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Research on the Impacts from the Implementation of an Urban Toll System in the Northeast Suburbs of Attica, Greece

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Abstract**—** The boost in suburban development has occurred as an outcome of various factors, leading to an extensive increase in mobility needs for housing and commuting. These travel needs were mostly covered through the private automobile, developing high traffic flows and jams in the peri-urban environment. In order to tackle with the above demands and decrease the public cost of road infrastructure among other issues, many countries are applying charging methods (such as tolls, congestion pricing etc.) to the users of the interurban street network. This approach raises a number of issues and finds numerous supporters and dissenters, as it is strongly doubted if charging practically decreases traffic and whether it excludes road users according to income criteria and housing location.

This paper aims to deal with the potential impacts of urban toll systems applied in highway road segments, on the local network of the adjacent residential areas. The research was centered at a local part of the Attica ring road that links the North-East Athenian suburbs with the city center, passing through numerous emerging suburbs. The key enquiry of the paper is whether the application of congestion charges in the studied segments would burden the local street network of the neighboring suburbs, as users would try to bypass the toll roads and use alternative connections.

The study looked in depth the suggested plans for the development of an integrated urban toll system in North-East Attica and explored the potential traffic impacts prior to the development. Quantitative and qualitative mobility indicators were taken into account and traffic capacity of the local networks was examined thoroughly. Moreover, potential land use, planning and environmental impacts were researched in the buffer zones among the ring road and the suburbs.

Keywords**—**Athens, Congestion Charges, Sustainable Mobility, Traffic Impact, Urban Toll System.

I. Introduction

The extensive tendency of suburbanization in housing and services, both local and supra-local, has led to an increase in daily trip lengths, traffic flows and car-dependency for the commuter. Hence, impacts are apparent in a number of fields, such as the fuel and time consumption, vehicle damages, environmental degradation, accidents, delays etc. In traffic planning terms, the urban highways and major arterial roads- especially during the peak hours in Athenian streets- it is observed that the number of vehicles can frequently excess the street capacity. According to several studies from Greek transportation authorities, 48% of the 10 million daily travels in the Athenian conurbation, are conducted by car and 10.3% by taxi, which is mostly due to the lack of public transit system and the overall mobility mentality of the Greeks, compared to other Europeans.

Traffic congestion occurs in the city center and the supra local arteries connecting the major suburbs and other developmental nodes of the wider prefecture of Attica, demanding decisive interventions in existing infrastructure and the construction of new routes or the strategic promotion of alternative transportation modes and ways of daily commuting.

The aforementioned conditions develop crucial degradation in urban planning terms, as they impact on land use distribution and the sitting of new nodes and activities. Alterations should deal with decisions related to street hierarchy, trucks and lorries' mobility, parking strategy, traffic calmed neighborhoods, mixed-use areas and most importantly with the environmental capacity of transport infrastructure.

Based on the principle of common environmental laws "the polluter pays" and specifying to the restoration of the urban environment for air and noise pollution by the drivers, there are many cities around Europe and internationally that consider the possibility of road pricing inside metropolitan centers in order to mitigate such impacts and increase the public funds for the relevant infrastructure.

Common issues that arise from the above relate to the rationale of charging a public good/ asset, such as the street which is and should remain a free public space and the exclusions this may have in social groups accessing those infrastructure. Moreover, as analyzed in this paper, road pricing in urban motorways impacts immensely in the adjacent urban and peri-urban centers and their local street network as traffic is commonly diverted to avoid tolls.

II. Aims and Objectives

The aim of this paper is to identify and assess the impacts of road charging methods, as predicted to be implemented in urban highway segments of PATHE national road (PiraeuS – Athens – Thessaloniki – Evzonoi connection), in the neighboring residential areas. The main objective of the research is related to the qualitative and quantitative characteristics of mobility and transportation elements with the impacts in the bordering centers and their capacity. The key parameter of bypassing toll systems and crossing urban centers is examined in depth and the potential burden arising from this is analyzed through a transportation equilibrium model. In parallel, planning and environment impacts are also researched in the buffer zones among the ring road and the aforementioned areas of influence. Lastly, the research states clearly that the specific plans in the studied PATHE segment for an urban toll system aim mostly to the co-financing in building new and improving the existing infrastructure rather than achieving the needed traffic decongestion in the overall territory.

