

**Managing traffic on Urban Limited Access Facilities.
Ingress through tolling and egress to large scale generators as keys to relieve congestion.
The case of Attica Tollway in Athens, Greece.**

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Abstract

Attica Tollway constitutes the ring road of Athens, extending along 70 km, enabling quicker access to areas which, until recently, were either unapproachable or required a great amount of travel time. Entry to the Attica Tollway is gained via toll plazas located at the extremities of the freeway and at each entry on-ramp. Attica Tollway constitutes a road axis connecting numerous municipalities of the Attica basin and meeting the transportation needs of millions of people, on an annual basis.

Attica Tollway was designed and constructed in such a way in order to provide an alternative solution to the congested urban network of Athens without providing disturbance to the surrounding areas. This principle is based mainly to its design that's comprises of 39 entry points and the potential provision of another three at three critical areas for future development.

The Tollway has exceeded traffic forecasts in terms of expectations of demand. The reason is that Attica Tollway has produced significant improvements to traffic conditions in the metropolitan area. On the other hand, Attica Tollway faces congestion problems especially in its central section. Taking into account the frequent and closely spaced interchanges, management of entry points can produce significant advantages to the traffic conditions of the motorway. How about constructing direct exits (not entries) directly onto the large traffic generators abutting the highway? Would ramp metering in conjunction with provision of additional exits relieve congestion?

1. Introduction

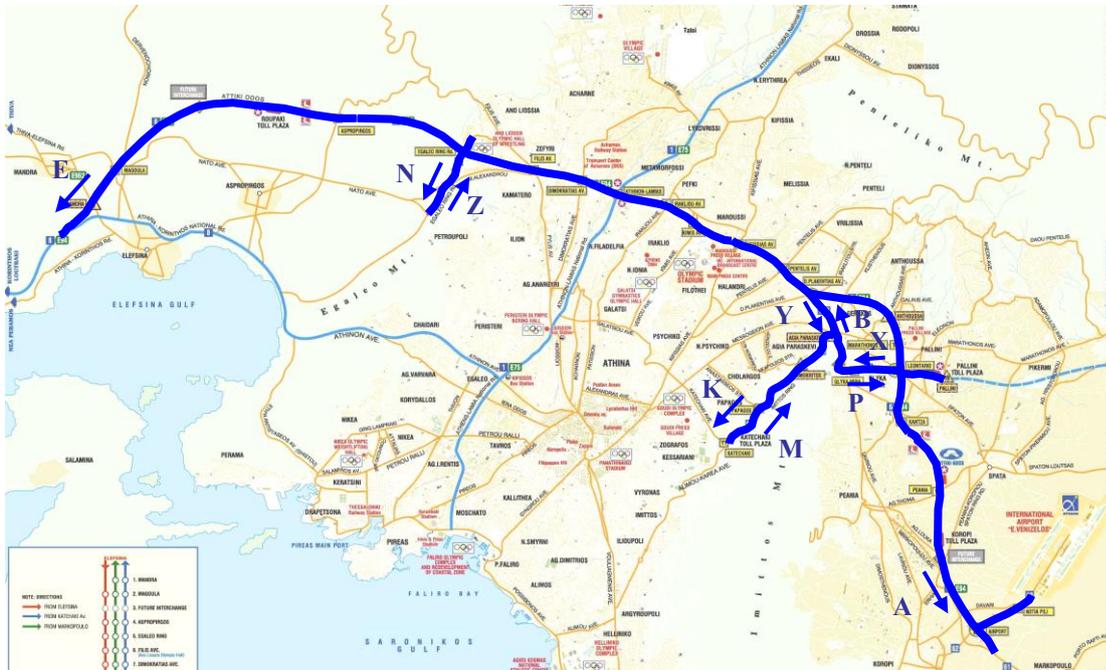
Attica Tollway is the Athens ring road providing decongestion of the city centre and its radial routes. It provides link of the national motorway network and access to the new Athens International Airport. It is part of the general transportation plan for the development of the Greater Athens transportation system. It also provides connections with mass transport mode facilities (Metro, Suburban Rail, and Buses).

