Periodica Polytechnica
Transportation Engineering

45(1), pp. 35-41, 2017
DOI: 10.3311/PPtr.9099

RESEARCH ARTICLE

Calculating the Impacts of Alternative Parking Pricing and Enforcement Policies in Urban Areas with Traffic Problems

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Received 17 February 2016; accepted 30 May 2016

Abstract

Called to seek fresh thinking in mobility management, European cities present strong interest in parking management. In contrast with traditional approaches where parking problem was treated as a problem of inadequate supply whose solution lies on abundant, free and on a first-come basis parking provision, the rational of parking management is conscripted so as to combat traffic and environmental problems. At the new parking approach, parking policy should respect particular needs of each area and should apply in a flexible way so as to serve an integrated development plan. At this framework, the current paper examines Thessaloniki's case, Greece, that presents severe traffic problems. The paper tries to evaluate the impacts on traffic and environmental indicators of the implementation of a controlled parking system. The results verify that when a parking system becomes controlled and a strong enforcement mechanism applies, the modal split changes in favor of public transport.

Keywords

parking management, parking pricing policy, traffic and environmental impacts, traffic models

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1 Introduction

Parking management refers to the various strategies and policies adopted with an ultimate goal to relieve congested areas from traffic externalities (Cats et al., 2015) by using in a more efficient way the existing parking resources (Litman, 2013) and the urban space in general. Parking management explores current parking problems, deals with parking pricing and savings to be achieved by improved parking schemes, outlines specific strategies and the way they can be applied, attach importance to the socioeconomic and environmental parameter of urban sustainability while focusing on specific mobility needs of each area. The literature review reveals a series of parking management strategies with different "dynamic" in congestion relief. According to a recent report of the Victoria Transport Policy Institute (Litman, 2011), the recorded strategies refer either to direct measures tackling parking problems (parking regulations, shared parking, parking maximums etc.) or to indirect measures aiming to reinforce alternative to private car measures leading to lower parking demand (smart integrated growth, improved bicycle and walking facilities, mobility management). Not all the strategies reduce congestion; however all contributes to the better use of existing parking spaces and to a reduction in the amount of parking required at a destination.

Parking management strategies play therefore a major role to ensure the balance between space supply and demand. An effective parking management strategy can mitigate congestion and improve road conditions of an urban center leading subsequently to a reduction of social and environmental impacts. It has been proved that the implementation of targeted policy for parking management can reduce up to 20–40% of the requirements in parking spaces compared to conventional strategies, providing multiple economic, social and environmental benefits.

In total, a car is parked for around 20 hours per day (Litman, 2011) while the average parking maneuver time is almost the 40% of the travel time (Axhausen et al., 1994). As indicated those manoeuvres drastically reduce road capacities (Nissan, 2012). In large urban areas, congestion gets intensified in a daily base from parking maneuvers, illegal parking phenomena, lack of systematic enforcement of parking policies, non-compliance with the parking maximums and regulations, the lack of coordinated actions towards sustainable mobility initiatives adoption and the limited or fragmented information provision to passengers that could add to modal shift in favor of alternative to private car modes.

The various measures having at times been used as a mean to reduce the negative effects of traffic not only affect the parking system of a city but also at the same time can affect the socio-economic structure and development of the urban area. For years, the so called traditional practices focused in the design and construction of new parking spaces by enhancing in this way the use of private vehicles and underestimating the key role that could be played by public transport and alternative ways of traveling in reducing congestion. In recent decades, this trend has changed and now what matters seems to be the effective management of existing infrastructure through a series of practices including the introduction of spatial and temporal restrictions, different parking pricing policies per zone, systematic enforcement, privileges to residents and employees as regards parking spaces, thus policies able to lead to a less private car dependent cities (Shiftan et al., 2001).

Focusing on pricing, in the modern parking management approach, this policy means that motorists pay directly for using parking spaces. The pricing is one of the most essential components of urban traffic planning (Verhoef et al., 1995; Higgins, 1992), especially when the goal is to reduce the number of daily trips (Higgins, 1992; 10; Shoup, 1997) and is considered to be the second best measure after urban tolls since it produces higher savings (Calthrop et al., 2000). Parking pricing presents multiple advantages as it can be used as mobility management strategy (to reduce the number of vehicles entering an area), as parking management strategy (mitigating parking related problems), as a mean to achieve other indirect objectives (e.g. cross-financing of other mobility interventions) or even as a way to achieve a combination of the above effects.

