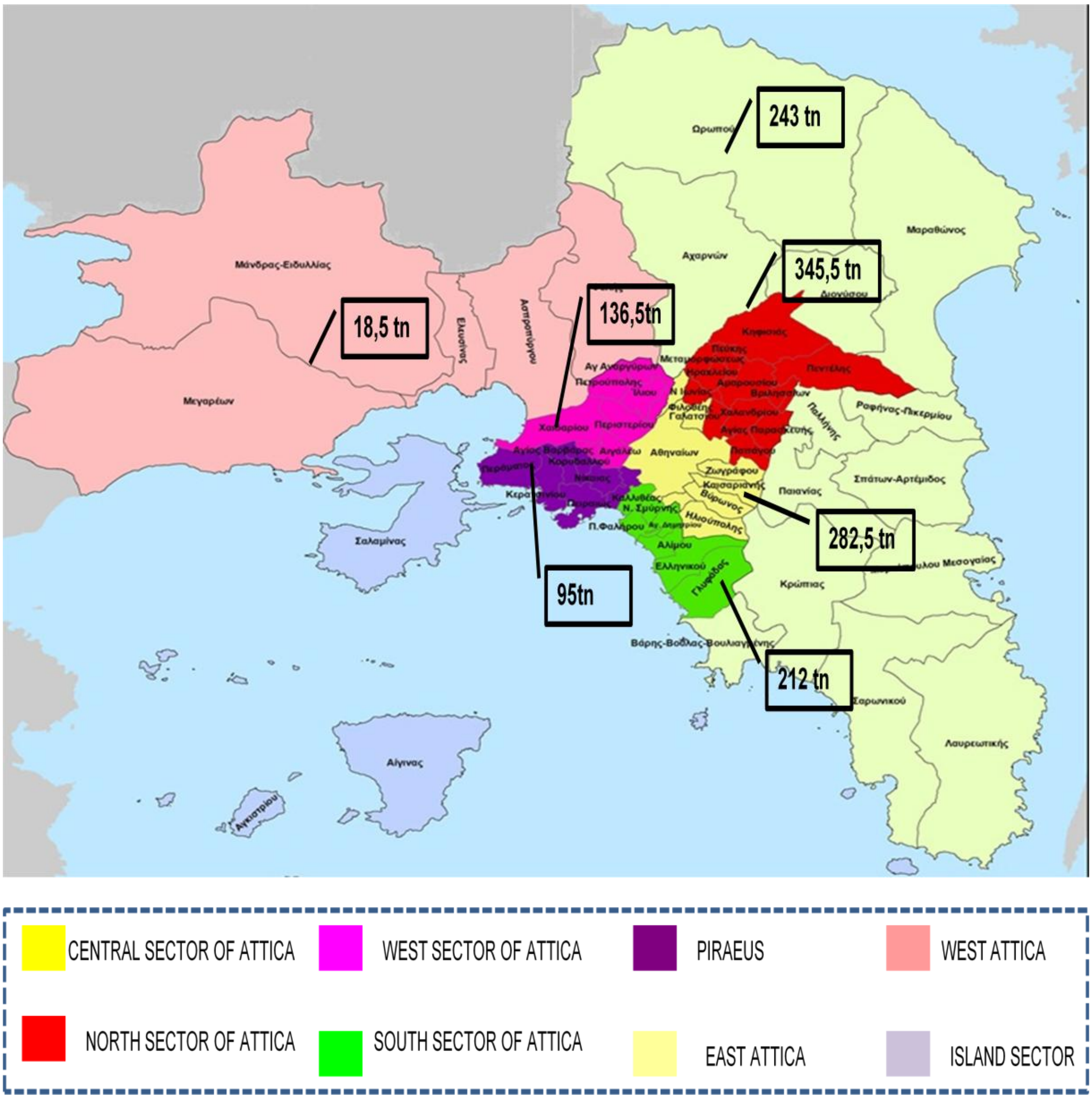

Fig. 5. 18: Allocation of total CO_2 emissions to the geographical sectors of Attica

From the figure above, we can notice that the highest CO_2 emissions are observerd in the northern and central sector of Attica with 345,5 and 282,5 tonnes, respectively. On the other hand, Piraeus and the west Attica seems to have the lowest CO_2 emissions with 95 and 18,5 tonnes, respectively. The CO_2 emissions that are allocated to the specific geographical sectors are proportional to the number of the deliveries that correspond to the particular sector as well as to the distance that trucks traveled from the distribution center to the specific geographical sector .

5.5. Summary of Findings

The main conclusions arose from the calculation of the retail company's carbon footprint are described below. Initially, the total CO_2 emissions during the semester amounted to 1333 tons with the lower emissions to be recorded in March (192 tons) while the highest were recorded in May (244 tonnes).The average CO_2 emissions per tonne-kilometer is 191 gr. May seems to be the most efficient month with 186 gr CO_2 per tonne-kilometer while both March and April appear to be the less efficient months with 196 gr CO_2 per tonne-kilometer. During the semester, a slight variation is observed in terms of CO_2 emissions per tonne-kilometer with all the months to be close to the average.

The averaged loading factor is 48.7%. The highest loading factor is recorded in May and equals to 49.5% while the lowest loading factor appeared in March and equals to 48.3%. As the loading factor increases, the CO_2 emissions per tonne-kilometer are decreasing. Considering the relatively "empty miles" made by the vehicles on their return trip, the company's loading factor is fairly high.

A particularly important Indicator for the estimation of vehicle's efficiency in terms of CO_2 emissions per tonne-kilometer is the fuel consumption compared to the vehicle's payload. Vehicles which are repeated as the most efficient have as a common feature the high payload compared to their average fuel consumption. Respectively, those vehicles described as the less efficient have low payload in proportion to their fuel consumption.

Conclusively, the total miles, kilometers, freight delivered and fuel consumption follow a similar trend during the semester. This is reinforced by the fact that the vehicles are usually full of freight during their trips from the distribution center to the delivery points , so the freight delivered follows a similar pattern with the kilometer travelled.

5.6. Conclusion

In the fifth chapter, there was a presentation of the data used and the assumption made for the calculation of the carbon footprint on behalf of the private owned fleet of AB Vassilopoulos which makes distributions in Attica. The calculation of the carbon footprint was based on the standard EN:16258:2012, presenting monthly and semi-annually results in terms of total CO_2 emissions, CO_2 emissions per tonne-kilometer and loading factors. Furthermore, the vehicles' efficiency in terms of CO_2 emissions per tonne-kilometer was examined, by developing scatter diagrams in monthly and semi-annual level. The chapter concludes with a display of the main findings accruing from the analysis of the calculation.

6. Recommendations for the carbon footprint reduction of company's fleet of vehicles

6.1. Introduction

The aim of the chapter is to provide recommendations for the reduction of the CO_2 emissions of the company's fleet of vehicles. The recommendations are based on two main axes of improvements. The first axis deals with the categorization and the assessment of fleet of vehicles based on their CO_2 emissions per tonne-kilometer. This assessment results to the classification of all vehicles based on the efficiency of each vehicle according to the above mentioned criterion. The second axis of improvement deals with vehicle routing based on the vehicle's fuel consumption. More specifically, for certain routes, vehicles with lower fuel consumption have been used in order to prove that green vehicle routing may minimize the carbon footprint of the transport operations as well as the cost for fuel. Furthermore, an analysis of the fuel consumption of articulated trucks took place in order to investigate their efficiency with or without the use of a trailer. Finally, the chapter concludes with the main findings from both recommendations.

6.2 Assessment of fleet of vehicles according to their CO_2 emissions and the cargo transferred

The first recommendation deals with the assessment and the classification of the fleet of vehicles. The classification that takes place is particularly useful for the company for various reasons. Firstly it can be used as a guide for the routing system, giving priority to the trucks that belong to the first categories. Furthermore, the categorization can be advantageous in case that the company decides to replace some of the existent vehicles. The vehicles that should be replaced are those that belong to the last category (category C for the rigid trucks and category B for the articulated trucks).

The main criterion according to which the classification took place was the CO_2 emissions per tonne-kilometer. The latter was calculated according to the average fuel consumption of each vehicle and the maximum load that the vehicle can carry. Thus, two types of tables were created. The first one includes the rigid vehicles while the second one includes the articulated trucks which can carry a trailer.

For the case of the rigid trucks, the optimal CO_2 emission per tonne-kilometer for each vehicle varied between 140 and 230 gr CO_2 per tonne-killometer. The rigid trucks were classified into three categories as follows: a) the fist category incorporated trucks with emissions between140-170 gr CO_2 per tonne-killometer, the second those with emissions between170-200 gr CO_2 per tonne-killometer and the third those with emissions between200-230 gr CO_2 per tonne-killometer.

Below, there is a table with the classification of the vehicles according to the optimal CO_2 emissions per tonne-kilometer.