Attica Tollway is an urban motorway with tolls, of two directionally separated carriageways each consisting of 3 lanes and an emergency lane (hard shoulder). The suburban railway of Athens has been constructed in central reservation of the motorway. By being a closed motorway, it has full control of its access points and consists of three sections, as follows:

- The Elefsina – Stavros – Spata A/P motorway (ESSM), extending along approximately 51 km,

- The Imittos Western Peripheral Motorway (IWPM), extending along approximately 14 km, and
- The Egaleo Western Peripheral Motorway (EWPM) extending along approximately 5 km.

Figure 1: Map of Attica Tollway



The major technical characteristics of the motorway can be summarized as follows:

Table 1: Major Technical Characteristics of Attica Tollway

<i>Project features</i>	<i>Value</i>
Total length	70 km.
Service / side roads network	150 km
Interchanges	29
Roadway bridges / Overpasses	100
Roadway bridges / Underpasses	25
Railroad bridges	38
Stream bridges	21
Pedestrian Overpasses	12
Tunnels / Cut & Cover Sections	56
Total length of Tunnels and Cut & Cover Sections	15.36 km
Toll Stations	39
Total number of toll lanes	195
Electronic toll lanes	54
Mixed toll lanes with toll collectors	139

The idea of building a freeway dates back to 1963, when Wilbur Smith came from the United States to undertake the first ever regional traffic planning study for the city of Athens and its metropolitan area.

Sprawling development to the north of Athens over the years, the decision in the late 70's to build the new airport in its present location at Mesogeia and the decision to build a city connector road along the foothills of the Mountain of Imittos in the early 90's departed from the concept of a "ring" road, and transformed Attica Tollway into an urban freeway that serves the heart of the city. It was only in the early 90's that the Greek Ministry of Public Works adopted the method of co-financing the road through a Build-Operate-Transfer contract. (Kitsos, 2008).

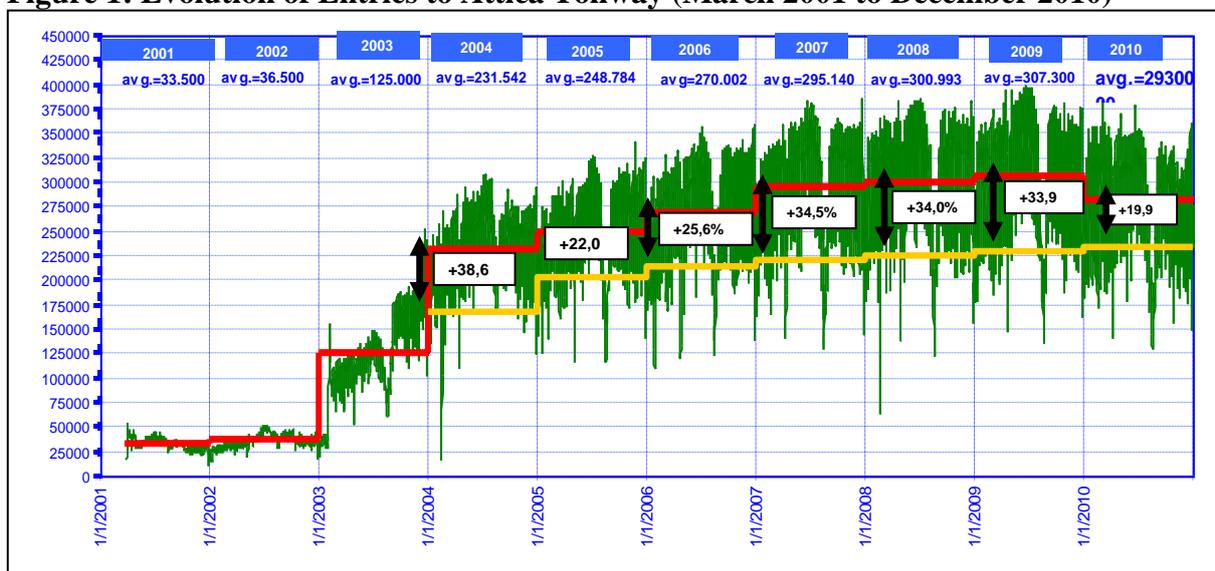
The construction was started in 1997 and the motorway was given to traffic in sections, it finally completed seven years later in 2004. Attica Tollway was built on time and on budget and it met the crucial deadline for the Athens Olympics Games 2004.