The pricing of parking spaces can regulate the number of cars traveling within a region (Ison et al., 2013) and can provide the most effective way to affect modal split (Booz Allen Hamilton, 2006). The increase in the price for longer parking duration leads to an increase in the availability of spaces for short-term parking (Bonsall et al., 2010). From the other side, the competent authority to implement a parking pricing policy must take into account several factors so as to present a scheme widely accepted as well as accessible.

Among these factors are:

- Fees per minute or hour for customer and visitor spaces depending on the special characteristics and the needs of the study area - Weekly or monthly fees for employees and residents
- Different fees (higher charges for peak hours)
- Fees integrated into the overall framework of mobility management policies
- Fees that cover part of the costs for the development of off-street parking spaces
- Fees that can cover the costs (or part thereof) of other supplementary policies- e.g. enforcement

On the other hand, the strengthening of enforcement, stricter laws and high fines are able to discourage the use of private vehicles and contribute in modal shift towards alternative modes of transportation. A fairly large number of offenders demonstrates the importance of the measures to be taken in order to prevent delinquent behaviour (Cullinane et al., 1995). Previous analyses have shown that the number of users who do not comply with the pricing policy increases as the enforcement reduces (Adiv et al., 1987; Elliott et al., 1982).

Considering the benefits of a well-structured and integrated parking management strategy and focusing on the specific case of Thessaloniki's Municipality that presents intense traffic problems partly caused from the extensive rate of illegal parking, this paper aims to assess the impact on modal split and from the implementation of controlled parking policies by making use of Thessaloniki's modal split model. Based on the modal split results, the authors present also the calculation of environmental effects from the implementation and possible expansion of the controlled parking policy in the wider urban area of Thessaloniki. In the paper's structure, the key findings of the literature review are followed by the description of the methodology for calculating impacts of alternative parking pricing schemes in the case of Thessaloniki. The results as regards traffic and environmental impacts of the tested scenarios are presented in section 3 followed by the last section with conclusions and policy considerations.

2 Methodology

This section presents the methodology followed for calculating the impacts of alternative parking pricing policies and estimating scenarios for the case of Thessaloniki. The 5-step methodology is summarized in the following:

- Determination of the study area for the implementation of the controlled parking system
- Identification and investigation of trip characteristics
- Calculation of the proportion of inhabitants who would decide to change the mode of transport they are currently using and to make a shift to public transport means, due to the increased generalized cost of private vehicles use (parking costs + average time spent by each motorist on the parking search + high fine from illegal parking) exploiting a logit model for modal split.
- Trip Assignment to a transportation network and
- Impact assessment in the level of service at the basic road axis of Thessaloniki as well as in the environment (CO reduction deriving from the lower rate of private vehicles use) in different scenarios of parking pricing and enforcement scenarios.

2.1 The study area

The city of Thessaloniki, the major city in the Region of Central Macedonia, is the second largest one in Greece accommodating, according to 2011 Census data, approximately 800.000 inhabitants within an area of 111.703 km2 (43.129 sq mi). Thessaloniki is Greece's second major economic, industrial, commercial and political centre, and a major transportation hub for the rest of south-eastern Europe.

At a daily basis, there are around 1.300.000 trips at the road network while the whole transportation network serves more than 2,5 million trips per day from which the 51% is made by private cars and the 39% via public means of transport.

Public transportation is provided only by one Bus Operator (OASTH) covering the Greater Thessaloniki Area, which is however not enough to meet the existing demand during peak periods. Thus, it cannot offer a reliable alternative to the private car use in terms of quality and availability. Bus fleet size increase is not possible due to legal restrictions governed by the contract between the State and the Operator. The currently constructed metro lines are expected to significantly contribute to congestion reduction. However, this will occur within a period of 4 years from now, while in the meantime, metro construction works at several locations across the city largely contribute to even more congestion.

The study area for the controlled parking system refers at a first stage to the historic center of the city which attracts more than 300.000 trips per day and at a second stage to basic axis of four Municipal Communities. More than 18% of the above mentioned trips are executed during the morning peak hour (8.00am to 11:00am).

Among the most severe problems faced in Thessaloniki today is congestion. Despite the significant impacts of the economic crisis, which has resulted to reduced activities and subsequently reduced demand for transport, the city of Thessaloniki is still facing severe congestion problems.