Table 6. 1: Classification of rigid trucks

Rigid trucks							
Category A	ZYI-9475	ZYI-9474	ZXM-4444	ZXI-1000	YXX-9184	ZXM -286	ZXH-9873
	ZXE-6968	ZXN-1854	ZXM-2222	ZXN-1815	ZXN-1817	ZXN-1819	YTA-8873
	ZXE-5368	ZXM-2285	ZXI-3810	ZXN-1816	YPO-9200	ZXM-2301	YTA-8884
	YPO-2951	ZXE-6969	ZXI-8439	ZXI-8494			
Category B	ZXI-8438	ZXH-3901	ZXI-8495	ZYN-2883	ZYY-2910	ZXA-6282	ZXH-3900
	YPO-9198	ZXM-2331	ZXM-2332	ZXN-1855	ZXM-2302	YPO-9199	ZXM-2335
	ZYN-2882	ZXA-6479	ZYY-2908	YTB-1623	YTA-9774	ZYY-2907	ZXM-2336
	ZYI-9473	YTA-8587					
Category C	YTA-8589	YTA-8584	YTA-8591	ZYY-2909	ZXK-2218	ZXK-2219	
	ZXA-6280	ZXA-6279					

Based on the findings, we notice that the majority of the rigid trucks belong to the first and the second category while the third category consists of the 16% of the total trucks in use.

Apart from the rigid vehicles, there was an assessment and classification for the articulated trucks. Again the evaluation criterion was the optimal CO_2 emissions per tonne-kilometer, which for the articulated trucks varied between 110 and 170 gr CO_2 per tonne-kilometer. Two categories were defined; The first category incorporates those with emissions between 110 to 140 gr CO_2 emission per tonne-kilometer and the second category those with emissions between 140 to 170 gr CO_2 per tonne-kilometer. Below there is a table with the classification of the articulated trucks.

Table 6. 2: Classification of articulated trucks

Articulated trucks					
Category A	YTA-9372	ZXN-1851	ZXE-7115	ZXA-6480	YXX-2653
	ZXN-1850	YXX-9214			
Category B	YXX-9206	YXX-9207	YXO-8516		

The findings above reveal that most of the articulated trucks belong to the first category which is the most efficient according to the CO_2 emissions per tonne-kilometer while the second category includes only three trucks

6.3 Vehicle routing based of vehicle's fuel consumption

The second part of the recommendations for the reduction of carbon footprint deals with the modification of the daily routing by taking into account the average fuel consumption as a constraint. The analysis was based on historical data of a period of six months, by examining six different days for the whole semester (one scenario per month). For each scenario, different vehicles were suggested in the daily routing in order to reduce the overall fuel consumption and therefore the total CO_2 emissions that the vehicles produce(per trip). The evaluation criteria that the routing replacement takes into account are the fuel consumption of the vehicle during a specific route and the average fuel consumption of the available vehicle which replaced it. For placing a replacement, the average fuel consumption of the available vehicle should be lower than the fuel consumption of the vehicle used during the specific trip.

In order to make the proposed changes, we took into consideration a number of assumptions that are described below:

- The total number of the routes performed in daily base remained unchanged. There were not carried out any route combinations since the company had already achieved a high loading factor.
- The deliveries were performed in accordance with the routing schedule, without making any changes in the time of the routes.
- The trucks used in the replacement process had the same or smaller payload with those that they replaced, having always the ability to carry the load of

the particular trip. This tactic was followed as there are traffic restrictions which have to be followed depending on the areas that the vehicles visit.

- The time constraints have been complied in order the trucks to be able to perform the rest of their deliveries in accordance with the daily routing schedule.
- The vehicles that were not participating in the daily schedule, were not used in the replacements since there were possibly in the maintenance process.

The results derived from the specific routing modifications are shown in Fig 6.1.

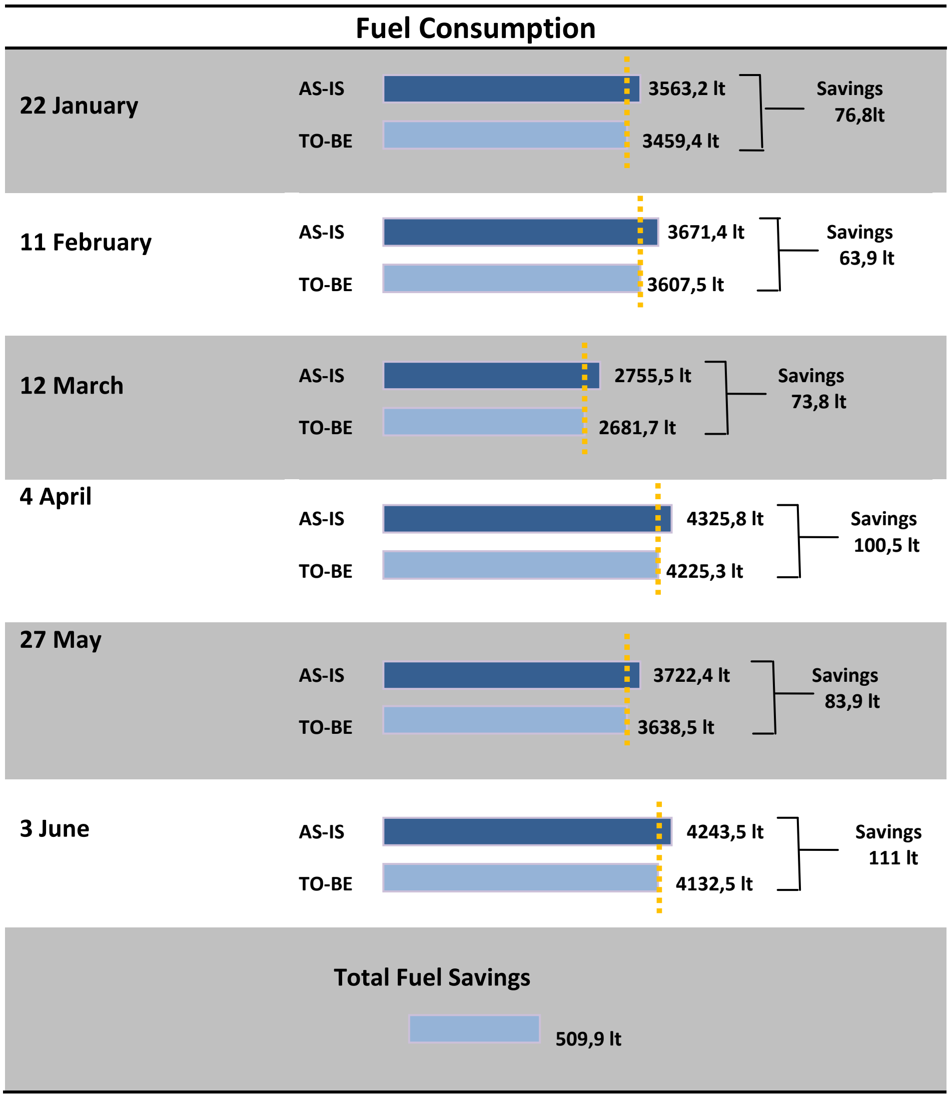

Fig. 6. 1: Savings in fuel consumption across the replacements

According to the figure above, the AS-IS illustration represents the fuel consumption during the six days according to the historical data while the TO-BE illustration represents the fuel consumption after making the replacements. We can notice that with the implementation of the routing replacements, the savings in fuel consumption is ranging between 63,9 lt and 111 lt per day.

Along with the reduction of the fuel consumption, a decrease in the vehicles used for the daily routes was also accomplished. At this point we should mention that out of the 67 vehicles of the fleet that we examine, the daily deliveries were performed with a fleet of approximately 59 to 63 vehicles. This derives from the fact that in daily base there are vehicles which take part in the process of maintenance. In the figure below, there is a description of the number of the vehicles participating in the daily routing.

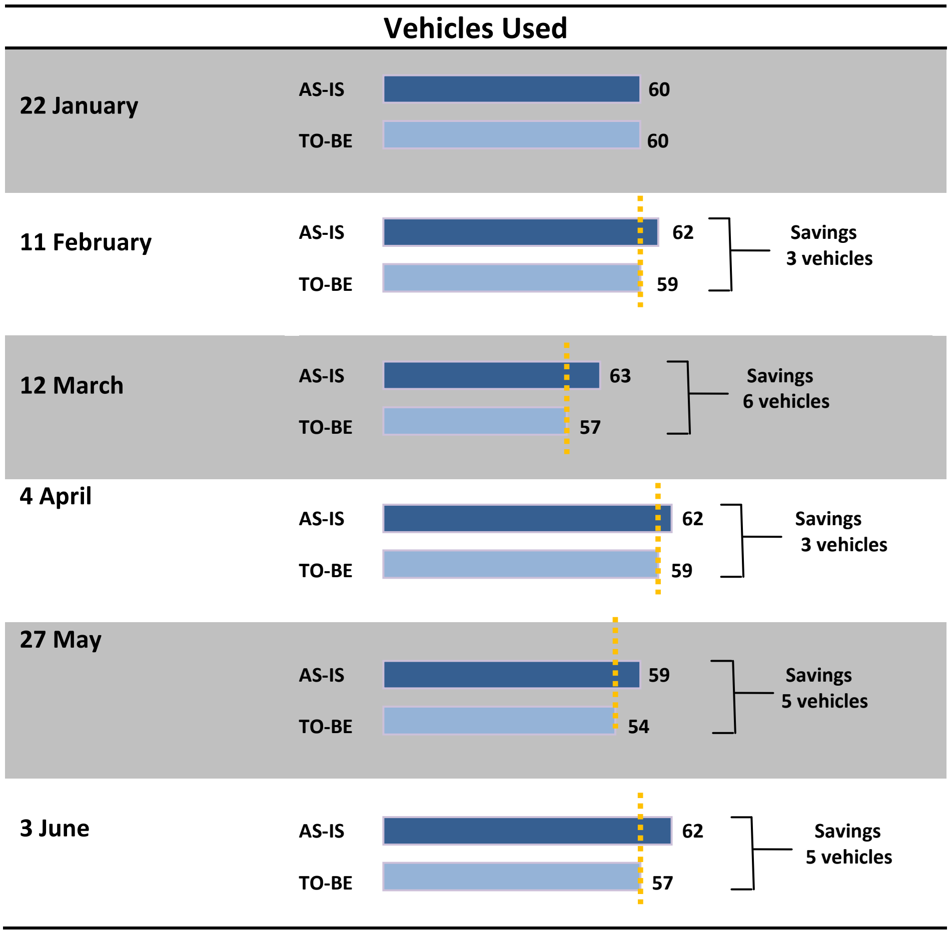

Fig. 6. 2: Savings in vehicles used in daily routing

According to the figure above, the AS-IS illustration represents the number of the vehicles that participate in the completion of the daily routing based on the historical data. The TO-BE illustration represents the number of the vehicles needed after making the replacements. For the specific days that we examine, we notice that the required fleet for the execution of the daily routes was decreased from 3 to 6 vehicles per day.