III. Overview of Toll and Urban Toll Systems in Greece and Worldwide

A. Theoretical Overview of Road Pricing. The key principles

This section aims to present a short theoretical overview of road and congestion pricing principles in urban metropolitan areas and the key notions related to these, in order to support the main arguments for the assessment demonstrated in the studied PATHE segments of East Attica Regional Unit.

First of all, road pricing has been promoted by transport economists for decades as a means of solving congestion problems in big cities [1], and as a term it means that motorists pay directly for driving on a particular roadway or in a particular area [2]. Transportation experts and economists consider road pricing as an efficient way to finance road infrastructure, which if combined with an integrated strategy in other means of transport, can also benefit the inner- city environment and the society.

That said, road pricing has two general objectives (Table 1) revenue generation and congestion management [3].

Table 1: Victoria Transport Policy Institute (2014), Comparing Road Pricing Objectives [3]

Comparing Road Pricing Objectives

Revenue Generation	Congestion Management
Generates funds	Reduces peak – period vehicle traffic
Rates set to maximize revenues or recover specific costs	Is a TDM strategy
Revenue often dedicated to road way projects	Revenue not dedicated to roadway projects
Shifts to other routes and modes not desired (because this reduces revenues)	Requires variable rates (higher during congested periods)
	Travel shifts to other modes and times considered desirable

The main aims and motives for road pricing as identified by Lindberg [4], Eliasson [6] and Papathanassopoulou [7] are: road construction financing, environmental upgrade and decrease in road congestion by implementing congestion pricing elements.

Congestion pricing, according to Victoria Transport Policy Institute [3], refers to variable road tolls (higher prices under congested conditions and lower prices at less congested times and locations) intended to reduce peak-period traffic volumes to optimal levels. They are implemented to raise revenue, or on existing roadways as a demand management strategy to avoid the need to add capacity. Some highways have a combination of unpriced lanes and Value Priced lanes, allowing motorists to choose between driving in congestion and paying a toll for an uncongested trip. This is a type off Responsive Pricing, meaning that it is intended to change consumption patterns [8].

The key principles of road pricing systems, as defined by Smeed [9] (in Papathanassopoulou [7]) and Victoria Transport Policy Institute [3] should cover all three major perspectives (namely the user, the traffic authority and the society). According to Victoria Transport Policy Institute [3] an effective and fair road pricing system should reflect the following principles.

1) User Perspective

- Easy for users to understand.
- Convenient – does not require vehicles to stop at toll booths.
- Transport options – consumers have viable travel options available (i.e., alternative modes, travel times, routes, destinations).
- Payment options – easy to use with multiple payment options (cash, prepaid card, credit card, etc.)
- Transparent – charges evident before trip is undertaken.
- Anonymous – privacy of users is assured.

2) Traffic authority Perspective

- Traffic impacts – does not require each vehicle to stop at toll booths or in other ways delay traffic.
- Efficient and equitable – charges reflect true user costs.
- Effective – reduces traffic congestion and other transportation problems by changing travel behavior.
- Flexible – easily accommodates occasional users and different vehicle types.
- Reliable – minimal incorrect charges.
- Secure and enforceable – minimal fraud or non-compliance.
- Cost effective – positive return on investments.
- Implementation – minimum disruption during development phase. Can be expanded as needed.

3) Society's Perspective

- Benefit/cost – positive net benefits (when all impacts are considered).
- Political acceptability – public perception of fairness and value.
- Environment – positive environmental impacts.
- Integrated – same charging system can be used to pay other public service fees (parking, public transit, etc.)