The extensive use of the private car (car ownership 450 vehicles per 1.000 residents) results to traffic problems in the main road network of the city. In main axis of the city's road network, during rush hours Volume-Demand-to-Capacity Ratio (V/C) reaches 1,04 resulting to average travel speed falling from 30 to 13 km/hour. The continuous increase of demand for parking as well as illegal on-street parking is also a major problem of the city. Conversely, parking space availability remains the same and therefore the increased demand/supply ratios (2,74 in the central area of the city) demonstrate a significant problem to meet the needs of residents and visitors of the city.

Seeking to add to city's sustainability, recently, the Municipality of Thessaloniki has launched the procedures for the installation of a smart controlled parking system in approximately 2500 parking places exclusively serving visitors. These places are mainly located in the historic center and on key roads beyond it.

2.2 Thessaloniki's transportation model

The four step transportation model used to assess the impact of the introduction of controlled parking in the Municipality of Thessaloniki was developed by the Hellenic Institute of Transport / Centre for Research and Technology Hellas (HIT/ CERTH) and was initially created in 2011 in the framework of the project "Thessaloniki's Intelligent Urban Mobility Management System" and daily updated from then on with real time data (volumes, speeds) collected through installed by the Region equipment.

The estimation of Origin – Destination matrix for car use was based on the results of a wide phone survey in a sample of 5000 inhabitants of the Greater Area of Thessaloniki and of the suburban zone that captured daily trip diaries. The existing trip generation model of Thessaloniki developed during the implementation of the General Transportation Study of Thessaloniki was updated based on the current phone survey outputs. Subsequently the trip distribution applied using a gravity model that took in several factors, including the number of trip productions, the number of trip attractions, and an impedance value (resistance to travel, which could include distance, time, tolls, or a combination of those) and the first OD of the survey was calculated.

The OD derived from an additional survey conducted on-street was taken into account so as to estimate the total OD matrix for private car. The survey revealed an OD matrix of 780.000 trips per day. From the merging of the two OD matrices, 24 hourly matrices were created that demonstrated a total of 889.000 vehicles per day.

In order to capture the complexity of modal shift for travellers owning or having the ability to travel by car, versus travellers that could only travel by mass transit means the model that was created for the city of Thessaloniki during the Implementation of the General Transportation Study of Thessaloniki is applied, which groups modal alternatives into private and mass transit. The model is a "nested-logit mode choice models". The development steps of the specific model were the following:

STEP 1: Definition of the utility functions Ui for all modes based on the results of a State Preference survey (for the General Transportation Study of Thessaloniki).

STEP 2: Definition of the expected maximum utility for the public and private means of transport.

The utility functions for the public and private means of transport included the partial utilities of the means of transport were calculated by the Eq. McFadden (1975):

$$EMU = \ln \sum \exp Ui \tag{1}$$

EMU: expected maximum utility (EMU) of each nest

Ui: the utility of the nest selection(s)

STEP 3:After all utilities were defined, the mode selection probabilities in each split level or node of the hierarchical decision tree were estimated according to Eq. (2):

$$P_i = eVi \Big/ \sum_j^V e^j \quad (2)$$

Pi: probability of trips conducted by mode i

Vi: the utility function of mode i

STEP 4: The total trips during morning peak hours were split in trips made using private transport modes or using public transport modes.

The utility functions for the car owners were calculated using the following parameters:

$$U_{car}{}^{ca} = IVT + 1.8OVT + PARK / VoT^{ca} \quad (3)$$

$$U_{bus}{}^{ca} = IVT + 1.8WAIT + 1.8WALK + FARE / VoT^{ca} + 5.51 \quad (4)$$

$$U_{taxi}{}^{ca} = IVT + 1.8OVT + FARE / VoT^{ca} + 60 \quad (5)$$

The utility functions for the non car owners were calculated using the following parameters:

$$U_{bus}{}^{nca} = IVT + 1.71WAIT + 1.94WALK + FARE / VoT^{nca} + 9.45 \quad (6)$$

$$U_{taxi}{}^{nca} = IVT + 1.71WAIT + 1.94WALK + FARE / VoT^{nca} + 14 \quad (7)$$

Each of the variables represents the most important factors for the modal choice:

For Private Transport Modes (IVT: In-Vehicle Time, OVT: Out of Vehicle Time, COST: Operational Cost, PARK: Parking Cost, VOT : Value of Time) and for Public Transport Modes (IVT: In-Vehicle Time, WAIT: Waiting time, WALK: Walking time, FARE: Tarification)

For the car users, the utility function of the private vehicles and the public transport mode is calculated as following:

$$U_{priv}{}^{ca} = -(1/\lambda_1)\ln\left(\exp\left(-\lambda_1 U_{car}{}^{ca}\right) + \exp\left(-\lambda_1 U_{taxi}{}^{ca}\right)\right) \quad (8)$$

$$U_{pt}{}^{ca} = -(1/\lambda_4)\ln\left(\exp\left(-\lambda_4 U_{bus}{}^{ca}\right) + \exp\left(-\lambda_4 U_{spmode}{}^{ca}\right)\right) \quad (9)$$

Where λ_x: calibration parameters

The trips by private vehicles and PT are calculated as following:

$$T_{ij}{}^{ca}{}_{priv} = T_{ij}{}^{ca} * p_{ij}{}^{ca}{}_{priv} \quad (10)$$

$$T_{ij}{}^{ca}{}_{pt} = T_{ij}{}^{ca} * \left(1 - p_{ij}{}^{ca}{}_{priv}\right) \quad (11)$$

where

$$p^{ca}{}_{priv} = 1/(1 - \exp\left(-\lambda_2\left(U_{bus}{}^{ca} - U_{pt}{}^{ca}\right)\right)$$

The modal split between car and taxi is presented below:

$$T_{ij}{}^{ca}{}_{car} = T_{ij}{}^{ca}{}_{priv} * p_{ij}{}^{ca}{}_{car} \quad (12)$$

$$T_{ij}{}^{ca}{}_{taxi} = T_{ij}{}^{ca}{}_{priv} * \left(1 - p_{ij}{}^{ca}{}_{car}\right) \quad (13)$$

where

$$p^{ca}{}_{car} = 1/(1 - \exp\left(-\lambda_1\left(U_{taxi}{}^{ca} - U_{car}{}^{ca}\right)\right) \quad (14)$$

Finally the trips between bus and the steady mode are assigned as following:

$$T_{ij}{}^{ca}{}_{bus} = T_{ij}{}^{ca}{}_{pt} * p_{ij}{}^{ca}{}_{bus} \quad (15)$$

$$T_{ij}{}^{ca}{}_{Stmode} = T_{ij}{}^{ca}{}_{pt} * \left(1 - p_{ij}{}^{ca}{}_{bus}\right) \quad (16)$$

where

$$p^{ca}{}_{bus} = 1/(1 - \exp\left(-\lambda_4\left(U_{stmode}{}^{ca} - U_{bus}{}^{ca}\right)\right) \quad (17)$$

For the non car users, the utility function of the public transport modes is calculated as following:

$$U_{pt}{}^{nca} = -(1/\lambda_5)\ln\left(\exp\left(-\lambda_5 U_{bus}{}^{nca}\right) + \exp\left(-\lambda_5 U_{stmode}{}^{nca}\right)\right) \quad (18)$$

The modal split between public transport modes and taxi is realized using the following calculation:

$$T_{ij}{}^{nca}{}_{pt} = T_{ij}{}^{nca} * p_{ij}{}^{nca}{}_{pt} \quad (19)$$

$$T_{ij}{}^{nca}{}_{taxi} = T_{ij}{}^{nca} * \left(1 - p_{ij}{}^{nca}{}_{pt}\right) \quad (20)$$

where:

$$p^{nca}{}_{pt} = 1/(1 - \exp\left(-\lambda_2\left(U_{taxi}{}^{nca} - U_{pt}{}^{nca}\right)\right) \quad (21)$$

Finally the assignment of the P.T. trips between the bus and the steady track mode is realized as following:

$$T_{ij}{}^{nca}{}_{bus} = T_{ij}{}^{nca}{}_{pt} * p_{ij}{}^{nca}{}_{bus} \quad (22)$$

$$T_{ij}{}^{nca}{}_{newmode} = T_{ij}{}^{nca}{}_{pt} * \left(1 - p_{ij}{}^{nca}{}_{bus}\right) \quad (23)$$

where:

$$p^{nca}{}_{bus} = 1/(1 - \exp\left(-\lambda_5\left(U_{newmode}{}^{nca} - U_{bus}{}^{nca}\right)\right) \quad (24)$$

