Dynamic Allocation of Traffic Light Plans as a Traffic Reduction Strategy

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Abstract

The city of Medellin, like other cities in the world, is facing major mobility issues caused by the accelerated growth of the vehicle fleet in the last decade. The efficient operation of the traffic light network plays a fundamental role in the search for solutions to achieve an agile, comfortable, safe and sustainable mobility. For this reason, the Municipal Administration has made important investments in its updating and technological modernization that allows actions for a better performance. Currently the traffic lights of the city are operated by classic programming models, mostly at fixed times in different time zones and others in modes actuated and semi-actuated as scheduled, without responding to changing traffic conditions, making it necessary to search for autonomous traffic regulation systems that adapt their behavior according to the conditions. While adaptive systems based on a wide sensorisation for obtaining information online are an alternative, their current costs of implementation, maintenance and operation, has led to evaluate the new global trends in terms of information capture, storage, processing and use in the optimization of the operation of the traffic signal network. This is how the city of Medellin has been consolidating a Big Data storage system and has developed a technological platform capable of receiving it and executing actions on the traffic light system when it identifies that there are events that generate traffic variations different from normal or daily conditions, which has allowed to improve mobility conditions according to the results obtained, which will be detailed later. This first part of this document is an introduction of the different modes of operation of a traffic light network commonly used; the second part contains a brief description of the city's traffic light network; in the third part, the collaborative data systems are studied; the fourth part develops the solution scheme adopted by Medellin based on the collaborative data system; subsequently the results of the implementation of the system in a specific crossroads of the city are presented; and it ends with some brief conclusions in this regard.

1 Introduction

Due to the significant increase of cars and other transport means in recent years, the mobility of our city has been affected, because an increased traffic flow inevitably increases the likelihood of jams or congestions being generated, which cause delays. Not only do these delays often have repercussions in the waste of time, but also waste of fuel is generated causing higher carbon emissions that are toxic to health, traffic accidents and other economic problems.

Traffic lights in intersections are the points of the roads in the city where congestion can most frequently occur and therefore longer travel times, the programming and mode of operation of a traffic light network being one of the components that most impact mobility. The optimal distribution of time has been determined through traditional methods based on observations and simulations of a wide range of traffic conditions (volumes, intensity, speed, gaps, jams, road geometry, among others.) which minimizes delays and maximizes the capacity of the road network. This information can be obtained manually or through the implementation of sensors that are taking online data from each of the different traffic variables. In recent years, thanks to the massification of different wireless communication systems with the help of Big Data platforms, data mining and "machine" tools, not only traffic conditions can be known, allowing actions on the traffic signal network to minimize delays, but they can also be predicted by taking into account outliers and events based on the information received online.

In the quest for an efficient performance of the traffic light networks, traffic control methods have been developed that are classified as: Fixed Time Control (FC), Semi-Actuated, Actuated and Adaptive Control [1]. In general terms, in the Fixed Time Control the parameters and times of the traffic signals are determined by making use of historical data about the traffic flow at such point and they are invariably programmed during the control stage [1]. This method, despite being easy to implement and at a very low cost, cannot respond to real traffic changes or adapt to the changing behavior of the environment.

With the aim of improving this method, the management of Semi-Actuated and Actuated traffic was executed, directly providing intersections with sensors that allow to determine the degree of congestion and determine which traffic light plan is appropriate. In addition, the Adaptive traffic management system is available to optimize the green-light times according to the measurements taken directly from the sensors installed in all the accesses and clearings of the road intersection.

The concept of Adaptive Traffic, which combines the use of various types of sensors [2–5], allows to measure the number of approaching vehicles leaving the intersection and to detect each car individually, in order to obtain information in real time from the state of the traffic and from a control station, where all information is centrally collected, make decisions and perform the corresponding actions to accelerate the traffic flow through the intersection by modifying the times in which the traffic light remains red, yellow or green. In view of the fact that the execution of this method involves high economic costs and a complex installation in the road network, the concept of Collaborative Traffic arises which making use of the large amount of information available thanks to the massification of cell phone services, mobile internet, social networks, cloud services, Wi-Fi communications networks, Bluetooth, etc., can not only determine the state of road congestion and make decisions about the behavior of traffic lights, but also make predictions of congestion based on the information received in real time and directly by the same road actors [6–8].

In Medellin (Colombia), a multidisciplinary group of traffic engineers, specialists in ”Data Sciences”, telecommunications engineers and technical support of suppliers was formed to face the challenge of improving mobility and dynamically controlling the traffic light intersections making use of the information from different sources of information including historical data, traffic sensors and the information from the different communities on the internet. As a result, a technological platform was created to determine, based on all available data, when a measure, event or situation presented in the city traffic, corresponds to a situation outside the normal parameters and execute an action on the traffic light system by changing the distribution of times at the intersection or intersections, so that this anomalous situation is returned to normal operating levels and thus maintain the mobility indicators in the areas of influence of the solution.

2 Traffic Light System in the city of Medellín

Traffic management systems are based on two existing control strategies: Centralized and Distributed. In centralized management, the intelligence of the application of the actions is carried out by a large central software and the traffic light controllers are automatons that receive orders that they directly execute. In the distributed systems, traffic light controllers have the autonomous ability to apply different traffic management strategies reporting their operating status to a central software.

Both strategies share the following conditions:

- Communications Network.
- Traffic Light Plans.
- Traffic Light Controllers
- Traffic Light Center.
- Traffic Variable Detection System.