But, the imposition of toll systems rarely has the public's acceptance as it raises a number of issues related to social exclusion. The parameters that affect and shape the public's acceptance [7], range from return investment, the aim of charging imposition, the technology used, to any complementary measures that improve the overall traffic conditions and most importantly the overall strategy for promoting the necessity of toll operation. Indeed, in most of the cases as spotted by Berger [10], the public acceptance of urban toll systems is negative (i.e. the Hungarian M15, M5).

An issue that should be thoroughly examined, and has received little attention by transport experts and researchers, relates to the effects of toll imposition in the neighboring local networks by the traffic diversion. Albalate and Germa [11], argue that the local networks that carry the extra burden caused by by-passers of the road segments with tolls, increases the accidents in those streets, compared to local networks that exist next to motorways free of tolls.

Road pricing procedure has several steps in order to achieve the fairer and more efficient application, which can be summarized in the following figure (Fig 1), as demonstrated by CURACAO [12]. Moreover, charges can follow different prototypes, such as the cordon pricing, the area pricing, or charges according to the distance travelled or the time spent on a particular road segment. The number of travelling passengers, and even charges depended on social costs.

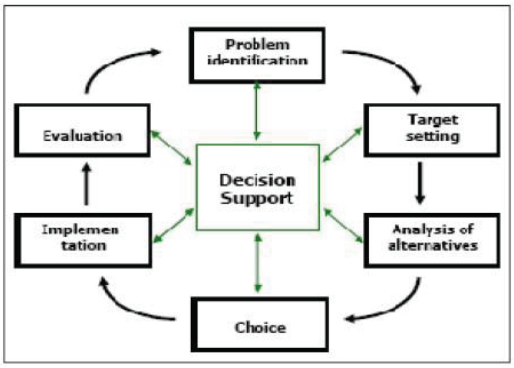


Fig. 1: Curacao,2009. Circular procedure of road pricing application [12]

Toll collection methods and their assisting technologies are also crucial matters in the success of such applications, though are not essential to the current study [25].

B. Toll systems: Overview and Examples

Urban toll systems have long been studied in many European cities, such as Dublin, Cambridge, Edinburgh, Copenhagen, Amsterdam and Brussels, in some Asian capital cities (Hong Kong), in several developing countries of Asia such as Seoul, Bangkong and Tokyo, as well as in some states of the USA like New York, Los Angeles, Washington and San Francisco. This study has researched some of them in order to predict and assess their potential development in the Athenian conurbation.

London authorities has examined several times the possibility of developing an urban toll system in London city center, already since 1964, in order to deal effectively with traffic congestion, which was finally implemented in 2003 by the Transport for London-TfL with the Áutomatic Number -Plate Recognition- ANPR' technology. London Congestion Charging Scheme has essentially changed since then with variations in charges, time zones and influence zones, while also particular schemes for exemptions and discounts are applied for special vehicles or permanent residents in central London. According to several TfL reports ([15] – [20]), net profits reached €137 million in the year 2007 to 2008, and €128 of them were invested in public transport system while the rest funded road infrastructure, traffic safety measures, environmental frameworks and particular measures for pedestrians and cyclists. In 2003, 33% less cars entered the charging areas, compared to 2002, before the toll operation began, but since 2007, there is no dynamic change in circulation due to this measure. Important changes were detected in terms of travel times which were decreased by 30% (2002 to 2003), resulting in proportional decrease in congestion. Public transportation has been upgrading constantly before the implementation of the toll system, as a complementary measure to deal with traffic congestion, and more than 50% of the increase in bus usage between 2002 and 2003 appears to be due to the toll operation. Besides that, environmental upgrade was apparent for the same period, with less emissions from car circulation in NOX (-13.4%), PM10 (-15.5%) and CO2 (-16.4%). The public acceptance of the scheme had rather successful outcomes with more than 40% being satisfied with the overall implementation and almost 30% had seen environmental upgrade [16], although surveys did not generally report the generated inequalities in low income commuters to central London.

