RAMP Metering Analysis

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***Abstract* – The great number of automobiles that are entering the freeways can cause intensification of the traffic which leads to congestions, traffic accidents, higher fuel consumption and CO2 emission in the atmosphere. This brings the need of managing the traffic flow through ramp metering of the vehicles which are trying to join the freeways in order to maintain the traffic flow.**

***Keywords* – *T*raffic, metering, algorithm, freeway, ramp.**

I. INTRODUCTION

The freeways that are connecting the urban areas are faced with congestions in the traffic flow operating at the limit of their capacity when the number of vehicles that are joining is rapidly growing in different periods of the day.

The main reasons for the congestions and traffic disturbances most frequently are accidents, queues of vehicles that are entering the freeway, bottlenecks, small capacity of the roads, growth of the vehicles number over the years and construction works on the freeways.

These occurrences are having negative impact on the traffic flow which brings the freeways to operate on their upper limit of capacity. As a result it leads to traffic congestions and greater time of travel accompanied with more travel costs.

II. THE PROCESS OF RAMP METERING

The metering of the traffic represents a technique of using traffic signs on the access lanes of the freeways in order to manage the number of vehicles entering on the main road. The purpose of this technique is to maintain balance between the demand and supply on the freeways and to enable the normal traffic flow and to avoid interruptions.

The traffic disorder can be classified as predictable and nonpredictable .congestions. The predictable are appearing in particular time periods such as the spillover of the traffic on the local roads, bottlenecks, the difference of the number of vehicles that are entering and leaving the freeway and the occurrence of platoons of entering vehicles. The unpredictable congestions are occurring as a result of temporal traffic flow reductions and traffic accidents. With the use of ramp metering systems the number of vehicles is controlled avoiding the situations of building platoons of vehicles over their segmenting and forcing the drivers for waiting on the ramp for the right moment to enter the freeway.

The purpose of this mechanism for regulation of the traffic flow is to provide normal traffic flow and to avoid the reaching of the peak of the road capacity which can bring to total collapse of the traffic [1]. The solution is found in the use of ramps (Fig. 1) on the access lanes on the freeways where the vehicle will have to wait some amount of time before they can enter the freeway.

The control of the flow on the ramp is regulated with fixed time periods or with flexible time periods which are determined from the condition of the freeway in the moment and the needs of the traffic.

The ramp metering control is considered for one of the most effective ways to manage the traffic flow. This mechanism is representing a strategy for maintaining the effectiveness of the traffic and to maintain the number of vehicles that are using the freeway under maximum capacity [2]. The ramp metering decreases the chances that traffic accidents will appear. The light signals are placed on the entrance of the lanes which are passing through the vehicles in accordance with the used cycle and number of vehicles. This system discourages the drivers to use the freeway for short trips leaving more space for the drivers that are already in the flow of the road and that are traveling on long distances.

The ramp metering management uses different types of algorithms which take real time measured variables detected from various detectors in order to get the results and reach the efficiency that is needed.

The technique of ramp metering is used in various cities in the world. For the first time it has been used in the United States in the 50ies and 60ies of the 20th Century.

III. SYSTEM COMPONENTS

The system of ramp metering consists of several components which are part of a larger architecture:

-*Signalization and controllers*- The signalization is usually placed on the left side of the vehicles or on both sides. The controller is programmed under certain algorithm which controls the access and the metering of the vehicles. The components of the system shown on Fig. 1 are the following:

-*Detector of demand*- this detector is located before the regulating system. It reports the controller that a vehicle is approaching on the ramp and sets the green interval for passing through.

-*Pass through detector*- it is located after the signal for regulating and metering. This detector informs the controller that an vehicles has passed by the ramp which should turn on the red interval which does not pass through any vehicles on the freeway.

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-*Merging detector*- the function of this detector is to sense the presence of any vehicles on the traffic merging point. Before the vehicles gets the merging point the signal is red and after the vehicle has entered the point, the interval is set to green.

-*Queue detector*- the detector is located on the ramp of the system. This detector disables the spillover of the traffic congestion on the regional and access roads. If there is a possibility for this then the degree of metering is reduced.

-*Main flow detectors*- The detectors o the main traffic flow are located before and after the area of merging the highway traffic [3] and the access lane on which the metering is performed. These detectors are signaling the condition the traffic flow and the need traffic regulating. This detector uses the technique of occupancy measurement of the road and the information about the vehicles speed.