The reduction in the fuel consumption leaded to a decrease in the total CO_2 emissions as shown in the Fig. 6.3.

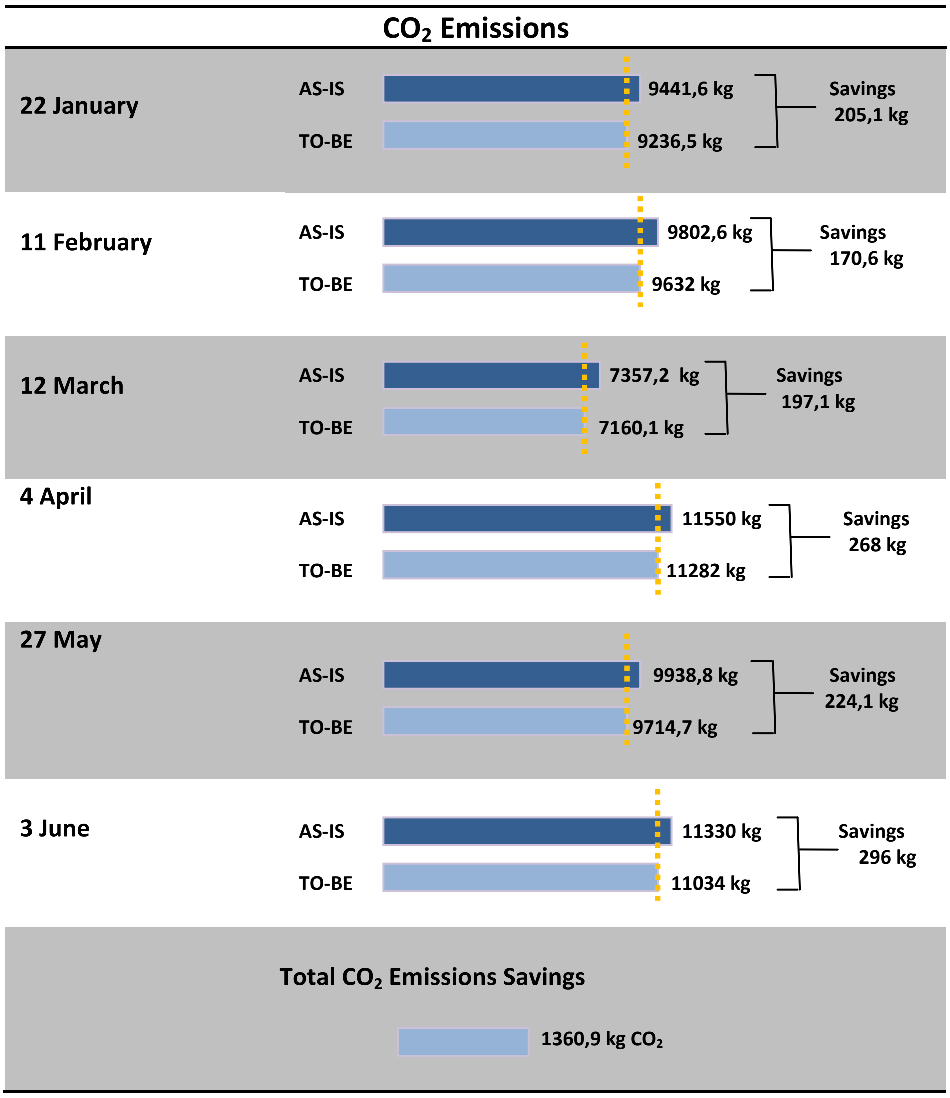

Fig. 6. 3: Reduction of CO_2 emissions across the replacements

According to the figure above, the AS-IS illustration represents the total CO_2 emissions based on the historical data while the TO-BE illustration represent the total CO_2 emission after implementing the replacements in the daily routes. What appears is that savings in total CO_2 emissions ranging from 170,6 kg to 296 kg per day can be accomplished.

According to the weekly working plan of the company, the vehicles operate 6 days a week. The figures of the fuel savings for the six selected days were grossed up in weekly, monthly and yearly base. According to this assumption, a reduction of 509,9 lt, 2.039,6 lt and 24.475 lt can be achieved in weekly, monthly and yearly base.

A reduction in fuel consumption is followed simultaneously by a decrease in CO_2 emissions. As described above, the savings in CO_2 emissions per week amount to

1.362,2 kg (6 days). By grossing up in monthly and yearly base, the reduction in CO_2 emissions amount to 5.445,2 kg and 65.342,4 kg, respectively.

Finally, with an average diesel price being around €1.2/litre , it can be realized an annual cost reduction of 30 K Euros.

6.4. Evaluation of the trailer use in articulated trucks

For the accomplishment of the daily routing, the company's private fleet is composed of various type of vehicles. From the sample of the vehicles that we examine, ten out of sixty seven are articulated trucks, having the ability carry a trailer. The payload of the articulated trucks with the trailer assistance is at least twice that of rigid trucks. However, there were cases where the articulated trucks were operating without trailer. In order to investigate how beneficial is the abovementioned use in terms of fuel consumption and CO_2 emissions, comparative data concerning the average fuel consumption and freight delivered were gathered.

Vehicle	Average freight delivered without trailer	Average fuel consumption without trailer (lt/100km)
	Average freight delivered with trailer	Average fuel consumption with trailer (lt/100km)

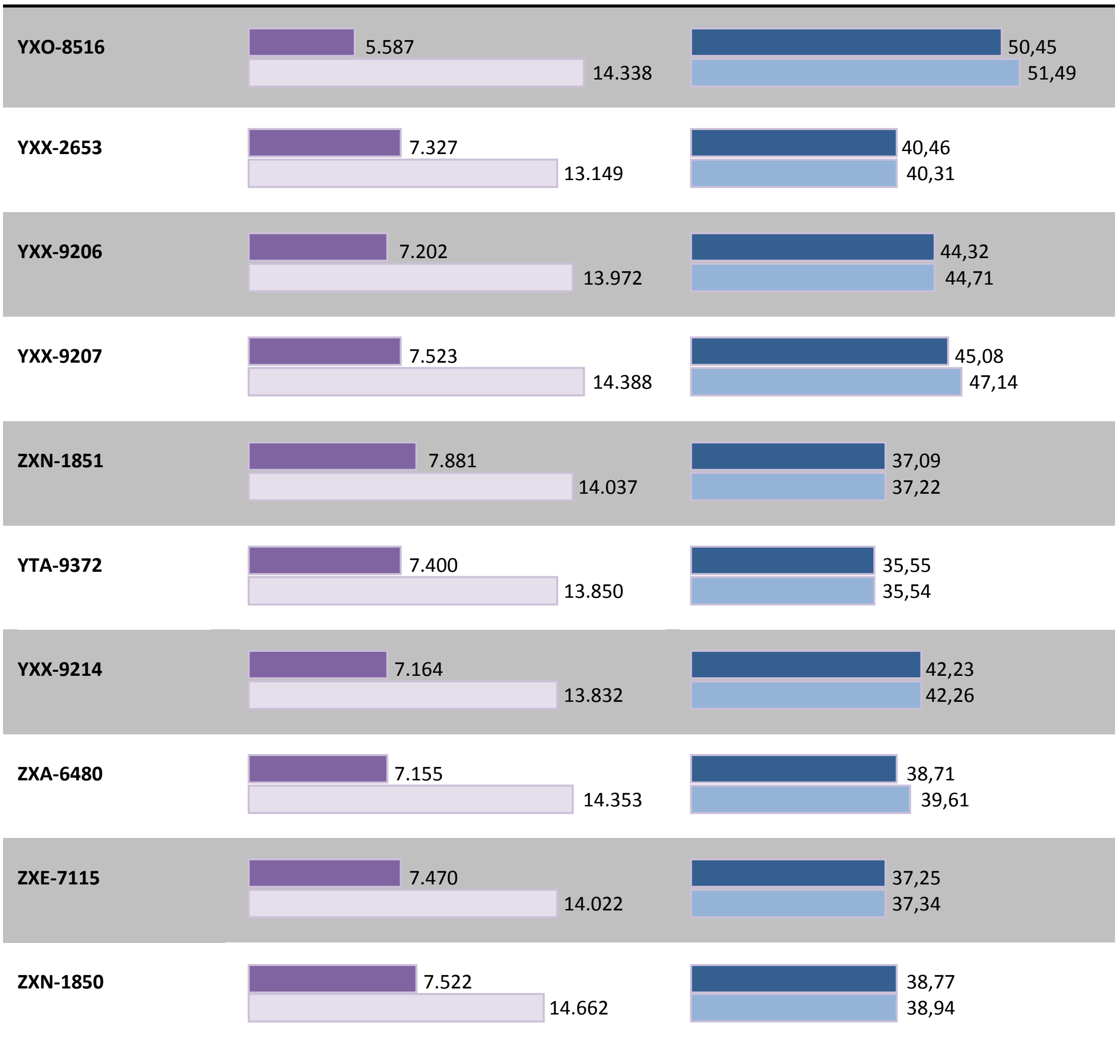

Fig. 6. 4: Fuel consumption of articulated vehicles with trailer or without

According to the semi-annual historical data, the average freight delivered and the average fuel consumption for each vehicle has been calculated in case of carrying a trailer or not. It is worth mentioning that the average fuel consumption remains almost steady in cases with double load. Similarly, we assume that the articulated trucks without trailer produce almost the same CO_2 emissions with those that carry a trailer, but transferring half the load. Thus, the operation of the above mentioned vehicles is proposed to be carried out only with trailer use.