Similarly, in the case of **Stockholm**, road pricing issues were discussed already since the 1980s and many attempts failed due to public opposition until 2006, when a pilot implementation started and was confirmed by a local referendum. Began in 2007, the toll system had positive outcomes in terms of traffic congestion as delays were decreased by 30 to 50% in the previously overburdened road arteries for the period 2007-2008 [21], as well as a beneficial impact emerged in the public transit system. Although the reported elements show an overall positive image, the Traffic Administration Department of Stockholm [21] had reported an increase in traffic of the adjusting local networks (+5%), as drivers were avoiding the toll segments of urban highways and used the peripheral streets to reach similar or close by destinations. Similarly in **Singapore**, an increase in accidents in the neighboring networks was accounted.

Other schemes in Singapore and **Bergen** had analogous outcomes in terms of traffic impacts, while others showed a surprising increase in traffic circulation (i.e. the case of Oslo road toll system), which though was not only due to the toll imposition.

An important finding, common in the cases of Singapore, **Milan** and others is the reported redistribution of activities in the daily agenda as several enterprises changed their timetable to attract customers off the peak hours, so drivers would not be charged for approaching the city center. Other issues that were raised in Norwegian and Italian cities were related to long term planning alterations as land uses slightly changed to absorb traffic impacts in more beneficial areas.

In the case of **Athens**, where tolls have been applied to national roads and only recently in the Attica Tollway (part of the PATHE studied road), the potential of further toll implementations remains a complex research subject as compensations are rarely been applied due to inefficient strategies and political profiteering. In general, car circulation remains high, public transport appears inadequate and the number of taxis has reached 14.000 vehicles (35 taxis per 10.000 citizens, when Paris has 15/10.000 residents [22]), burdening further the congested capital and its suburbs. Hence, traffic congestion is a crucial matter in today's transport studies and any further research for potential toll implementation should encounter both urban planning and traffic engineering policies and measures. The affluent East- Athenian sprawling suburbs present linear commercial development corridors with overburdened street arteries, while the travel demand is constantly increasing. Based on these, the potential of an integrated urban toll system is PATHE roadway is explored, in order to evaluate its challenges and complexities and finally conclude on its necessity.

IV. Planning and Traffic Analysis of the Impact Area of PATHE Motorway

The aim of the research is the identification and the evaluation of the potential effects of new toll in the PATHE National Road in Athens' northern – east suburbs (East Attica Regional Unit).

A. *Study Area*

The research area expands within the East Attica Regional Unit including several suburbs that present incompatible land uses, complex topography, variations in population and building density, as well as socioeconomic inequalities among their residents. Housing is the key land use in the larger part of the area, while commercial and recreational activities with some industries are concentrated in linear development (see Fig. 2) along the main urban thoroughfares and avenues. These linear commercial centralities and poor road infrastructure stress further the traffic conditions in the overall study area and form hazardous status for vulnerable road users (i.e. pedestrians).

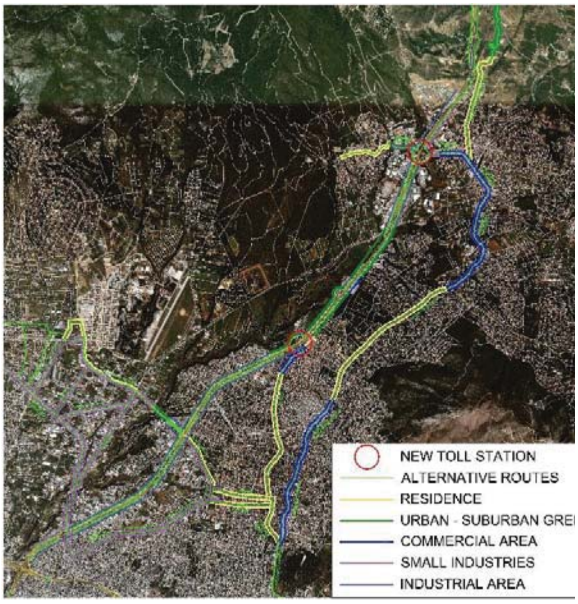


Fig. 2: Land use concentration around the main arterial roads in East Attica Regional Unit [25]