Finally, the mathematical formulation of the equilibrium solution algorithm is Eq. (26) subject to the constraints of the Eq. (27), (28), (29) and (30):

$$\min \sum_{a \in E} \int_0^{q_a} R_a(x)\,dx \quad (25)$$

subject to:

$$q_{ijr} > 0, \quad \forall ijr \quad (26)$$

$$\sum_r q_{ijr} = q_{ij}, \quad \forall ij \quad (27)$$

$$\sum_{ijr:a \in P_{ijr}} q_{ijr} = q_a, \quad \forall a \quad (29)$$

$$\sum_{a \in E_u^+} q_a - \sum_{a \in E_u^-} q_a = \sum_i q_{iu} - \sum_i q_{ij} = D_u - O_u, \quad \forall u \quad (30)$$

where

E set of Links

q_a traffic flow on link a

$R_a(x)$ friction of link a with traffic flow x (travel cost)

q_{ij} transportation demand from zone i to zone j

q_{ijr} traffic flow of route r from zone i to zone j

$E+_u$ set of incoming links at node u

$E-_u$ set of outgoing links at node u

D_u traffic heading to node u

O_u traffic originating from node u

The solution algorithm adopted solves iteratively the optimization problem presented using the ICA methodology and the BPR functions for the estimation of the friction of links with traffic flows.

3 Estimation of traffic and environmental impacts

The basic parameters affecting modal split refers to the generalized cost. Two basic scenarios are examined in the current paper regarding the increase of private car use cost, either as direct parking fees or indirectly by high fine costs for illegal parking. Using the modal split algorithm, for each scenario two new OD matrices were calculated, one referring to private car and one to public transport.

The calculated matrices per mode were used for the trip assignment so as to map the new traffic conditions and to be able to make comparisons with the current situation.

The latest examined impacts refer mainly to the operational characteristics of basic road axis of the study area, namely traffic volumes at peak hours, average speeds, congestion (v/c) and average trip time in specific links. Furthermore, impacts on environment, specifically the decrease in CO emissions deriving from the lower use of private car, were calculated.

3.1 Impacts of pricing policy to modal share

The pricing policy of a proposed controlled parking system, on the one hand should prevent the use of private cars by increasing all respective costs, while on the other hand should not make its use prohibitive, either because the system will then remain untapped or it will lead to a systemic irregularity.

The existing controlled parking policy defines a cost of around 1.7 € / hour, regarding the historical center of the city. The scenarios examined are related to a small increase of this amount corresponding to 2.0 € / hour, to a middle increase raising the parking fee at 2.25 € / hour and a sharp increase where the cost reaches 2.5 € / h.

The above three scenarios affect the generalized cost of private car while the new modal split and the corresponding variation from the current situation are presented below (Table 1).

Table 1 Variation of modal split per pricing policy scenario

	Controlled parking hourly rate	Percentage of trips made by private cars in Thessaloniki	Percentage of trips made by P.T. in Thessaloniki	Ridership increase percentage in Thessaloniki
Scenario 0	1.70 €/hour	50.85%	49.15%	-
Scenario 1	2.00 €/hour	49.49%	50.51%	2.83%
Scenario 2	2.25 €/hour	49.15%	50.85%	3.56%
Scenario 3	2.50 €/hour	48.86%	51.14%	4.18%

As seen from the above data, the maximum variation of the hourly parking charges corresponding to 80 cents, reduces the use of private car and increases the ridership of the Public Transport system at a rate which exceeds 4%.

3.2 Impacts of enforcement policy to modal share

A substantial factor which determines the successful implementation of measures related to parking and traffic issues, is a systematic law enforcement system. Imposing any costs on parking fee may has no impact on traffic if it is not combined with the imposition of the respective fines in a systematic and organized way.

Therefore, law enforcement scenarios provide another weight in the above pricing policy scenarios. Related surveys have led to the conclusion that the likelihood for an offender to take a fine is only 20%. So, if someone would like to park on street in the city center for eight hours, with a cost of 1.7 € / hour, will have to pay a total of 13.6 €. The slight chance of paying a fine of 20 € leads the 25% of drivers to act unlawfully. The examined scenarios are related to the “intensity” of law enforcement at a rate of offenders 10, 25 and 50% after the implementation of controlled parking in all parking spaces proposed with a cost of 2 € / hour.