6.4 Main findings

Summing up, there are some general conclusions that arose from the above evaluation. As concerns the fleet classification, the vehicles were assessed according to the optimum CO_2 emissions per tonne-kilometer. The categories of vehicles that emerged are a significant tool that can be used by the company in multiple ways. It can be used for the accomplishment of the daily deliveries by giving priority to the vehicles that belong to the first categories. Furthermore, it can be also useful in case of a possible partial replacement of the fleet where the priority will be given to the vehicles of the last category.

The second recommendation for the reduction of carbon footprint was the implementation of the daily routing based on the fuel consumption. There were a series of replacements to vehicles that were making specific deliveries with other available vehicles which had lower average fuel consumption. The vehicles that constantly appear in the replacements had, as a common feature, the high fuel consumption in proportion to the freight carried. Those vehicles belong to the second and third category of to the classification tables that are presented above. Through the process of the replacements, there were savings in fuel consumption. More specifically, it could be achieved a reduction of 24.457,2 lt per year in fuel. The reduction in fuel consumption will cause at the same time a decrease of 65.342,4kg CO_2 emission per year while with the diesel price being around €1.2/litre, the monetary savings amount to 30 K euros.

Conclusively, the articulated trucks should operate by trailer assistance, since the fuel consumption remains almost unchanged regardless of the freight delivered.

6.5 Conclusion

In this Chapter, there was mainly an analysis of the process followed for the reduction of company's carbon footprint. Initially, the first recommendation included the categorization of the fleet of vehicles according to the optimum CO_2 emission per tonne-kilometer. The latter can play a significant role in company's fleet management, giving priority to the most efficient vehicles as well as suggesting the less efficient vehicles in a possible fleet replacement. The second recommendation was the modification of the routing schedule based on vehicle's fuel consumption. Specific routes were replaced by available vehicles with lower average fuel consumption. Conclusively, there was an analysis of the articulated trucks' fuel consumption in case of carrying a trailer, where deemed necessary the use of trailer for producing lower CO_2 emissions.

7. Conclusions

7.1. Summary of the dissertation

The main aim of this thesis was to review the current status of the most significant methods and tools for the calculation of carbon footprint in transport sector and adopt the most appropriate for the calculation of CO_2 emissions in the fleet of vehicles of the Greek retail company, AB Vasilopoulos.

Initially, a literature review of green logistics was conducted in order to map the current situation of transport sector in urban areas. Although the freight distribution is essential for the city's function, various problems in terms of environmental, societal and economical aspect arise. The existing situation became more complex by the development of e-commerce and the increase of last-mile deliveries. Various EU programs and projects have been implemented by the European Union in cooperation with member states, making recommendations for adopting green freight transport in city level, also known as "best-practices".

As far as best practices are concerned, polices and measures are based on three main pillars: a) pickup and delivery schemes, b)consolidating and pooling strategies and c) vehicle's technology. In terms of product's pickup and delivery, night deliveries, tolls, LEZs and ITS were logistics strategies which led to reductions in traffic congestion and noise pollutions. Regarding consolidating and pooling strategies, UCCs and logistics pooling contributed to the optimization of vehicle's load capacity. Finally, alternative fuels such as CNG/LNG, as well as hybrid and electric powered vehicles were a perspective with plenty of potential.

For the calculation of the carbon footprint in the freight transport sector various methods, tools and databases have been developed. The three most well-known methods for calculating the carbon footprint for road freight transport are: a) the EMEP/EEA method of the European Environmental Agency, b) the European Standard EN 16258: 2012 and c) the methodology proposed by the European Chemical Industry Council (CEFIC). The scope of the method assessment was the adoption of the most appropriate for the calculation of the CO_2 emissions in the fleet of vehicles of the retail company, AB Vassilopoulos. The EN 16258:2012 standard was adopted for the calculation, as it was considered to be the most suitable due to the available energy based data. The parameters taken into account were as follows: fuel consumption, distance travelled, cargo delivered, vehicle's payload, product returns and backhauling.

Finally, a series of recommendations were made, presenting proposals for reducing the CO_2 emissions. An assessment of the fleet of vehicles according to their CO_2

emission per tonne-kilometer and suggestions for vehicle-routing based on vehicle's fuel consumption were made, resulting in fuel and CO_2 emission savings of 5%.

7.2 Main findings

Based on the analysis of the results from Chapters 5 and 6 respectively, we can draw useful conclusions about the factors that affect CO_2 emissions in road freight transport. More specifically, the main aim of the case study was to map the current status concerning the freight transport operation in the Attica region as well as calculate and measure the carbon footprint of the fleet of vehicles of AB Vassilopoulos. The main findings and recommendations for reducing the carbon footprint of the freight transport operations are described below.

According to the existing fleet operation, a significant finding is when increasing the vehicle's loading factor, the CO_2 emissions per tonne-kilometer decrease. The latter is an indicator of vehicle's efficiency in terms of environmental evaluation. Furthermore, another significant indicator is the vehicle's fuel consumption in proportion to the vehicle's payload. The loading factor for the particular company which amounted to 48,7% during the semester is nearly optimal, concerning the relatively empty kilometers made during the return trips from the delivery points to the distribution center. The total cargo delivered during the semester amounted to 141.185 tonnes while the total distance travelled equals to 1.704.070 km. The average CO_2 emissions per tonne kilometer amounted to 191 gr with the majority of the vehicles not to exhibit significant fluctuations. Moreover, the fuel consumption of vehicles equipped trailer (articulated trucks) is slightly increased when they carry a trailer compared with the cases operating without a trailer assistance.

After mapping the current status, certain recommendations were made for reducing company's carbon footprint in the delivery process. The criterion that plays a significant role in vehicles efficiency in terms of CO_2 emissions, is the fuel consumption in proportion to the vehicle's payload. The first recommendation included the assessment of the fleet of vehicles based on the aforementioned criterion. The rigid and articulated trucks of the fleet were classified into three and two categories, respectively. The outcome of this evaluation is valuable for AB Vassilopoulos since is enabled to be aware of the performance of the fleet in terms of CO_2 emissions and fuel consumption. Indeed, the classification can be used as a tool for the daily routing schedule or in possible partial replacement of the fleet.

The second recommendation concerns the daily routing based on vehicle's fuel consumption. By performing routing replacements, savings in fuel consumption and in CO_2 emissions were accomplished. It is estimated that in annual base, fuel savings of 24.475 liters with a relevant reduction in CO_2 emissions of 65.342 kg can be achieved. With an average diesel price of about €1.2/litre, the reduction in fuel consumption is combined with cost savings of 30 K euro per year.

To conclude, as far as the articulated trucks are concerned, it is recommended to operate with the trailer assistance in order to achieve lower CO_2 emissions per tonne-kilometer.

7.3. Future steps

This section provides a list of future steps for further research concerning the calculation of the carbon footprint in freight transport operation of AB Vassilopoulos. Initially, a future step is the calculation of the total carbon footprint of the overall freight transport of the company.

Furthermore, in case that the suggestions made for reducing the carbon footprint were implemented by AB Vassilopoulos, it would be interesting to re-calculate the actual fuel and emission savings and compare them with the results obtained from the analysis performed based on the historical data. In this way, we could investigate the accuracy of the results obtained during our recommendations.

Finally, since AB Vassilopoulos sells private label products, it would be interesting to implement a product life cycle assessment by using PAS 2050 standard. In that way it would be able to calculate the CO_2 of the whole value chain and promote in that way environmental friendly products to its customers.