Principal arterial roads and collectors pass through residential areas, while the location of industrial units in the west of PATHE national road burdens the existing street network with heavy vehicle traffic. First thoughts consider that a potential toll operation in PATHE (see location in Fig. 2) will pull heavy vehicles to their first alternative, the main commercial avenue (i.e. Kifisias) **passing through** the residential and commercial zones. The continuous reallocation of housing from the center to suburbia and sparse structure of activities are the main problematic urban issues. These, in combination to the absence of public transport lead to complete car-dependency behaviour. In addition, the street network is used for through traffic by vehicles leaving and entering Athens throughout the day. Pedestrian and cyclists' movement are degraded and environmental pollutants are on the rise.

B. *Street hierarchy*

A common issue on several municipalities is the lack of street hierarchy in the local network, with many of them presenting similar image and geometric characteristics regardless of their role and traffic flows and loads. Critical decisions for hierarchy should concern the distribution of traffic loads, traffic flow and speed, heavy vehicle restrictions, traffic calming and protected zones, location of parking policy implementations, public transport system and routes, design of special facilities for pedestrians, cyclists as well as land use policies and strategies for combined traffic and urban planning.
Street hierarchy criteria include the geometric and operational characteristics of the network, the street location in the overall study area, land uses, traffic composition and other urban and transportation planning elements. The street hierarchy in the study area include a number of first and second level roads (primary and secondary) as well as collectors, local and pedestrian streets (see Fig. 3).

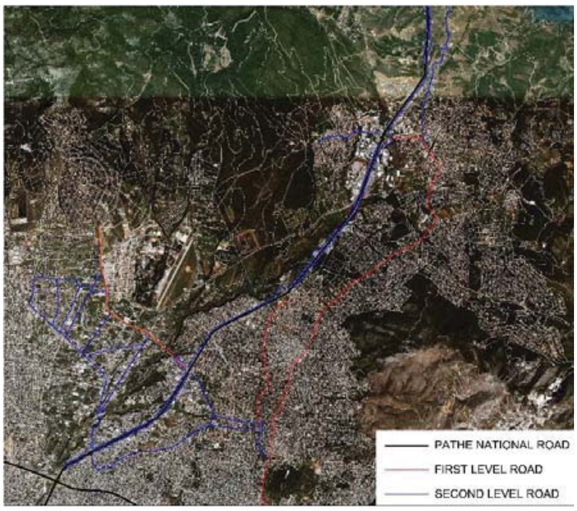


Fig. 3: Road Classification in the study area [25]

C. Identification of alternative routes

Applying a road pricing system commonly leads to the exploration of alternatives, so as to conduct the same travel without being charged. Experience has shown that vehicles using a previously free motorway, tend to seek for alternatives through local roads, service roads or the existing urban streets. The local networks of the neighboring suburbs (i.e. Dionysos, Kifisia, Pefki) are expected to be primarily stressed due to their current inadequate condition and impacts will include delays, jams, decrease in traffic safety and environmental degradation. The existing Environmental Impact Study [25] has not yet explored these impacts in the surrounding zones, however focused on specified effects from the linear development of the infrastructure.

The presented study has considered all the alternative routes that would serve similar connections if tolls would be applied in the neighboring PATHE segments starting from Dionysos to the rest of the Athenian conurbation (see Fig. 4), using solely first and second level roads (primary and secondary). All potential destinations starting from each one of the seven (7) centralities have been explored along with the probable routes to be followed excluding the studied PATHE segment (see example in Fig. 5). Moreover, all PATHE bypass routes have been researched for all the possible origin-destination pairs and special cross-sections were planned to show the capacity of the network (See example of cross-section in Fig. 6).

