Centralized traffic management system as response to the effective realization of urban traffic fluency

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ABSTRACT
The paper is a form of mathematical description of the tool - a computer whose primary function is to manage liquidity through follow-up control of the traffic (in less than 1 second) to send signals to the drivers of management traffic light intersections of application is mentioned.
The purpose of this paper is to provide reliable knowledge in this area with particular emphasis on implementation of the criterion of maintaining traffic flow take account of any abnormalities that occur as a dynamic and random variables in the urban space.

KEYWORDS: intelligent transport system, IT

1. Introduction for ITS objectives

Conditioning economical and social aspects, each city wants to find solutions to organize the best circulation of people and merchandizes on the network of the metropolitan area.

But, what is the best solution and who to reach it?

40 or 30 years ago, the main objective was easy to understand, single and frequently oriented to make the traffic flow growing up and growing up again.

Today, ways of thinking the cities are different.
It’s impossible to cancel and forget private cars, but a bigger “place” is requested for pedestrians, bicycles, public transports and lower level of contamination.

Quality of life in the cities is now the main objective of the responsible of the cities.
Requiring different priorities in relation with each local strategy an I. T. System must be able to give answer to several aspects.

- Increase traffic flow in some dedicated places
- Control traffic flow
- Manage public transport priority
- Control the contamination’s levels
- Create and protect pedestrian’s or bicycle’s areas
- Increase the urban security
- Use traffic lights to manage speed
- Inform the citizens
- Help citizens during travel to park their cars
- Create alternative in the ways of “moving in the city”

A good solution is a solution able to apply and assume several solutions
2. Traffic management in metropolitan area (Complexity of the network and liquidity flow)

Traffic flow crossing the network of the city is like water inside a pipe. This network has to support conditions and rules. Physical and fixed parameters:
- Street size
- Intersections complexity and basic capacity

Irregular events:
- Dynamic evolution of traffic flow
- Perturbation and random events
- Incidents
- Each change on green time traffic light

Unforeseeable and permanents modifications of the network:
- Pressure on pipe
- Permanents new balances

Consequences:
Flow is not a regular one and traffic jams are the consequence of this irregularity and a frequently bad balance between offer (Physical capacity associated with green time) and demand (Traffic flow).

3. Measurement of efficiency or inefficiency

To make the evaluation of the efficiency or inefficiency of a network, traffic conditions and parameters, main criteria used are "travel time", "waiting or stop time" and "quantity of flow able to cross city or area.

Several research have been done to give an expression of one synthetic criterion, the "Delay" representing the losing time between a free circulation without stop, without red traffic lights and a real travel respecting rules and traffic conditions.

First approach:
- "May" Model considering free and regular arrivals
- Considering also a higher capacity than traffic flow in circulation

Figure 2 is representing the problem to be solved and in the red surface the value of this "Delay criterion".

"Arrivals" are considering regular on a line of traffic lights and "departures" are considering zero when the traffic light is red and constant to maximal capacity flow when the traffic light is green.

The expression of the Delay is like following:

\[ R = \frac{qr^2}{2(1 - y)} \]

Where \( y = \frac{q}{s} \)

- \( q \) - flow of arrivals
- \( w \) - maximal capacity flow of departure

Second approach:
- Loosing time within free movement
- "University of Bordeaux" Model considering managed arrivals by departure of precedent traffic light
- Taking in consideration loosing time for each beginning of green light

The figure 3 shows the representation of the new area for the Delay.

Within this approach the expression of the Delay is like following and depending of several cases in saturation conditions or not.

\[ R = N \text{Decal} + \frac{N(N + 1)}{2} \left( \frac{q_1 - q_2}{q_1q_2} \right) \]

\[ R = N(\text{Decal} + TR) - \frac{1}{2} \int_0^{TR} s(t) dt \]
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As following this criterion is used to evaluate the difference of efficiency between a fix approach and a dynamic solution to manage the traffic lights using a centralized and real time system.

4. Evaluation and evolution of “delay” in case of bad balance between offer and traffic flow

For this evaluation, the following definitions are taken.
- “Traffic flow”: Arrivals on traffic lights
- “Offer”: Instantaneous physical capacity and green time on traffic light

Using a simulation process on a reference network with individual rules for each vehicle, the objective is to evaluate the Delay and the quantity of traffic flow crossing the network in several characteristic conditions.

Each simulation is done using the same protocol.
- Empty network is the beginning condition
- 5 cycles are used to put the network in charge
- Evaluation done during 30 cycles

First evaluation
- Fix green times on traffic lights
- Regular arrivals on each entrance point of the network
- Evaluations of the Delay and traffic flow moving the balance between arrivals quantities and green time allocated on each traffic light creating, step by step, a stronger difference within the optimized balance.

The Delay is growing up very quickly until reach 328,88% when green times on traffic lights are 8 seconds far away the best balance in relation with traffic flow (Fig. 4.).

Using the same process of simulation and at the same time, traffic flow crossing the area is decreasing until it reaches -29,44% when green times on traffic lights are 8 seconds far away the best balance in relation with traffic flow (Fig. 5.).

Those results show a strong sensibility of the efficiency of the network to bad parameters on green times for traffic lights.

Taking in consideration that traffic conditions are never regular and that the operational capacity of the network are permanently changing, those results show also the necessity to use a process able to adjust the parameters and green times with the best precision and speed in relation with the real conditions.