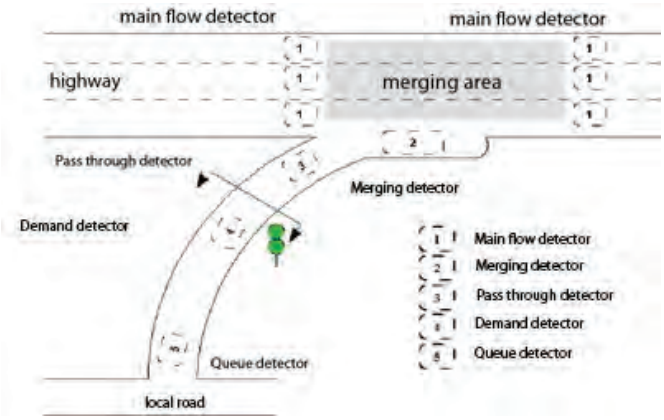

Fig. 1 Components of the Ramp Metering

IV. TYPES OF RAMP METERING SYSTEMS

There are many strategies and types of ramp metering systems which are used in depending the needs and traffic conditions. They can be based on fixed time of action which is coordinated by previous gathered data about the traffic flow or by some simulated predictions.
The strategies can be implemented locally or in one global system. There are mainly three types of ramp metering systems:

-*Systems with fixed operating time*- these systems are the most simple for construction and installation of all types. Their function is to scatter the platoons of vehicles which are entering the freeway. The used technology is very simple and the whole system is not very expensive because there is no central managing system. The system cannot withstand the congestions caused by time factor and traffic accidents. This strategy is implemented on easily predictable situations in cases of road construction sites.

-*System with local operation based on feedback information*- this type of system for ramp metering is operating based on controllers and algorithms which are adjusting the degree of metering over analysis of the road occupancy and the traffic flow. The data is gathered by the detectors on the main highway flow [4]. This kind of systems is more expensive but they are capable to perform very well on unpredictable traffic changes. Sometimes this kind of system is set as backup when the main ramp metering system has failed. The costs are higher because there is need for additional placement of detectors which from other side are justified by the adaptability of the system and the better results compared to the system for fixed ramp metering.

-*Systems with global operation based on feedback information* -is type of ramp metering systems which aims to improve the traffic management over several ramps for metering in order to avoid congestions and bottlenecks. The structure of the system introduces metering doses on a ramp that are influenced by the conditions on the other ramps on the highway or particular part or corridor. Similar to the systems with local operation, the data is collected from various detectors on the ramp and from number of local detectors along the highway controlled by the system. The regulating os performed over central computer which is controlling the ramps. This kind of systems enables full control of different part of the traffic network from one center.. the systems can perform very strong metering at the particular segment of the highway where the traffic accident has occurred. This kind of configuration needs larger technical capacity which can operate and interconnect the detectors and the control center.

V. OPERATIONAL FACTORS

-*The distance between he place of metering and the place of traffic merging*
The vehicles are accessing the highway with different speed of movement. It is found that the vehicles needs a speed of about 60 km/h in order to perform smooth merging of the traffic in the ramp with the traffic on the highway. The distance to the merging point increases with the raising of the speed of merging and the degree of ramp metering.

-*Safe distance to stop and align*
The distance is limited by the construction of the system, the location of the signal and the detectors. The researches have recommended detector of the queue should be placed on a distance of 250 [5] feet after the merging in order to improve save braking behind the queue that is forming on the ramp. Basing on this information there is a generalized model for determining the queries for aligning of the vehicles on the ramp:

$$L = 0{,}820V - 0.002435V^2 \quad (1)$$

Where L is the total distance needed from the queue detector in meters, V is the expected value during the peak in vehicles per hour (vph).The distance for a ramp serving 900 vehicles (vph) and the required distance is about 541 fees.

-*The space on the ramp depending on the time of service*

The available space on the ramp should be long enough to obtain reasonable time of service during peak time and to provide high degree of metering.
The time that one vehicle is spending on the ramp S, depends on the length of the queue and the time of services T_s which is the time of one cycle. Therefore:

$$S = E(n) \times T_s = \frac{L(ft)}{25(ft/veh)} \times \frac{60(\min/hr)}{M(vphpl)} = 2.4 \frac{L(ft)}{M(vphpl)} \quad (2)$$

where:

$S =$ time of service on the ramp over one lane in minutes.

$E(n) =$ expected number of vehicles in the queue when the length is L in vehicles.

$L =$ length of the queue in feet

$M =$ degree of metering of vehicles in hour by lane (vphpl)

VI. ALINEA ALGORITHM

Asservissement Linéaire d'Entrée Auotroutière (ALINEA), is an algorithm which is used by the strategies for ramp metering on local base. It is represented in the late 80ies of the 20th century by Papageorgiu. This algorithm is implemented in several European cities like Paris, Munich, and Amsterdam. As a process that is considered is the traffic flow and the degree of metering is acting as control variable. This algorithm is based on the theory of control of feedback information where the algorithm is aims to maintain ramp metering on the freeway which will not exceed the capacity of the highway. For every time interval the algorithm is implementing the following formula [6] for the degree of ramp metering :

$$\left[r(k) = r(k-1) \pm K_R \{o_c - o_{out}(k)\}\right] \quad (3)$$

where:

$r(k) =$ metering value in the interval k

$K_R =$ variable parameter (weight factor) >0

$o_{out} =$ local occupancy of the ramp (measured by the detector on the main flow)

$o_c =$ predefined value of occupancy on the ramp capacity (the desired maximum capacity)

The algorithm is using the difference between the values of the occupancy or the desired occupancy compared to the measured occupancy. One of the characteristics of this algorithm is the possibility to insert the values of ramp metering from previous time periods.