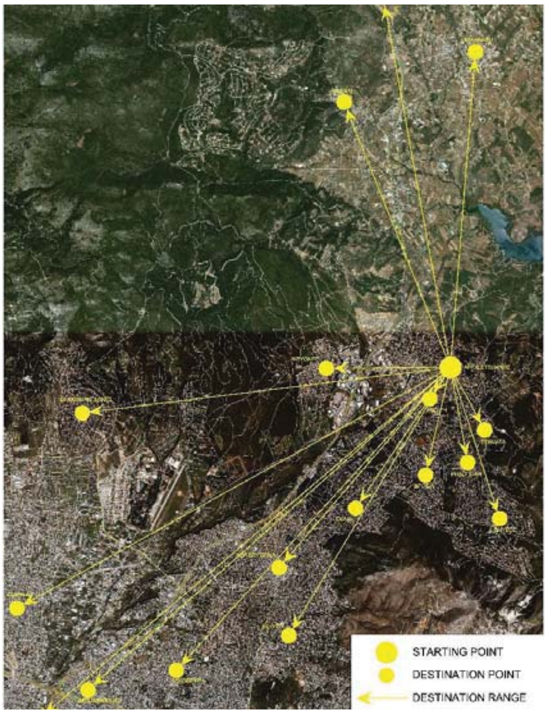


Fig. 4: Potential destination starting from North- East Athens (Ag. Stefanos) [25]

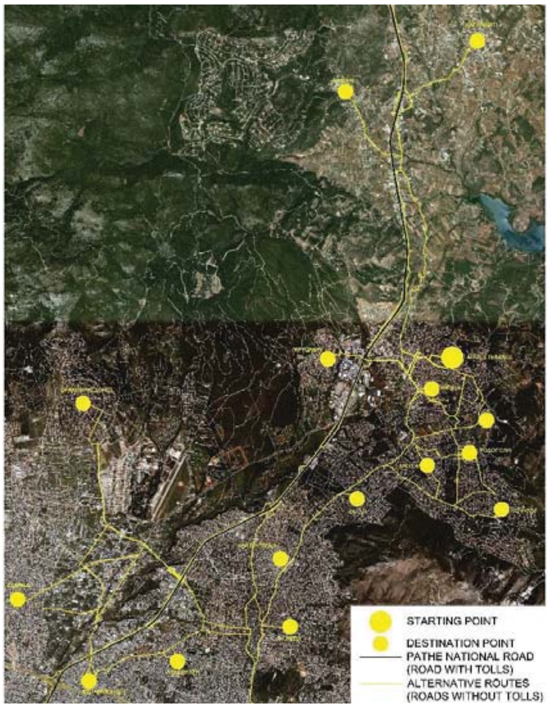
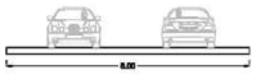


Fig. 5: Alternatives to PATHE, starting from Ag. Stefanos [25]



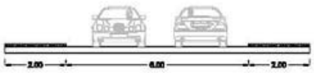


Fig. 6: Examples of cross sections [25]

D.Simulation model

As part of the study was to investigate and assess the dynamic effects of road charging to the neighboring local road network, a simulation model was applied in the network of Northeast Attica. The aim of the model is to study and analyze travels and export qualitative and quantitative characteristics. Traffic volume forecast and, therefore, the revenue of concession projects for the total of supra-local travels, are based on the 2002 study of the consortium Steer Davies Gleave – NAMA – SALFO [26]. The installation of tolls aimed mainly at the increase of revenue for the motorway and the key assumptions and data included:

- Travel time value and operational cost
- Highway traffic volume forecasts, based on the evolution of GDP and car ownership ratio.
- Travel time value was considered to be increasing for a ½ of the GDP growth per year.
- The vehicle operating cost is assumed to remain constant.
- The Origin- Destination table [23]

Motorway diversion rate, after the implementation of the toll system, is calculated as follows:
Distribution of traffic flow is applied in the current situation (toll-free highway) and future condition (after the toll implementation), while origin and destination route choices include areas within the overall study zone. Traffic loads for all cases are registered in all studied segments and the percentage of the diversion rate is calculated as the excess amount between the two.