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Appendix A – Primary data for carbon footprint calculation

Primary data for vehicle's trips (indicative)

PRIMARY DATA FOR THE CALCULATION OF CARBON FOOTPRINT							
Period of data collection:	January-June 2014						
Vehicle's plate		YPO 2951					
Vehicle's type (e.g. Articulated 34-40Tn):		....	**Gross weight (kg):**	18.000	**Payload (kg):**	8.432	
Engine's technology (e.g. EURO III):		III					
Type of network:		100% Urban	....% **rural**	**.... % highway**			

Date of Delivery	Total distance travelled (klm)	Total fuel consumption per delivery (lt)	Points visited (per trip)	Region	Zip Code	Pallets	Freight Delivered (kg)
2/1/2014	64,092	20,32	1	1 CHALANDRI	152 34	18	8100
2/1/2014	64,569	20,48	1	1 PERISTERI	121 32	12	5400
3/1/2014	44,018	13,96	1	AG. I. RENTI	182 33	17	7650
3/1/2014	66,749	21,17	1	CASTELLA	185 33	18	8100
3/1/2014	83,853	26,59	1	1 VIRONAS	162 31	18	8100
3/1/2014	50,626	16,05	1	PETROYPOLI	131 21	18	8100
4/1/2014	97,395	30,89	1	1 CHALANDRI	152 34	18	8100
7/1/2014	34,308	10,88	1	ERYTHRAIA	145 64	18	8100
7/1/2014	102,92	32,64	1	SOGRAFOY	157 72	18	8100
8/1/2014	39,551	12,54	1	AG. VARVARA	123 51	18	8100
8/1/2014	19,85	6,29	1	ASPROPIRGOS2	193 00	18	8100
9/1/2014	75,595	23,97	1	ZOGRAFOY	157 72	18	8100
9/1/2014	62,385	19,78	2	RADIO CITY;ILION	112 53; 131 23	18	8100
10/1/2014	98,529	31,25	1	MELISIA	151 27	18	8100
10/1/2014	79,984	25,36	1	ILIOYPOLI 2	163 45	18	8100
10/1/2014	87,755	27,83	1	ILIOYPOLI	163 45	18	8100
11/1/2014	64,569	20,48	1	1 PERISTERI	121 32	18	8100
11/1/2014	48,615	15,42	1	MENIDI 2	136 71	14	6300

Results of carbon footprint calculation

PROCESS OF CARBON FOOTPRINT CALCULATION				
Date of Delivery	**CO_2 emissions: kg CO_2**	**TN-KM**	**CO_2/TN-KM (gr)**	**LOADING FACTOR**
2/1/2014	54,267	308,740	175,771	0,571293
2/1/2014	54,671	223,870	244,211	0,411188

3/1/2014	37,271	202,137	184,383	0,544609
3/1/2014	56,517	321,539	175,771	0,571293
3/1/2014	70,999	403,932	175,771	0,571293
3/1/2014	42,866	243,873	175,771	0,571293
4/1/2014	82,466	469,165	175,771	0,571293
7/1/2014	29,049	165,266	175,771	0,571293
7/1/2014	87,144	495,780	175,771	0,571293
8/1/2014	33,488	190,523	175,771	0,571293
8/1/2014	16,807	95,620	175,771	0,571293
9/1/2014	64,007	364,152	175,771	0,571293
9/1/2014	52,822	300,517	175,771	0,571293
10/1/2014	83,426	474,628	175,771	0,571293
10/1/2014	67,723	385,294	175,771	0,571293
10/1/2014	74,303	422,728	175,771	0,571293
11/1/2014	54,671	311,038	175,771	0,571293
11/1/2014	41,163	190,432	216,156	0,464556

Monthly results according to CO_2 emissions ,tn-km, average CO_2 emissions per tn-km and average loading factor for every single vehicle (January-March)

MONTHLY RESULTS FOR EVERY SINGLE VEHICLE											
JANUARY				FEBRUARY				MARCH			
CO_2 emissions (kg)	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**	**CO_2 emissions (kg)**	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**	**CO_2 emissions (kg)**	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**
2841,327	15693,871	181,478	0,555795	2183,936	12920,439	170,761	0,55236	2692,268	14724,953	185,2573	0,54177

Monthly results according to CO_2 emissions, tn-km, average CO_2 emissions per tn-km and average loading factor for every single vehicle (April-June)

MONTHLY RESULTS FOR EVERY SINGLE VEHICLE											
APRIL				MAY				JUNE			
CO_2 emissions (kg)	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**	**CO_2 emissions (kg)**	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**	**CO_2 emissions (kg)**	**TN-KM**	**AVERAGE CO_2/TN-KM (gr)**	**AVERAGE LOADING FACTOR**
3433,300	17792,861	193,760	0,540557	2.732,82	14710,807	187,2669	0,545063	3.050,29	16507,015	190,92	3433,300

Monthly results according to distance travelled, freight delivered, fuel consumption and average fuel consumption for every single vehicle (January-March)

MONTHLY RESULTS FOR EVERY SINGLE VEHICLE											
JANUARY				FEBRUARY				MARCH			
DISTANCE	**FREIGHT**	**FUEL CONSU**	**AVERAGE**	**DISTANCE**	**FREIGHT**	**FUEL CONSU**	**AVERAGE**	**DISTANCE**	**FREIGHT**	**FUEL CONSU**	**AVERAGE**

TRAVELLED (km)	DELIVERED (kg)	MPTION (lt)	FUEL CONSUMPTION (lt/100 km)	TRAVELLED (km)	DELIVERED (kg)	MPTION (lt)	FUEL CONSUMPTION (lt/100 km)	TRAVELLED (km)	DELIVERED (kg)	MPTION (lt)	FUEL CONSUMPTION (lt/100 km)
3355,72	487392,56	1064,17	31,71	2765,66	391229,76	817,95	29,58	3216,44	429411,16	1008,34	31,35

Monthly results according to distance travelled, freight delivered, fuel consumption and average fuel consumption for every single vehicle (April-June)

MONTHLY RESULTS FOR EVERY SINGLE VEHICLE											
APRIL				MAY				JUNE			
DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)
3936,87	492261,12	1285,88	32,66	3198,520	432.021,160	1.023,53	32	3685,259	443.554,000	1.142,43	31

Total results according to CO_2 emissions, tn-km, average CO_2 emissions per tn-km, average loading factor distance travelled, freight delivered, fuel consumption and average fuel consumption for every single vehicle

TOTAL RESULTS FOR EVERY SINGLE VEHICLE							
CO_2 emissions (kg)	TN-KM	AVERAGE CO_2/TN-KM (gr)	AVERAGE LOADING FACTOR	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100km)
16933,93	92349,9	184,907	0,54359	20158,45	2.675.869	6.342,3	31,383

Monthly results according to CO_2 emissions ,tn-km, average CO_2 emissions per tn-km and average loading factor for all vehicles (January-March)

MONTHLY RESULTS FOR ALL VEHICLES											
JANUARY				**FEBRUARY**				MARCH			
CO_2 emissio	TN-KM	AVERAGE	AVERAGE	CO_2 emissio	TN-KM	AVERAGE	AVERAGE	CO_2 emissio	TN-KM	AVERAGE	AVERAGE

ns (kg)		CO_2/TN-KM (gr)	LOADING FACTOR	ns (kg)		CO_2/TN-KM (gr)	LOADING FACTOR	ns (kg)		CO_2/TN-KM (gr)	LOADING FACTOR
216929,5	1180341	190,56	0,48	213597,7	1167928	190,9	0,484859	192089,8	1031788	194,91	0,48

Monthly results according to CO_2 emissions, tn-km, average CO_2 emissions per tn-km and average loading factor for all vehicles (April-June)

MONTHLY RESULTS FOR ALL VEHICLES											
APRIL				MAY				JUNE			
CO_2 emissions (kg)	TN-KM	AVERAGE CO_2/TN-KM (gr)	AVERAGE LOADING FACTOR	CO_2 emissions (kg)	TN-KM	AVERAGE CO_2/TN-KM (gr)	AVERAGE LOADING FACTOR	CO_2 emissions (kg)	TN-KM	AVERAGE CO_2/TN-KM (gr)	AVERAGE LOADING FACTOR
234079	1248808	195	0,48491973	243872,7	1362179,22	186,48	0,49	232369,4	1286987	188,02	0,48

Monthly results according to distance travelled, freight delivered, fuel consumption and average fuel consumption for all vehicles (January-March)

MONTHLY RESULTS FOR ALL VEHICLES											
JANUARY				FEBRUARY				MARCH			
DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)
277549,8	28879759	81247	29,90117	277891	27763991	79999,12	29,62093	243236,2	25761739	71943,75	30,18152

Monthly results according to distance travelled, freight delivered, fuel consumption and average fuel consumption for all vehicles (April-June)

MONTHLY RESULTS FOR ALL VEHICLES											
APRIL				MAY				JUNE			
DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100 km)

29795	28636		30	31461	31186			29282	29639	87029,7	30
3,7	251	87670		9	751,5	91361,4	30,06	0,5	277	5	

Total results according to CO_2 emissions, tn-km, average CO_2 emissions per tn-km, average loading factor distance travelled, freight delivered, fuel consumption and average fuel consumption for all vehicles

TOTAL RESULTS FOR EVERY SINGLE VEHICLE

CO_2 emissions (kg)	TN-KM	AVERAGE CO_2/TN-KM (gr)	AVERAGE LOADING FACTOR	DISTANCE TRAVELLED (km)	FREIGHT DELIVERED (kg)	FUEL CONSUMPTION (lt)	AVERAGE FUEL CONSUMPTION (lt/100km)
	727803				17186777		29,97
1332938	0	190,9	0,48	1704070	0	499251	