5. Centralized and Real Time I.T. System to react efficiently to the dynamic and random events within network and traffic flow

The GERTRUDE I.T. System is developed to be able to react instantaneously to the traffic conditions evolutions and to maintain the best balance between traffic flow and parameter’s regulation as frequently as possible.
The GERTRUDE I.T. System is able to apply the following process, one time per each second.

- 1 - Manage the acquisition of data from all sensors
- 2 - Data’s analyze and building of synthetic variables
- 3 - Define and calculate the best setting of regulation
- 4 - Send individual orders to the traffic light to be immediately executed by the controllers

Main objectives and functionalities
- Give an immediate answer to the random events
- React to the variations of traffic flow
- Reduce negative sensibility to events
- Maintain the 100 % efficiency of infrastructures

GERTRUDE: IT MEANS 4 TECHNICAL FEATURES
Gertrude Real Time is an expert system that combines statistical knowledge, macro-regulation, micro-regulation, and a very high standard of processing speed and precision.

Centralized Management
All the available information, concerning “macro-regulation” but also “micro regulation”, is sent to the Control Room. This Control Room therefore has full latitude to analyze, compare, calculate and synthesize the data. In nominal operation all the regulation intelligence is activated by the central system, thereby guaranteeing the global nature and cohesion of processing operations. This architectural principle allows, for example, the processing within the same algorithm and at the same time of a “bus” request for help and of a potentially contradictory saturation management operation, resulting in the best possible global decision integrating the precise traffic status of the moment and all the strategic orientations.

Real-time Management
So that the process may be as dynamic as possible and therefore as efficient as possible, data collection, analysis, command decisions, and traffic signal control are all carried out on a second-by-second basis. In this way the entire chain of the system is activated and the junction controllers receive the best adapted orders each and every second of the day.

Dissociated Management
With the aim of maximizing the system’s ability to respond to the constraints and variations of the traffic, the traffic signals at each junction are individually controlled. Thanks to this technique it is possible to respond to traffic events, not by modifying the end-of-phase go-aheads or anything else, but by creating – where necessary – new traffic signal statuses, thereby providing a perfect response to the problem of the moment.

Parallel Management
To be able to apply different strategies according to the required objectives, the system is able to process several parallel processes simultaneously. This technique results in an acyclic phase in a traffic signal diagram, for example in order to give priority to a tram whilst maintaining the normal, coordinated running of the junction. The result is an extremely quick return to normal, reducing the effects of the tram priority to a minimum.

More efficient than a simply model’s system, GERTRUDE real time is an expert system, which can react very quickly, each second with logical and combination rules that made the system complexly secure to react, with coherency, for each micro event.

6. Associated tools to reach the best traffic regulation

Main target: The quality of data’s analyze
- Know exactly the traffic conditions in real time
- Be able to build synthetic and strategic variables
- Model “Flow – Occupancy”
- Traffic charge on each “part of street”
8. Global performance for the GERTRUDE I.T. System

Third evaluation
- Dynamic and random arrivals on each entrance point of the network respecting a gauss repartition around average value
- Dynamic green times on traffic lights managed by the GERTRUDE process
- Fix green times corresponding at average value of flow arrivals for the reference comparison
- Evaluations of the Delay and traffic flow comparing results with fix approach and dynamic one using the GERTRUDE Real Time Process
- Realization of several simulations making, step by step, growing up the traffic flow until reach and over reach the maximal capacity of the net work
- Using the same reference network

Those results show for this basic evaluation the level of performance reach by the GERTRUDE System reducing particularly the Delay of 19,10% in congestion conditions.

Those results show also that, bigger are the traffic conditions higher is the difference between the classic approach and the dynamic GERTRUDE process.
Since 10 years, an official and real evaluation is done each four months in the metropolitan area of Monterrey (Mexique) by the University Autonomous of NUEVO LEON. The average of those evaluation gives an amelioration of the travel time about 24,12% compared with the situation without the GERTRUDE System.

9. Scope of “activities” of the GERTRUDE I.T. System

Managing a city require to use global solution able to manage the traffic flow, but not only. Scope are present on figure 12.

In the same way, addition of technology is not enough.

Technology must be in services to global strategy and politic decisions and introduce city’s responsible orientations and priorities must be possible in automatic decision process of the I.T. System.

A general study has to define answers on several aspects shown on Fig. 13.

In addition, the I.T. System must facilitate an evaluative life years after years.

To reach those objectives, the I.T. System must be built in specific way in accordance with city’s strategy and traffic limits and opportunities.

Engineering traffic studies are done to integrate all the characteristics of each specific network, including, traffic, areas, streets, intersections, to establish a traffic strategy integrated with the General Strategy of the city, particularly define the critical intersections or group representing frequently the origins of the traffic difficulties.

The introduction of hierarchy and main tasks for each intersection gives the structure for the organization of the automatic decision process, to be sure that the traffic strategy will respect the specificities of the city and his general strategy, as basic example on figure 15.

Hierarchic and priority tasks can be represented on the logic following tree, processing the real time activities of the I.T. System, respecting global coherency and strategy.
Basic Functions
- Influence by junctions on others
- Cycle
- Offset
- Split (Green Time)
- Order “Green – Red “ directly on traffic light

Finally the GERTRUDE I.T. System practice a full real time process, including typical decision, each second to always maintain the best balance between offer and demand. The following algorithm resumes the organization of this real time process.