Table 2: Daily Vehicle Trips [25]

TABLE II
DAILY VEHICLE TRIPS

Time	% Daily Vehicle Trips
0	0.7
1	0.2
2	0.8
3	0.1
4	0.1
5	1
6	3.2
7	8.9
8	4.1
9	3.2
10	3.9
11	4.1
12	5.2
13	4.8
14	4.9
15	6.7
16	9.3
17	8.5
18	6.4
19	7.9
20	5.9
21	4.8
22	3.2
23	2.1

Travel time value:
In the case of this study area time value is not examined as an objective type value, but rather as a subjective element reflecting the possibility of users who are willing to pay the toll fee and the subjective assessment of parameters such road safety conditions, reliability of travel time, etc. The travel time value range is determined up to 12,18 and 24 euros / hour.

Cost of driving:
The cost of driving includes both fuel costs and the cost of maintenance (damage, repairs, insurance depreciation etc). Fuel cost depend highly on the speed, calculated according to the British method using the formula (1):

$$L = K(a + b.v + c.v2 + d.v3) / v \quad (1)$$

Where v=speed, L=liters per km and a,b,c,d,κ = 2260.649, 70.18338, 0.292632, 0.00302, 0.04197. Values of the listed parameters refer to a typical passenger car engine class EURO 3, with 1400 cc, representing the medium standard of the vehicle fleet. The average speed (door-to-door) is considered to be 40km/hour. So, the average driving cost per kilometer is 0.09 euros (if the average fuel cost is 1,5 euros per liter).

Air pollutant emissions:

The difference in emissions from car diversion (from the toll way to the local network) is similarly calculated according to the British method using the formula (2):

$$y = k * (a + bx + cx2 + dx3 + ex4 + fx5 + gx6)/x \quad (2)$$

where x=speed, y=emissions (gr/km) and a,b,c,d,e,f,g rates that vary by type.

Implementing the described model leads to the following results regarding the percentages of car diversion to the local network.

Table 3: Car diversion to the local network [25]

TABLE III
CAR DIVERSION TO THE LOCAL NETWORK

Municipality	Travel Time Value (Euro/hour)		
	12	18	24
Krioneri	49.0	30.4	15.1
Agios Stefanos	53.8	46.9	41.3
Anixi	65.6	34.2	22.5
Stamata	71.0	49.2	29.7
Rodopoli	90.7	72.9	62.1
Drosia	94.5	77.9	71.0
Dionysos	94.8	77.3	69.8

Elaboration of results has shown two key findings: 1) The lower the travel time value, the greater the diversion rate from the motorway and 2) The larger the distance from the motorway, (ie. The dependence on this), the greater the diversion rate.

Evidently, the impact on the studied reference network will not be uniform. There will be reduced congestion on certain road segments (especially those leading to the highway) whereas there will be an increase in alternative parallel routes (see Fig. 7).

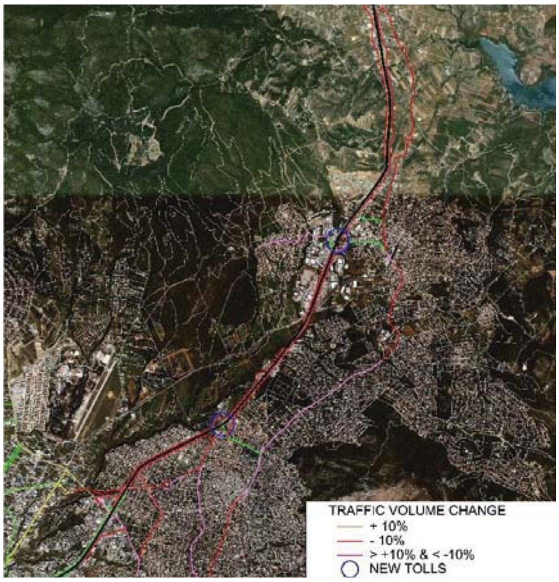


Fig. 7: Traffic Volume change [25]

Emissions vary depending on the diversion rate of traffic load. The total impact (increase) will vary spatially depending on the increase or decrease of the load and movement speed on each road segment. For the travel time value of 18 euros/hour, NOX pollutant distribution is shown on Fig. 8. The increase (in percentage) is generally higher than the reduction rate, caused by the low speeds due to the additional charging of the local network.