Technical characteristics of the fleet of vehicles

TECHNICAL FEATURES OF VEHICLES

VEHICLE	MAKE	MODEL	EURO	GROSS WEIGHT	PAYLOAD	PAYLOAD (PALLETS)
YXO 8516	VOLVO	FL10	II	18.000	7.562	34
YXX 2653	MERCEDES	2540	II	26.000	14540	35
YXX 9184	MERCEDES	1317	II	13.500	5.952	35
YXX 9206	MERCEDES	2540	II	26.000	13.660	35
YXX 9207	MERCEDES	2540	II	26.000	13.660	18
YXX 9214	MERCEDES	2540	II	26.000	13.660	35
ZYI 9473	MERCEDES	1317	II	13.500	5.960	15
ZYI 9474	MERCEDES	1317	II	13.500	6.060	15
ZYI 9475	MERCEDES	1317	II	13.500	6.010	15
ZYN 2882	VOLVO	FL6	III	19.000	9.322	18
ZYN 2883	VOLVO	FL6	III	19.000	9.322	18
YPO 2951	VOLVO	FL6	III	19.000	8.570	18
YPO 9198	IVECO	ML 180 E 24	III	18.000	8.432	18
YPO 9199	VOLVO	FL6	III	19.000	8.512	18
YPO 9200	VOLVO	FL6	III	19.000	8.470	18
ZYY 2910	SCANIA	P94DB	III	19.000	8.666	18
ZYY 2907	VOLVO	FL6	III	15.000	6.748	15
ZYY 2908	VOLVO	FL6	III	15.000	6.682	15
ZYY 2909	IVECO	ML 130 E 18	III	13.500	5.932	10
ZYX 2302	DAF	LF 55 180 E 13	III	13.000	7.450	10
ZXA 6279	DAF	LF 55 180 E 13	III	13.000	5.480	10
ZXA 6280	DAF	LF 55 180 E 13	III	13.000	5.470	10
ZXA 6282	DAF	LF 55 180 E 13	III	13.000	5.200	15
ZXA 6479	DAF	CF 75 250	III	19.000	8.550	18
ZXA 6480	DAF	XF105 460,	V	25.000	11.950	35
ZXE 5368	IVECO	ML 140 E 22	IV	14.000	5.850	15
ZXE 6969	VOLVO	Fes	IV	19.000	9.234	18
ZXE 6968	VOLVO	Fes	IV	19.000	13.365	18
ZXE 7115	SCANIA	R 480	IV	25.000	11.790	35
ZXH 3900	DAF	LF 55 250	IV	16.000	7.610	15

ZXH 3901	DAF	LF 55 250	IV	16.000	7.610	15
ZXI 1000	DAF	CF 75	IV	19.000	8.500	18
ZXH 9873	DAF	CF 75	IV	19.000	8.498	18
ZXI 3810	DAF	CF 75	IV	19.000	8.498	18
ZXI 8438	DAF	CF 75	V	19.000	8.550	18
ZXI 8439	DAF	CF 75	V	19.000	8.550	18
ZXI 8494	DAF	LF 55 250	V	16.000	8.570	15
ZXI 8495	DAF	LF 55 250	V	16.000	8.570	15
ZXK 2218	IVECO	160 E 25	V	16.000	8.410	10
ZXK 2219	IVECO	160 E 25	V	16.000	8.410	10
ZXM 2301	DAF	LF 55 250	V	16.000	8.020	15
ZXM 2302	DAF	LF 55 250	V	16.000	8.020	15
ZXM 2331	DAF	LF 55 250	V	16.000	8.400	15
ZXM 2332	DAF	LF 55 250	V	16.000	8.400	15
ZXM 2335	DAF	LF 55 250	V	16.000	8.400	15
ZXM 2336	DAF	LF 55 250	V	16.000	8.400	15
ZXM 2222	MAN	TGM 18 290	V	18.500	9.640	18
ZXM 2285	MAN	TGM 18 290	V	18.500	9.640	18
ZXM 2286	MAN	TGM 18 290	V	18.500	9.640	18
ZXM 4444	MAN	TGM 18 290	V	18.500	9.640	18
ZXN 1815	DAF	LF 55 250	V	16.000	7.950	15
ZXN 1816	DAF	LF 55 250	V	16.000	7.990	15
ZXN 1817	DAF	LF 55 250	V	16.000	7.950	15
ZXN 1819	DAF	LF 55 250	V	16.000	7.970	15
ZXN 1850	VOLVO	FH 13	V	25.000	11.120	35
ZXN 1851	VOLVO	FH 13	V	25.000	11.130	35
ZXN 1854	DAF	LF 55 250	V	16.000	7.990	15
ZXN 1855	DAF	LF 55 250	V	16.000	8.000	15
YTA 8584	DAF	LF 55 250	V	16.000	6.960	15
YTA 8587	DAF	LF 55 250	V	16.000	6.870	15
YTA 8589	DAF	LF 55 250	V	16.000	6.980	15
YTA 8591	DAF	LF 55 250	V	16.000	6.940	15
YTA 8873	MAN	TGM 18 290	V	18.000	7.720	18
YTA 8884	MAN	TGM 18 290	V	18.000	7.700	18
YTA 9372	MAN	TGX 26.480	V	26.000	13.160	34
YTA 9774	MAN	TGM 18 290 swap body	V	18.000	11.140	16
YTB 1623	MAN	TGM 18 290 swap body	V	18.500	9.800	16

Data for backhauling operations (indicative)

DATE	SUPPLIER	VEHICLE	CAPACITY	BACKHAULING
01/04/2014	ELBISCO A.B.E.E(PEKERMI)	YXX 9214	18	18
01/04/2014	ELBISCO A.B.E.E(MAGOULA)	YXX 9207	35	34
01/04/2014	NESTLE	ZXE 7115	35	32
01/04/2014	COLGATE	ZXN 1850	18	18
01/04/2014	NESTLE	ZXM 2301	15	15
01/04/2014	NESTLE	YXO 8516	35	34

01/04/2014	KIKIZAS	ZXH 9873	18	10
01/04/2014	GIOTIS(CAPTAIN)	ZXA 6479	18	13
02/04/2014	ΜΕΛΙΣΣΟΣ	ZXH 3900	15	3
02/04/2014	BDF	ZXH 3901	15	10
02/04/2014	COLGATE	YXX 9206	35	35
02/04/2014	COLGATE	YXX 9207	35	35
02/04/2014	COLGATE	YXX 2653	35	35
02/04/2014	COLGATE	ZXN 1851	35	35
02/04/2014	ELBISCO A.B.E.E(PEKERMI)	YXX 9214	35	32
02/04/2014	ELBISCO A.B.E.E(PEKERMI)	ZXI 1000	18	16
02/04/2014	COLGATE	YXO 8516	35	32
02/04/2014	COLGATE	ZXE 6968	18	16
02/04/2014	ELBISCO A.B.E.E(PEKERMI)	ZXN 1850	35	35
02/04/2014	COLGATE	YPO 9199	18	6
02/04/2014	NESTLE	YXX 9214	18	18
03/04/2014	COLGATE	YXO 8516	35	34
03/04/2014	ELBISCO A.B.E.E(MAGOULA)	YXX 9214	35	33
03/04/2014	ELBISCO A.B.E.E(MAGOULA)	ZXN 1850	35	33
03/04/2014	NESTLE	ZXE 6968	18	14
03/04/2014	NESTLE	ZXA 6282	15	13
03/04/2014	COLGATE	YXX 9214	18	18
03/04/2014	NESTLE	ZXN 1854	15	15
03/04/2014	ELBISCO A.B.E.E(MAGOULA)	ZYN 2882	18	18
03/04/2014	ILIOS	ZXE 6969	18	15
03/04/2014	NESTLE	ZXH 3900	15	15
03/04/2014	ILIOS	ZXA 6479	18	18
03/04/2014	NESTLE	YXX 9207	35	34
03/04/2014	COLGATE	YXX 9206	35	35
04/04/2014	COLGATE	YXX 9214	35	29
04/04/2014	NESTLE	ZXE 6968	18	15
04/04/2014	COLGATE	YXX 9207	35	28
04/04/2014	BDF	ZXI 1000	18	18
07/04/2014	COLGATE	YXX 9214	35	28
07/04/2014	COLGATE	ZXN 1851	35	35

Appendix B – Data used for providing recommendations for the reduction of carbon footprint

Classification of rigid trucks- Category A

CATEGORY A								
VEHICLE	**MAKE**	**MODEL**	**Euro**	**MIXED**	**PAYLOAD**	**PAYLOAD IN PALLETS**	**AVERAGE FUEL CONSUMPTION (lt)**	**OPTIMAL CO_2/tn-km (gr)**
ZYI-9475	MERCEDES	1317	II	13500	6010	15	23,1	148,7
ZYI-9474	MERCEDES	1317	II	13500	6060	15	23,4	151,0
ZXM-4444	MAN	TGM 18 290	V	18500	9640	18	27,9	154,7
ZXI-1000	DAF	CF 75	IV	19000	8500	18	28,2	156,1
YXX-9184	MERCEDES	1317	II	13500	5952	15	24,3	156,6
ZXM-2286	MAN	TGM 18 290	V	18500	9640	18	28,3	156,7
ZXH-9873	DAF	CF 75	IV	19000	8498	18	28,3	157,0
ZXE-6969	VOLVO	Fes	IV	19000	13365	18	28,4	157,5
ZXN-1854	DAF	LF 55 250	V	16000	7990	15	24,5	157,6
ZXM-2222	MAN	TGM 18 290	V	18500	9640	18	28,7	158,9
ZXN-1815	DAF	LF 55 250	V	16000	7950	15	24,7	159,3
ZXN-1817	DAF	LF 55 250	V	16000	7950	15	24,7	159,5
ZXN-1819	DAF	LF 55 250	V	16000	7970	15	25,0	161,0
YTA-8873	MAN	TGM 18 290	V	18000	7720	18	29,1	161,3
ZXE-5368	IVECO	ML 140 E 22	IV	14000	5850	15	25,1	161,6
ZXM-2285	MAN	TGM 18 290	V	18500	9640	18	29,3	162,4
ZXI-3810	DAF	CF 75	IV	19000	8498	18	29,4	163,1
ZXN-1816	DAF	LF 55 250	V	16000	7990	15	25,4	164,0