Attica Tollway played a critical role to the development of urban and land use planning requirements of the metropolitan area of Athens. The presence of Attica Tollway impelled significantly the development of Mesogeia (east boroughs of the metropolitan area) since it provided a direct link to these areas with the centre of Athens.

2. Traffic Characteristics of Attica Tollway

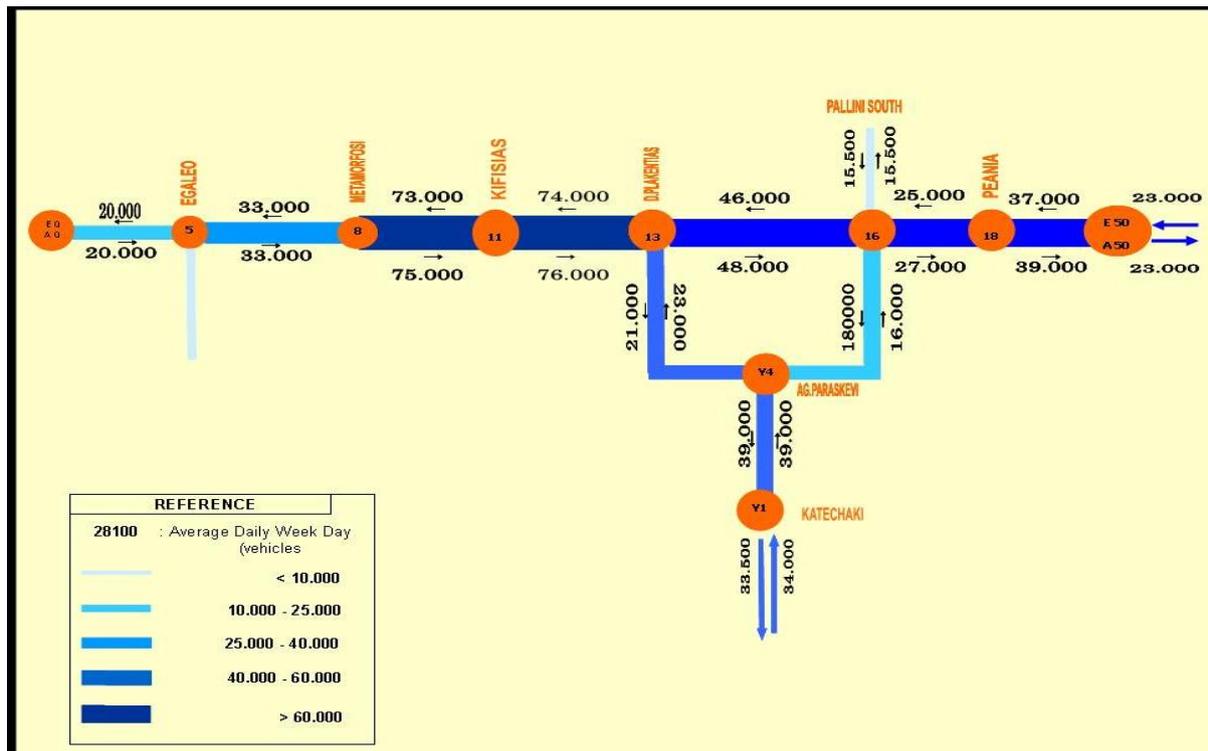
The Tollway has exceeded traffic forecasts in terms of expectations of demand. The reason is that Attica Tollway has produced significant improvements to traffic conditions in the metropolitan area. The graph below illustrates the evolution of the entries to the Attica Tollway from the beginning of its operation in March 2001 until December 2010. Additionally, the projected entries in comparison to the actual ones are shown.