The results of these scenarios in terms of modal split and the respective variation regarding the current situation are presented in Table 2 and Fig. 1 below

Table 2 Variation of modal split per law enforcement scenario

	% of offenders who don’t pay controlled paerkig fees	% of trips made by p.c.	% of trips made by P.T.	Ridership increase %
Scenario 0	-	50.85%	49.15%	-
Scenario 1	50% (less law enforcement	50.16%	49.84%	1.39%
Scenario 2	25% (same enforcement)	49.49%	50.51%	2.83%
Scenario 3	10% (systematic enforcement)	48.81%	51.19%	4.28%

From the above, it is obvious that a systematic law enforcement may discourage the use of private car and increase ridership in public transport means up to 4.28% even if the controlled parking policy remains the same.

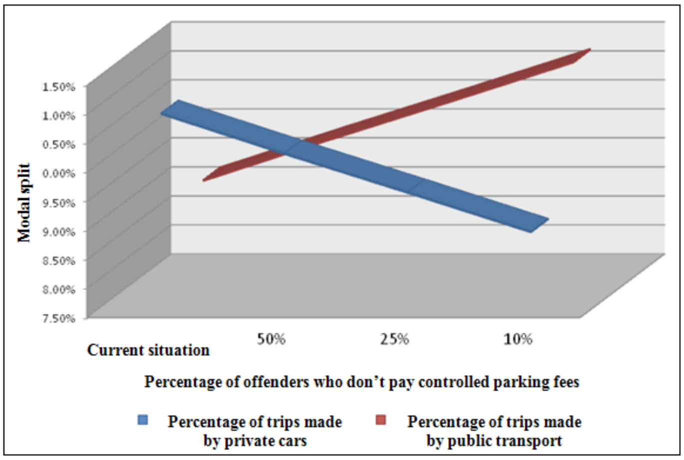

Fig. 1 Benchmarking of law enforcement scenarios related to modal split.

3.3 Impacts on the traffic profile and CO emissions in Thessaloniki's Urban Area

After examining the influence of each factor on the modal share due to pricing and enforcement policy, two more scenarios were established in order to calculate the traffic impact as well as the CO emissions impact. The first one foresaw an immediate implementation of the measure in the city center while the second one foresaw a future extension of the measure to a wider area beyond the historic center of the city (therefore, four main axes were chosen of four other Thessaloniki's Municipal Communities). The characteristics of both the direct and future measures' implementation scenarios are presented in Table 3 below.

Table 3 Key operational characteristics of final implementation scenarios

	% of controlled parking spaces increase	Hourly controlled parking cost	Percentage of offenders who don't pay controlled parking fees
Scenario 0	0%	1.7 €/h	25%
Scenario 1	25%	2.0 €/h	10%
Scenario 2	35%	2.5 €/h	0%

At the beginning of the possible implementation of the measure (Scenario 1), immediately after installing the system, the hourly cost is proposed to not exceed 2.00 € / hour as it will be a trial period for users. The system is proposed to be installed in the city center where controlled parking already exists as well as on main axes of four Municipal Communities. It is considered that law enforcement during the first period of the measure will have much better results by reducing 10% of users who don't pay for parking in specific spaces.

In the future situation (Scenario 2) the cost rises up to 2.50 €, the percentage of offered parking spaces increase to 35%, and law enforcement becomes systematic and continual thereby infringements are zeroed.

3.4 Impacts on the traffic profile of Thessaloniki

In the current situation (Scenario 0), the percentage of car use in the Thessaloniki Urban Area reaches the 70% in contrast with the 52% in the Municipality of Thessaloniki since the longest distance from the center ones lives, the lower the service from public transport means it receives.

The implementation of a controlled parking system for the first scenario will result in a total decrease of private car use at around 4% in the whole Urban Area, namely 3500 travelers seems to shift to public transport. The total number of vehicles in the road network will be reduced by about 3000. The respective increase in public transport use reaches the 9% of the total traffic.

The impacts of the implementation of a controlled parking system for the second scenario will be much greater; private cars are reduced by 5400 in the study area, thus 4500 car users shift to public transport (12% increase in PT share).