YPO-9200	VOLVO	FL6	III	19000	8470	18	29,6	164,3
ZXM-2301	DAF	LF 55 250	V	16000	8020	15	25,5	164,3
YTA-8884	MAN	TGM 18 290	V	18000	7700	18	30,0	166,3
YPO-2951	VOLVO	FL6	III	19000	8570	18	30,1	166,6
ZXE-6968	VOLVO	Fes	IV	19000	9234	18	30,1	166,7
ZXI-8439	DAF	CF 75	V	19000	8550	18	30,2	167,5
ZXI-8494	DAF	LF 55 250	V	16000	8570	15	26,4	169,9

Classification of rigid trucks-Category B

CATEGORY B

VEHICLE	MAKE	MODEL	Euro	MIXED	PAYLOAD	PAYLOAD IN PALLETS	AVERAGE FUEL CONSUMPTION (lt)	OPTIMAL CO_2/tn-km (gr)
ZXI-8438	DAF	CF 75	V	19000	8550	18	30,8	170,5
ZXH-3901	DAF	LF 55 250	IV	16000	7610	15	26,5	170,6
ZXI-8495	DAF	LF 55 250	V	16000	8570	15	26,6	171,2
ZYN-2883	VOLVO	FL6	III	19000	9322	18	31,2	173.1
ZYY-2910	SCANIA	P94DB	III	19000	8666	18	31,2	173,2
ZXA-6282	DAF	LF 55 180 E 13	III	13000	5200	15	26,9	173,4
ZXH-3900	DAF	LF 55 250	IV	16000	7610	15	26,9	173,5
YPO-9198	IVECO	ML 180 E 24	III	18000	8432	18	31,4	173,9
ZXM-2331	DAF	LF 55 250	V	16000	8400	15	27,4	176,4
ZXM-2332	DAF	LF 55 250	V	16000	8400	15	27,6	177,7
ZXN-1855	DAF	LF 55 250	V	16000	8000	15	27,6	177,8

ZXM-2302	DAF	LF 55 250	V	16000	8020	15	27,7	178,7
YPO-9199	VOLVO	FL6	III	19000	8512	18	32,3	178,8
ZXM-2335	DAF	LF 55 250	V	16000	8400	15	27,7	178,8
ZYN-2882	VOLVO	FL6	III	19000	9322	18	32,4	179,7
ZXA-6479	DAF	CF 75 250	III	19000	8550	18	32,5	180,0
ZYY-2908	VOLVO	FL6	III	15000	6682	15	28,8	185,5
YTB-1623	MAN	TGM 18 290 swap body	V	18500	9800	16	30,5	186,3
YTA-9774	MAN	TGM 18 290 swap body	V	18000	11140	16	30,7	187,6
ZYY-2907	VOLVO	FL6	III	15000	6748	15	29,3	188,6
ZXM-2336	DAF	LF 55 250	V	16000	8400	15	29,3	189,0
ZYI-9473	MERCEDES	1317	II	13500	5960	15	30,2	194,8
YTA-8587	DAF	LF 55 250	V	16000	6870	15	31,0	200,0

Classification of rigid trucks-Category C

CATEGORY C								
VEHICLE	**MAKE**	**MODEL**	**Euro**	**MIXED**	**PAYLOAD**	**PAYLOAD IN PALLETS**	**AVERAGE FUEL CONSUMPTION (lt)**	**OPTIMAL CO_2/tn-km (gr)**
YTA-8589	DAF	LF 55 250	V	16000	6980	15	31,2	201,0
YTA-8584	DAF	LF 55 250	V	16000	6960	15	31,4	202,1
YTA-8591	DAF	LF 55 250	V	16000	6940	15	31,6	203,8
ZYY-2909	IVECO	ML 130 E 18	III	13500	5932	10	23,2	205,4
ZXK-2218	IVECO	160 E 25	V	16000	8410	10	23,3	206,5

ZXK-2219	IVECO	160 E 25	V	16000	8410	10	23,7	209,5
ZYX-2302	DAF	LF 55 180 E 13	III	13000	7450	10	24,1	213,1
ZXA-6280	DAF	LF 55 180 E 13	III	13000	5470	10	25,7	227,5
ZXA-6279	DAF	LF 55 180 E 13	III	13000	5480	10	25,8	228,5

Classification of articulated trucks-Category A

CATEGORY A											
VEHICLE	**MAKE**	**MODEL**	**Euro**	**MIXED**	**PAYLOAD**	**PAYLOAD WITH TRAILER**	**AVERAGE FUEL CONSUMPTION (lt)**	**PAYLOAD IN PALLETS**	**PAYLOAD WITH TRAILER IN PALLETS**	**OPTIMAL CO_2/tn-km (gr)**	**OPTIMAL CO_2/tn-km WITH TRAILER (gr)**
YTA-9372	MAN	TGX 26.480	V	26000	13160	20370	35,5	18	34	196,7	112,6
ZXN-1851	VOLVO	FH 13	V	25000	11130	18450	37,2	18	34	205,9	117,9
ZXE-7115	SCANIA	R 480	IV	25000	11790	19850	37,3	18	34	206,8	118,3
ZXN-1850	VOLVO	FH 13	V	25000	11120	18520	38,9	18	34	215,5	123,3
ZXA-6480	DAF	XF105 460	V	25000	11950	19950	39,6	18	34	219,6	125,7
YXX-2653	MERCEDES	2540	II	26000	14540	20950	40,4	18	34	223,7	128,0
YXX-9214	MERCEDES	2540	II	26000	13660	19410	42,2	18	34	234,0	133,9

Classification of articulated trucks-Category B

CATEGORY B											
VEHICLE	**MAKE**	**MODEL**	**Euro**	**MIXED**	**PAYLOAD**	**PAYLOAD WITH TRAILER**	**AVERAGE FUEL CONSUMPTION (lt)**	**PAYLOAD IN PALLETS**	**PAYLOAD WITH TRAILER IN PALLETS**	**OPTIMAL CO_2/tn-km (gr)**	**OPTIMAL CO_2/tn-km WITH TRAILER (gr)**
YXX-9206	MERCEDES	2540	II	26000	13660	19410	44,7	18	34	247,6	141,7

YXX-9207	MERCEDES	2540	II	26000	13660	19410	45,4	18	34	251,5	143,9
YXO-8516	VOLVO	FL10	II	18000	7562	19922	51,1	14	34	348,1	162,0

Routing based on consumption -22 January

	SCENARIO AS-IS			SCENARIO TO-BE			
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
13:00	YTA-8584	31,4	39,40	ZYY-2907	29,3	36,41	2,99
5:00	YTA-8587	31	38,85	ZYI-9475	23,1	27,49	11,36
17:03	YTA-8587	31	34,90	ZYI-9475	23,1	24,7	10,2
5:40	YTA-8589	31,2	29,10	ZXM-2301	25,5	24,04	5,06
13:06	YTA-8591	31,6	37,90	ZXN-1819	25	31,04	6,86
6:13	YXO-8516	51,1	31,97	YXX-9214	42,2	24,62	7,35
6:00	YXX-9206	44,7	72,62	ZXE-7115	37,3	62,65	9,97
16:48	ZXA-6279	25,8	26,43	ZYY-2909	23,2	25,17	1,26
0:51	ZXA-6479	32,5	18,85	ZXH-9873	28,3	18,27	0,58
6:53	ZXE-7115	37,3	41,48	ZXI-3810	29,4	33,29	8,19
0:50	ZYN-2882	32,4	22,43	ZXM-2286	28,3	19,37	3,06
19:21	ZYN-2882	32,4	21,55	ZXI-1000	28,2	18,55	3
0:50	ZYN-2883	31,2	21,45	ZXM-4444	27,9	18,2	3,25
12:00	ZYN-2883	31,2	28,86	ZXM-2222	28,7	25,19	3,67
							TOTAL

							76,8 lt

Routing based on consumption – 11 February

		SCENARIO AS-IS			SCENARIO TO-BE		
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
13:06	YTA-8584	31,4	17,58	ZXN-1816	25,4	16,01	1,57
5:06	YTA-8587	31	31,25	ZXH-3900	26,9	28,65	2,6
8:30	YTA-8587	31	29,20	ZXN-1855	27,6	27,47	1,73
13:01	YTA-8587	31	35,83	XZI-8494	26,4	32,23	3,6
5:03	YTA-8589	31,2	32,67	ZXN-1819	25	26,88	5,79
5:00	YTA-8591	31,6	36,84	ZXN-1855	27,6	33,41	3,43
16:37	YTA-8591	31,6	29,53	ZYI-9475	23,1	22,41	7,12
5:54	YXO-8516	51,1	35,11	YTA-9372	35,5	24,83	10,28
11:29	YXO-8516	51,1	21,02	YTA-9372	35,5	14,86	6,16
21:16	YXX-9214	42,2	32,07	ZXE-7115	37,3	28,24	3,83
23:00	YXX-9214	42,2	29,23	ZXE-7115	37,3	25,73	3,5
0:30	ZXA-6479	32,5	36,54	ZXM-4444	27,9	34,47	2,07
13:11	ZXA-6479	32,5	25,41	ZXM-2286	28,3	24,31	1,1
21:00	ZXM-2336	29,3	28,31	ZXN-1815	24,7	24,31	4
3:00	ZYN-2882	32,4	26,28	ZXH-9873	28,3	22,12	4,16
13:12	ZYN-2882	32,4	25,04	YPO-9200	29,6	22,04	3