Figure 1: Evolution of Entries to Attica Tollway (March 2001 to December 2010)



Attica Tollway faces congestion problems especially in its central section. Looking in more detail the traffic volumes of the central section, the average daily weekday flow is about 75,000 vehicles per direction (referring to a three lane segment). The daily traffic volumes of Attica Tollway per section and per directions are presented in the Figure 2.

Figure 2 Annual Average Daily Traffic per direction for year 2010



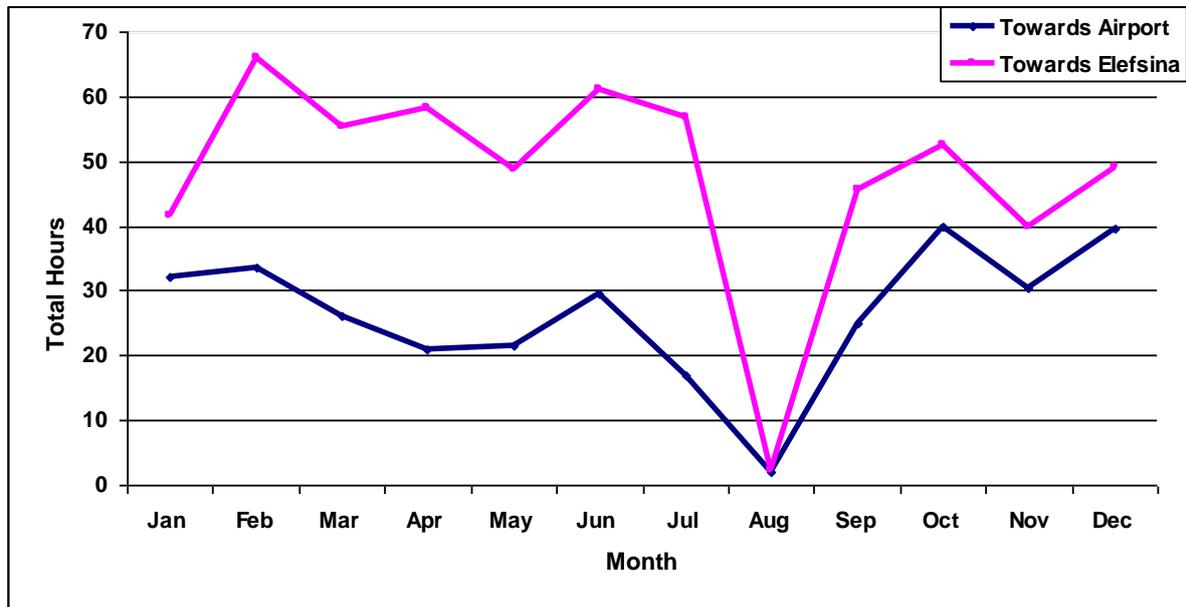
The issues of traffic congestion and bottlenecks are intimately familiar to freeway and tollway agencies in metropolitan areas. Basically a freeway bottleneck is characterized by congestion with queues upstream and freely flowing traffic downstream. Typical characteristics of a bottleneck include location, time of activation, duration of impact to traffic flow, and severity of impact to traffic flow. (Chen ,2004).

A definition of congestion involves elevated density (detector occupancy above 30%) and low speed, usually under 30 mph (or 48kmh), although speeds in the range between 40 and 60 mph (64kmh to 96kmh) are indicative of congestion, if speed downstream the bottleneck is clearly above 60 mph and detector occupancy is at or below 10%.(Walters, 2005).