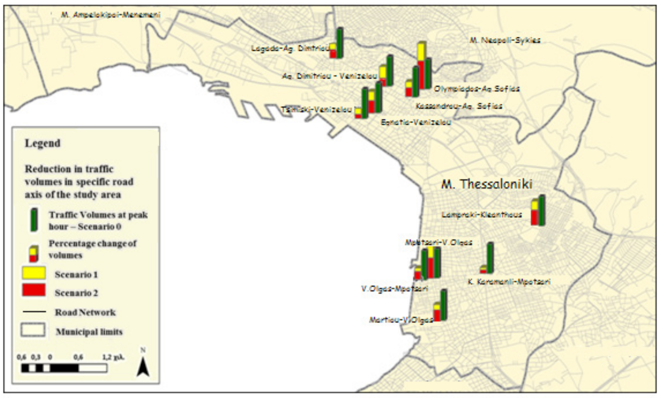

Fig. 2 Shift from private car to P.T.

3.5 Impacts on CO emissions in Thessaloniki's Urban Area

For the calculation of the impacts of the proposed parking policy scheme on the environment, the current study concentrated on CO since traffic highly affects the percentage of CO emissions in urban areas (it is estimated that traffic contributes at a rate of 95% in CO emissions in urban areas). Another assumption made for the calculation of CO emissions is that the majority of cars in the city center is Euro 4 technology. For this calculation, the results for the traffic profile (average speed and volume per link) derived from the abovementioned model are used. EMEP/EEA air pollutant emission inventory guidebook (previously referred as EMEP CORINAIR emission inventory guidebook) provided with the methodology and the mathematic formulas for CO calculations. Figure 3 presents the result of the calculations (CO in gr/km) in certain road links. The results are strongly dependent on average speeds and on the five constant coefficients as shown in Eq. (31).

$$EF = \left(a + c \times V + e \times V^2 \right) / \left(1 + b \times V + d \times V^2 \right) \quad (31)$$

As can be seen from Fig. 3, the reduction of CO reaches the percentage of 20% in the first scenario and the percentage of 33% in the future one.

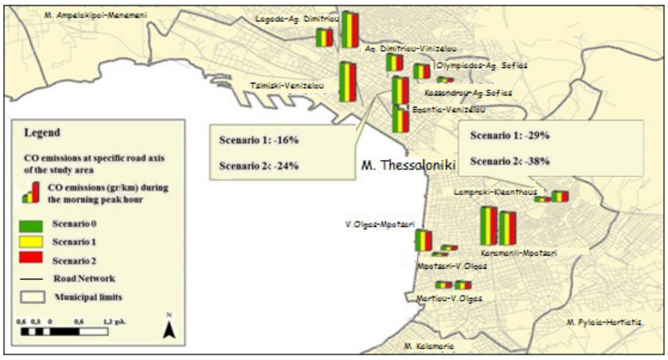

Fig. 3 Changes in CO emissions per pricing scenario.

4 Conclusions

The discourage of private car use and the strengthening of demand management for better utilization of the limited capacity (TRB, parking) in urban areas are the main goals of the adoption of parking policies. Impacts intensity of such strategies depends on the degree of achievement of the above objectives.

Increasing the generalized cost of on-street parking seems to highly affect the modal split in favor of public means of transport. Major inhibiting factors for the use of private car are both the reduced probability to find a free parking space as well as the higher costs of controlled parking especially for travelers who want to park their cars for a large period.

The modern approaches on parking management, which include parking pricing and enforcement and monitoring policies in combination with the provision of integrated information tools giving access to holistic and reliable information to passengers for the traffic situation embedded in a broader framework of sustainable mobility strategy seem to be able to contribute in the traffic and environmental relief of urban areas (Costa et al., 2014).

Key prerequisites for the successful adoption of parking policies are: citizens' participation in every step of the measures' implementation, common parameters for the effectiveness of any mobility management strategy and comprehensive information regarding the benefits to both the society and the environment. On the other hand, local authorities and stakeholders should be able to maintain a comprehensive monitoring mechanism of the effectiveness of decisions taken. Thus, regularly and depending on users' response will be able to feed back with innovative ideas the integrated parking plan.

Regarding the specific example examined in the present paper, the implementation of the proposed controlled parking system even though does not increase the cost compared to the existing one (at least no more than 0.3 €) seems to confirm the positive effect on modal split by increasing the use of public transport by 3% in the Municipality of Thessaloniki and 4% in Thessaloniki' Urban Area. This change leads to a reduction in traffic volumes on the main axes of the city and reduces CO emissions.

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