	TOTAL
	63,94 lt

Routing based on consumption – 12 March

	SCENARIO AS-IS			SCENARIO TO-BE			
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
15:46	YPO-9199	32,3	13,25	ZXI-1000	28,2	11,55	1,7
5:51	YTA-8584	31,4	12,90	ZXN-1816	25,4	10,42	2,48
16:01	YTA-8584	31,4	18,63	ZXH-3901	26,5	15,72	2,91
5:07	YTA-8589	31,2	33,02	ZXN-1854	24,5	25,53	7,49
13:55	YTA-8589	31,2	29,09	ZYI-9474	23,4	21,49	7,6
6:01	YTA-8591	31,6	36,56	ZXM-2332	27,6	23,78	5,31
13:55	YTA-8591	31,6	40,14	ZYI-9475	23,1	28,73	11,41
16:02	YTA-9372	35,5	20,34	ZXH-3901	26,5	14,73	5,61
8:00	YXO-8516	51,1	15,66	ZXN-1851	37,2	10,79	4,87
3:46	YXX-9206	44,7	23,91	ZXN-1850	38,9	22,26	1,65
20:00	YXX-9206	44,7	46,06	YTA-9372	35,5	39,06	7
14:00	YXX-9207	45,4	30,75	ZXA-6480	39,6	27,85	2,9
20:00	YXX-9214	42,2	49,31	YTA-9372	35,5	40,81	8,5
0:22	ZXA-6479	32,5	15,20	ZXH-9873	28,3	14,70	0,5

3:00	ZXA-6479	32,5	18,84	ZXI-1000	28,2	18,21	0,63
0:22	ZYN-2882	32,4	21,39	ZXM-4444	27,9	18,19	3,2
							TOTAL
							73,76 lt

Routing based on consumption – 4 April

	SCENARIO AS-IS			SCENARIO TO-BE			
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
5:00	YTA-8584	31,4	38,95	ZXM-2331	27,4	32,34	6,61
7:42	YTA-8584	31,4	37,26	ZXM-2331	27,4	30,69	6,57
17:03	YTA-8584	31,4	37,94	ZXM-2331	27,4	30,5	7,44
5:04	YTA-8587	31	33,22	ZXN-1819	25	26	7,22
7:22	YTA-8587	31	40,09	ZXN-1819	25	31,25	8,84
13:00	YTA-8587	31	38,62	ZXM-2331	27,4	33,16	5,46
0:13	YTA-8591	31,6	43,11	ZYI-9475	23,1	30,96	12,15
12:28	YTA-8591	31,6	38,62	ZYI-9475	23,1	27,72	10,9
6:20	YXO-8516	51,1	28,71	ZXN-1851	37,2	22,99	5,72
20:20	YXX-2653	40,4	30,49	ZXE-7115	37,3	28,09	2,4
0:07	YXX-9206	44,7	49,66	YTA-9372	35,5	40,83	8,83
5:50	ZXA-6280	25,7	26,84	ZYY-2909	23,2	21,81	5,03

0:51	ZXA-6479	32,5	15,57	ZXM-4444	27,9	14,57	1
3:02	ZXA-6479	32,5	19,95	ZXM-4444	27,9	18,61	1,34
15:03	ZXA-6479	32,5	22,26	ZXE-6968	28,4	21,13	1,13
5:28	ZXM-2331	27,4	24,56	YTA-8584	31,4	27	-2,44
17:35	ZXN-1851	37,2	24,95	ZXM-2286	28,3	18,82	6,13
3:11	ZYN-2882	32,4	27,14	ZXH-9873	28,3	23,61	3,53
							TOTAL
							100,46 lt

Routing based on consumption-27 May

	SCENARIO AS-IS			**SCENARIO TO-BE**			
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
17:30	YPO-9198	31,4	18,72	ZXM-2222	28,7	16,77	1,95
2:30	YPO-9199	32,3	25,99	ZXI-1000	28,2	23,65	2,34
8:02	YPO-9199	32,3	32,90	ZXM-2286	28,3	30	2,9
20:59	YPO-9199	32,3	49,08	ZXM-4444	27,9	44,17	16
1:16	YTA-8584	31,4	21,86	YXX-9184	24,3	16,89	4,97
3:53	YTA-8587	31	32,21	ZXE-5368	25,1	26,61	5,6
8:03	YTA-8587	31	39,84	ZXE-5368	25,1	33,06	6,78
3:52	YTA-8589	31,2	28,54	ZYI-9475	23,1	20,79	7,75
7:51	YTA-8589	31,2	41,79	ZYI-9474	23,4	30,87	10,92

5:06	YTA-8591	31,6	21,27	ZXN-1854	24,5	16,14	5,13
13:00	YTA-8591	31,6	65,44	ZXE-5368	25,1	50,86	14,58
10:30	YXX-2653	40,4	26,62	ZXM-2222	28,7	19,09	7,53
11:04	YXX-9206	44,7	20,51	ZXM-2222	28,7	12	8,51
							TOTAL
							83,87 lt

Routing based on consumption-3 June

SCENARIO AS-IS				SCENARIO TO-BE			
ROUTE	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**VEHICLE**	**AVERAGE FUEL CONSUMPTION (lt/100km)**	**FUEL CONSUMPTION PER TRIP (lt)**	**BALANCE (lt)**
4:07	YTA-8587	31	33,74	ZXH-3901	26,5	28,07	5,67
11:26	YTA-8587	31	28,48	ZYY-2907	29,3	26,17	2,31
17:42	YTA-8587	31	22,81	ZXN-1819	25	17,9	4,91
4:04	YTA-8591	31,6	37,57	ZXN-1816	25,4	29,72	7,85
16:09	YTA-8591	31,6	36,92	ZXN-1816	25,4	29,21	7,71
14:13	YTA-9372	35,5	39,28	ZXM-4444	27,9	31,87	7,41
0:01	YXX-2653	40,4	21,75	YTA-9372	35,5	20,31	1,44
5:20	YXX-9206	44,7	32,97	ZXN-1851	37,2	26,64	6,33
21:16	YXX-9206	44,7	43,69	ZXN-1851	37,2	35,33	8,36
23:30	YXX-9206	44,7	30,43	ZXN-1851	37,2	24,61	5,82
6:35	YXX-9207	45,4	28,89	YTA-9372	35,5	22,79	6,1
11:16	YXX-9207	45,4	19,71	YTA-9372	35,5	15,55	4,16

17:20	YXX-9207	45,4	30,28	YTA-9372	35,5	23,86	6,42
19:30	YXX-9207	45,4	29,77	YTA-9372	35,5	23,47	6,3
20:00	YXX-9214	42,2	48,51	ZXN-1850	38,9	44,9	30
23:30	YXX-9214	42,2	28,98	ZXN-1850	38,9	26,85	2,13
3:30	ZXA-6479	32,5	30,39	ZXE-6968	28,4	21,58	8,81
7:55	ZXA-6479	32,5	37,60	ZXE-6968	28,4	26,7	10,9
19:38	ZXM-2302	27,7	26,98	ZYI-9475	23,1	22,26	4,72
							TOTAL
							110,96 lt

Total results based according to the routing based on vehicle’s fuel consumption:

Fuel Consumption							
	22 JANUARY	11 FEBRUARY	12 MARCH	4 APRIL	27 MAY	3 JUNE	TOTAL
AS-IS	3536,2 lt	3671,4 lt	2755,5 lt	4325,8 lt	3722,4 lt	4243,5 lt	22254,9 lt
TO-BE	3459,4 lt	3607,5 lt	2681,7 lt	4225,3 lt	3638,5 lt	4132,5 lt	21745,1 lt

CO_2 EMISSIONS

	22 JANUARY	11 FEBRUARY	12 MARCH	4 APRIL	27 MAY	3 JUNE	TOTAL
AS-IS	9441,6 kg	9802,6 kg	7357,2 kg	11549,9 kg	9938,8 kg	11330,1 kg	59420,6 kg
TO-BE	9236,5 kg	9632 kg	7160,1 kg	11281,5 kg	9714,7 kg	11,033,7 kg	58059,4 kg

NUMBER OF VEHICLES USED						
	22 JANUARY	11 FEBRUARY	12 MARCH	4 APRIL	27 MAY	3 JUNE
AS-IS	60	62	63	62	59	62
TO-BE	60	59	57	59	54	57

Fuel consumption of articulated trucks with or without a trailer

ZXN-1850			
Vehicle		**Trailer**	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7522	38,77	14662	38,94

YXX-2653			
Vehicle		Trailer	
Average freight	Average fuel consumption(lt/100	Average freight	Average fuel

transferred (kg)	km)	transferred (kg)	consumption (lt/100 km)
7327	40,46	13149	40,31

ZXN-1851

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7881	37,09	14037	37,22

YXX-9206

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7202	44,32	13972	44,71

YXX-9207

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7523	45,08	14388	47,14

YTA-9372

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7400	35,55	13850	35,54

YXX-9214

Vehicle	Trailer

Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7161	42,23	13832	42,26

ZXA-6480

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7155	38,71	14353	39,61

ZZE-7115

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7470	37,25	14022	37,34

ZXN-1850

Vehicle		Trailer	
Average freight transferred (kg)	Average fuel consumption(lt/100 km)	Average freight transferred (kg)	Average fuel consumption (lt/100 km)
7522	38,77	14662	38,94