VII. SIGNALISATION

The traffic signalization is placed on the ramps usually in two levels. The distance from the point of merging with the main traffic where the signalization is placed should be large enough to enable vehicle acceleration to a speed that is enough to perform smooth merge to the traffic flow. In some cases the light signals that are used are identical with the traffic lights placed on the intersections and in some other cases there is a special signalization for this purposes with ability to show more complex messages to the drivers.

VIII. DETECTORS

The devices that supply the system with data are the detectors which can be divided in to two groups. There are detectors on the main stream of the traffic flow and detectors which are placed on the ramp for metering. Particular highways are using detectors placed on the main stream on 500m distance between them and in other cases we have additional equipment that is making evaluation for the position of the detectors according to the traffic situation. It is important to point that the position of the detectors is set mainly by the algorithm that is used in the system of ramp metering.

IX. EVALUATION OF RAMP METERING SYSTEMS

The evaluation of ramp metering systems is done based on data gathered from realworld experiments or simulations [7]. In the particular case the data are obtained from the Paris highway network which is facing large congestions in the morning peak hours. In the first case there are no metering ramps, then we have ramps with fixed metering which were used in the morning hours. Later they are changed in a experiment which introduced ramp metering system based on ALINEA algorithm where each ramp acts locally basing its service on the situation of the traffic flow.
The idea is to collect and evaluate the data in order to note the impact of different ramp metering systems and to check their effectiveness.
The variables that have been used are taken in 6 minutes intervals [8] and they contain the following data: The volume of the traffic measured in vehicles x km, the time spent on a highway section, the average speed, time of travel all measured in different time periods.

X. . APPLICATION FOR GRAPHICAL DATA ANALYSIS

In order to compare the data gathered from the ramp metering system we will use an application called "*RAMP METER DATA COMPARISON*" which is an.NET application that allows us to enter all the gathered data form an experiment or simulation over particular time period of the day. There are three main cases: without existing ramp metering system, with fixed ramp metering and with ramp

metering that uses the ALINEA algorithm. The graphic (Fig 2) represents one of the important measurement and meaningful data in this case that is the total travel time in all three cases.

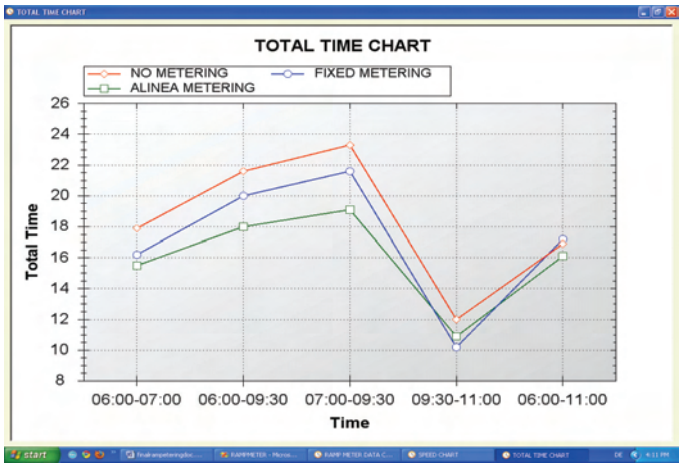

Fig. 2 time of traveling

XI. CONCLUSION

With the intensifying of the traffic and the number of vehicles it becomes necessary to manage the flow of the traffic. The large number of vehicles that are entering the fhighways is causing congestions and traffic accidents as a result of the irregular and dangerous traffic flow.

The use of ramp metering systems should reduce of the load on the highways which will lower the time of traveling and the costs of the trip. In many places in the world the ramp metering systems has been proved as the best solution for improving the traffic condition and avoiding congestions and queues [9]. This kind of systems could reduce the pollution of the air through avoiding frequent stop and go movements when congestions and queues occur.

With the process of regulating the highway access roads the number of platoon so vehicles that are accessing the main road especially in the morning peak hours will be reduced.

The data from the traffic condition are gathered, analyzed and inserted into different experiments and simulations. The simulation will show if the right metering system is chosen or another one will be more suited for implementation. Before the ramp metering systems can be enforced it is important to inspect the capacity and the needs of the traffic infrastructure. The investment in the traffic networks is very expensive so the right strategy should find the optimal solution for the traffic problems.

This is important to achieve the needed benefits and results form the ramp metering system with conduction of extensive analysis and experiments followed by the needed technology and capital which has to be well presented to the society and the authorities for supplying full support in the project implementation.

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