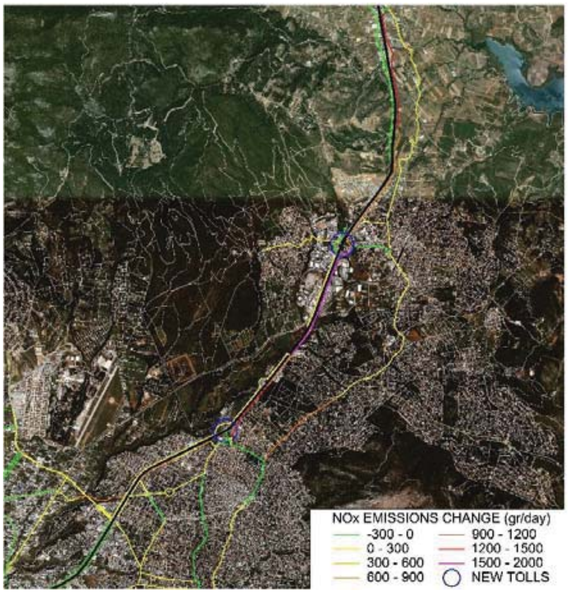


Fig. 8: NOx Emissions change [25]

V. IDENTIFICATION OF INEFFICIENCIES AND CONCLUSIONS

Charging road usage could benefit and relieve congestion as well as improve the quality of life in metropolitan areas, if applied in a way that driving cost would include the cost of strains and congestion caused to other travelers. Such regulations would lead to reduced travel demand and thus reduction of bottlenecks, as travelers would rather choose not to conduct specific trips or change transportation means. In the case of PATHE road, the imposition of congestion charging would reduce congestion in particular segments, however part of the traffic will be channeled to local roads within the study area. Travel behavior change due to toll implementation, may include several other elements related to the various urban and transportation characteristics of the area as well as the trip purpose and time availability. Indeed, the dominant expected behavior is highly linked to local diversion phenomena.

The charges imposed for the entrance to a particular area, combined to the non-charging for the entrance to a neighboring one, may result in the reallocation of activities and hence the re-establishment of focal points, transferring the issue rather than solving it.

The urban planning implications from the toll operation and traffic diversion to the local urban street network may include:

- The strengthening of current discontinuity in the urban fabric
- Change in land uses, removal of housing and intensification other incompatible land uses highly dependent on vehicle use
- Increased pressure for allocation of uses related to car accommodation (ie. car parking, new roads, etc.).

Moreover, the increased local traffic is expected to lead to higher accident rates although accessibility and traffic safety will be increased on specific neighboring zones. Car accessibility will be improved and travelers with high travel time value will prefer to bypass local networks and use the toll-way. On the other hand, travelers seeking to avoid the tolls will either use the local network or plan to use public transportation. The study area is poorly equipped with public transport means, hence this choice will lead to an immediate increase in travel time.

Roads' and travelers' justice call equal rights and obligations, therefore each traveler should be able to cover his marginal external cost involved. However, covering the marginal external cost demands specific predetermined monetary exchange, resources that may increase inequality for travelers in daily basis.

Adopting and reassuring the principle of justice in the transport sector is a highly perplexing subject in the urban discourse, whether it refers to metropolitan areas or regional centralities. Congestion charging as a method is intended to raise revenue and reduce peak hour traffic volumes to optimal levels. The overall strategy for toll operation though, should account the effects of such an imposition in the neighboring local networks –if any- and provide alternatives as well as include critical interventions and regulations to ensure traffic safety, alter or maintain travel and consumption patterns and lastly ensure optimal public acceptance.

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