Recurrent congestion is generally the consequence of factors that act regularly or periodically on the transportation system, such as daily commuting or weekend trips. However, even recurrent congestion can display a large degree of randomness, especially in its duration and severity. Non-recurrent congestion is the effect of unexpected, unplanned or large events (e.g. road works, crashes, special events and so on) that affect parts of the transportation system more or less randomly and, as such, cannot be easily predicted. The share of non-recurrent congestion varies from road network to road network and is linked to the presence and effectiveness of incident response strategies, roadwork scheduling and prevailing atmospheric conditions (snow, rain, fog, etc.). (OECD, 2007).

Studying the speed characteristics of the central section of Attica Tollway, the occurrence of speeds ranging between 40 and 60 mph (64kmh to 96kmh) is very common. The Figure 3 below presents the number of hours with average speed below 50mph (80kph) separately for the two directions of the motorway.

Figure 3: Central Section: Number of hours with average speed <80kph (Average values for years 2008, 2009 and 2010)



As presented above, for all the months of the year (excluding August which is considered as the month of vacations) the number of hours with average speed less than 80 kph (for the direction towards Elefsina) ranges between 40 and 65. Therefore, for at least 2 hours for weekdays the central section of the westbound direction of motorway is saturated.

But in order to have a full and more precise picture of the congestion profile along Attica Tollway, it is important to define the locations with the highest frequency of delays. Table 2 that follows presents the three locations along the motorway with the majority of delays for significant period of time (three years of recent operation). All of locations are located in the direction towards Elefsina.

Table 2: Locations of Attica Tollway with the highest frequency of recurrent congestion for a three years period (2008-2009-2010)

Location of Attica Tollway	Time Period	Days with Queues (for 3 years)	Avg Extent of Queues (Km)	Avg Delay (veh-hrs)	Avg Duration (mins)
E23.7 km	Morning Peak	229	9,444	115,274	64,74
E26.7 km	Morning Peak	135	6,719	56,458	54,15
E29.6 km	Morning Peak	354	4,771	40,418	36,85
E26.7 km	Afternoon Peak	131	6,470	104,421	69,66
E23.7 km	Afternoon Peak	79	7,748	112,108	73,42

Source: PeMs

The location with the highest frequency of delays is found in the Vrillissia tunnel between Douk. Plakentias I/C 13 and Pentelis I/C 12. (Chainage E29.6). About 120 working days per

year an average queue of 4.8 km upstream is created during the morning peak (usually between 8am and 9 am).

Frequent queues are created at the connection of Attica Tollway with Athens-Lamia National Road at Metamorfossi I/C (Chainage E23,7). About 70 days per year an average queue of 9.4 km is created during the morning peak. This location presents queues also during the afternoon peak but in a less frequent pattern (about 26 days per year).

Another section that presents congestion frequently is the segment between Kifissias I/C 11 and Kymis I/C 10. The frequency of queues at this location throughout the year is the same for both the morning and afternoon peak

It should be noted that the three mentioned locations succeed each other. Therefore the morning queue created at E23.7 with length of 9.4km passes through E26.7km and through E29.7km. Respectively, the afternoon queue created at E23.7km with an average length of 7,7km passes through again E26.7km. Summarizing, the above mentioned delays are interlinked to each other since and the impact of congestion affect a significant segment of the motorway.

4. Investigate the causes of bottlenecks in Attica Tollway

It is critical to investigate the causes of recurring bottlenecks. From the literature, there is a long list of causes of recurring bottlenecks, including underlying characteristics that affect demand, capacity or both:

1. Regional or local growth affects demand on either the mainline and/or the on-ramps.
2. Regional or local development patterns may affect the growth in heavy vehicles, which, in turn affects both demand (increase) and capacity (reduction).
3. Geometric features have a direct impact on capacity. Generally, narrow or minimal shoulders, narrow lanes, tunnels, tall retaining walls, bridge guardrails or other lateral obstructions, lengthy uphill grades, and horizontal curves with sight distance restrictions tend to reduce capacity, directly or by reducing the prevailing free flow speed. In addition, lane drops reduce capacity directly, and reduced speed limits affect capacity via a reduction in average speeds.
4. Bottlenecks in several metropolitan areas arise at the neighborhood of the connection between older (narrower, or otherwise substandard by current standards) freeway sections with newer freeway expansions.
5. A special class of freeway geometry is weaving sections, the capacity of which is affected by both the type (design) of the weave, the available lengths and the number of lane-changing maneuvers. (Banks, 2002)

Considering the central section of Attica Tollway, local growth beyond expectations in the area of Mesogeia during the decades of 1990's and 2000's have considerable impact on the high volumes of the direction towards Elefsina especially during the morning peak. Long tunnel, lane drop and tall retaining walls are also present and they also affect negatively the capacity of the segment.

In addition, as mentioned above, the connection of Attica Tollway with the National Road of Athens is a typical location of creation of queues. It is a typical form of connection between older (substandard by current standards) freeway with newer and higher standards freeway.

Moreover, bottlenecks are not always recurring. The list of causes of non-recurring bottlenecks includes multi-vehicle collisions, single vehicle crashes, disabled vehicles, debris on the pavement, spillage of fluids or cargo, presence of police, cleaning, maintenance, or landscaping crews working on the shoulder or berms, lane closures for a variety of reasons ranging from temporary closure for maintenance to long-term closures for construction, special events, and weather phenomena. (Banks, 2002)

5. Finding the Keys to relieve congestion

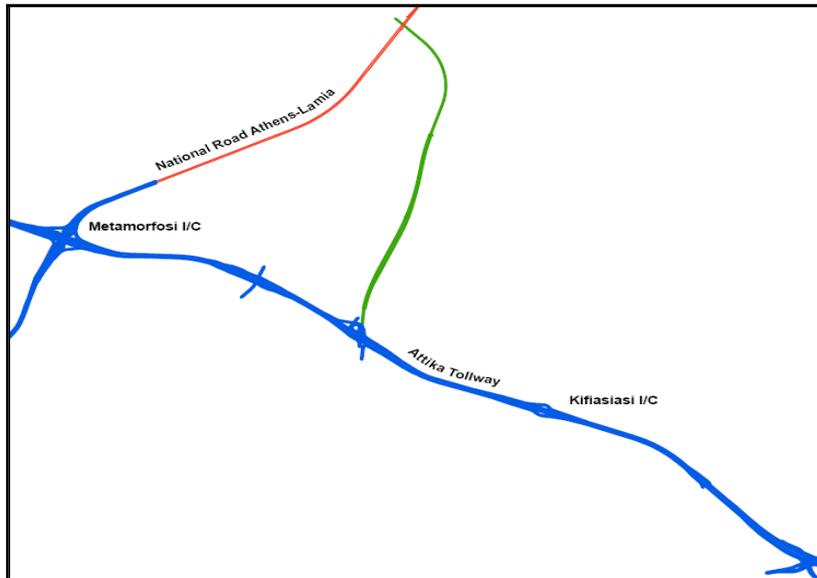
Taking into account the frequent and closely spaced interchanges, management of entry points can produce significant advantages to the traffic conditions of the motorway. Ramp metering is the most typical form of entry management. Basically, ramp meter systems work by allowing one driver to pass through the green light at a time creating a 5-15 second delay between cars. This will then help merge traffic together and decrease the amount of potential accidents that may occur during merging traffic. (Gardes, 2002).

This method has proved to be successful in causing fewer accidents than if a ramp metering system was not in place. Ramp metering systems also run at designated times during the day when the traffic is at its most congested. Ramp metering systems are located all across the United States and Europe. Countless studies have shown the decrease in highway and on-ramp accidents with the use of ramp metering systems installed all across the United States and Europe.

In Attica Tollway, access is gained via toll lanes. As a consequence drivers are slowing to pay their tolls in both manual and automatic toll lanes. The delay created by toll lanes ranges close to the levels of the typical ramp metering applications with traffic lights. In order to achieve the level of delay of traffic lights, toll lanes providing access to saturated central sections at Vrillisa tunnel and Kifissias-Kimis segment could reduce the level of service and generate traffic flows in a lower rate.

Another option to tackle congestion is the construction of direct exits (without relevant entries) directly onto to a major traffic generators (such as a major sporting venue, an university or a shopping mall etc) abutting the motorway. (Prevedouros, 2003). Evaluating the current situation in Attica Tollway, the construction of an axis connecting directly Attica Tollway and National Road of Athens- Lamia via Kimis I/C will act as a direct exit to a major traffic generators (in our case National Road) over passing the saturated section of Attica Tollway and enhancing the traffic conditions at Metamorfossi I/C.

Figure 4: Proposed axis connecting Attica Tollway to National Rd via Kimis (I/C)

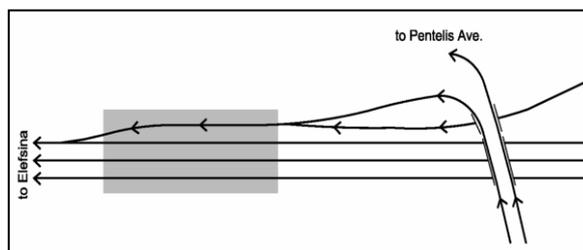


In conclusion, the successful relief of congestion should incorporate ramp metering in conjunction with provision of additional exits. Large exits are not capable to control large entry flows if the mainline has its own bottlenecks such as Vrilisia tunnel from 5 to 3 lanes

6. Implemented congestion relief measure

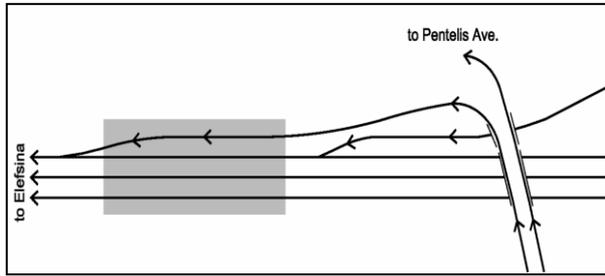
A significant congestion relief measure was implemented at the congested freeway to freeway merge of M and B onto E on the Attica Tollway (see Figure 1), where the situation was exacerbated by the presence of a busy on-ramp also merging in the vicinity of the freeway merge. A number of alternative scenarios were examined. Most applicable bottleneck resolution measures were analyzed including ramp closure, ramp metering, on-ramp with two narrow lanes, mainline narrowing (to provide a open lane for the on-ramp,) and re-direction of the on-ramp from merging onto B to merging onto E. The latter scenario provided good results and was feasible. (Halkias et al, 2007).

Figure 5: Initial (before) traffic lane arrangement



Having obtained reliable base case models, alternative scenarios were analyzed and a set of intermediate results were obtained. From these, the decision of the most preferred alternative was made, which is turn was simulated with more detailed adjustments and growth scenarios after a preliminary engineering study which addressed detail geometrics and physical implementation issues. The implemented traffic lane arrangement is presented in Figure 6.

Figure 6: Final (after) traffic lane arrangement



In conclusion, after almost 5 years of operation the implemented solution proved successful and queues are occurring at the merge of two freeways.

7. Conclusions

Attica Tollway played a critical role to the development of urban and land use planning requirements of the metropolitan area of Athens. The presence of Attica Tollway impelled significantly the development of east boroughs of the metropolitan area since it provided a direct link to these areas with the centre of Athens. The Tollway has exceeded traffic forecasts in terms of expectations of demand. The reason is that Attica Tollway has produced significant improvements to traffic conditions in the metropolitan area.

As a result of these higher traffic volumes than the ones anticipated, Attica Tollway faces congestion problems in its central section especially at the westbound direction. The management of entry points can produce some advantages to the traffic conditions of the motorway considering the fact of frequent and closely spaced interchanges along the motorway.

But in order to achieve significant relief of congestion, management of entries should be implemented in conjunction with other measures such as provision of direct exits to large traffic generators (such as a major sporting venue, an university or a shopping mall etc) abutting the motorway.

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