While it is difficult to determine which method is better in the traffic management of the city, if it is clear that the distributed control system has significant advantages over the optimization of the use of the communications network, fault tolerance and over the autonomous application of strategies in places that for some reason are temporarily or permanently isolated. In the case of Medellin, the system mostly consists of technological components that allow distributed systems strategies.

In order to carry out traffic management in the city, there is an Engineering and Traffic Light Operation Center (CIOS) where the following technological components are operated, which mainly comprise the total traffic light system:

1. Central system of monitoring, management and control of the status of traffic light controllers, called Remote Monitoring System (RMS) provided by the firm PEEK Traffic Netherlands.
2. Traffic light controllers provided by the latest generation PEEK Traffic Netherlands with open management and communications protocols.
3. The city’s own broadband communications network with xDSL technology that interconnects traffic light intersections with all its components.
4. Big Data information platform where the data coming from the analytical video sensors, electromagnetic meshes, Bluetooth sensors, information from the WAZE traffic community are centralized.

The technology installed in the traffic light system of the city has been acquired under the premise of interconnection, interoperability, manageability and openness. This is how all the components comply with the following protocols:

- TCP/IP interconnection protocol
- XML, JSON and OBDC Interoperability protocols
- Manageable with the SNMP protocol
- Open with the ALERT + traffic light protocol with exclusive use for the city of Medellin.

The monitoring and control of the components described above is carried out in the CIOS by specialized technical personnel who manage traffic indicators in the city in real time aiming at making the conditions as stable as possible. The method of traffic management implemented in the city is mainly based on fixed traffic time schedules, which are switched during the day regardless of the road congestion level.

3 Description of Collaborative Data

In order to carry out control strategies that depend on traffic conditions such as Actuated, Semi-Actuated, Responsive or Adaptive; The traffic light systems require the implementation of a system for measuring traffic variables that is directly connected to the traffic light controllers. This information is the basis for decisions made at intersections, corridors or areas where the traffic management strategy is implemented.

Traditionally, systems of traffic variables detection use electromagnetic loops or screens as a sensor, which are the most reliable ones. However, the fact that interventions and civil works are made on the road make them the least cost-effective. Additionally, the technological development has allowed to have different options such as Video Analytics, Radar Systems, Bluetooth Readers and Magnetometers.

Likewise, these new detection systems offer much more information that is very useful for traffic engineers to carry out the respective simulations and determine the best programming to apply at the traffic light intersection. In order for the traffic light system to use these measurement systems directly in the application of the traffic management strategy, they must be directly connected to the inputs and outputs of sensors provided in the traffic light controllers, so that in the end they behave as meshes or basic electromagnetic loops. The other information generated by the detection system is only centrally used by the traffic engineers for their respective calculations in the design of the most appropriate strategy.

It must be made clear that taking the city to a level of sensors installed on its roads implies a significant financial investment that means that in the vast majority of cases it cannot be done. This is one of the main reasons for the city to have a method of traffic management by fixed plans applied at pre-established times. That is, if the city does not include sensors allowing to measure traffic conditions dynamically and directly connected to the traffic light system within its traffic management, it is not possible to have a dynamic model of traffic management. To overcome the barrier of high levels of investment in the installation of thousands of sensors in the city, a global trend is being established to be able to use information external to traffic light systems to perform traffic management in what has been called "Collaborative model of traffic management". This model is based on the behavior of the different actors on the road, which are somehow generating information using current personal communication systems.

Nowadays, the different road actors such as pedestrians, cyclists, drivers of vehicles and public transport systems are constantly generating information via communication devices that can be used to optimize the traffic management of the city traffic. This is how we determine that technologies such as Bluetooth on cell phones and on-board equipment, information generated by users of social networks such as WAZE, Twitter, Facebook, public transport signaling systems BRT, among others, provide valuable information to determine the values of the origin-destination variables, average speed, queue length, incidents on the road, infrastructure conditions, works on the road and complementary data that can be analyzed to determine the indicators of the use of the roads. All this information is called collaborative because it comes from the road users themselves in their normal interaction with their devices and with the communities of their preference. This data, organized by means of Big-Data tools, is converted into information that, once analyzed, provides indicators of traffic conditions on the city roads.

Because the traditional tools used by traffic engineers for the design of the traffic light plans are oriented to have data on the number of vehicles, type of vehicle, floating vehicle and in general with deterministic information taken on the road by a specific sensor or by trained personnel, the results of the analysis of the collaborative information are not easy to use with these tools. That is why it is necessary to implement new forms of traffic management that allow improving the mobility indicators starting from the information generated directly from the users and the different road actors.

4 Problem-Solving Framework

Given the city's challenge to provide solutions to the different mobility problems in a social, economic and sustainable manner, it has developed a technological platform that allows the dynamic assignment of traffic light plans stored in the controllers according to traffic conditions and information from collaborative models.

This is how communities like WAZE, Google Transit, Google Traffic, Moovit, Strava, Garmin, Polar, UBER and the cellular companies offer valuable information and with a lot of variety to the entities in charge to manage and improve the mobility of the city. This information generated by actors external to the traffic light system is setting the trend and determines the use of the roads by the actors in it.

Therefore, it was necessary to provide the traffic light system with input and output modules that allow this information to be used in such a way that traffic management and the application of the different control strategies are carried out with the new information sources dynamically. Using this type of information generated collaboratively with users on the road interactively with the traffic light system is equivalent to having thousands of sensors simultaneously in the city offering truthful information about the behavior of mobility.

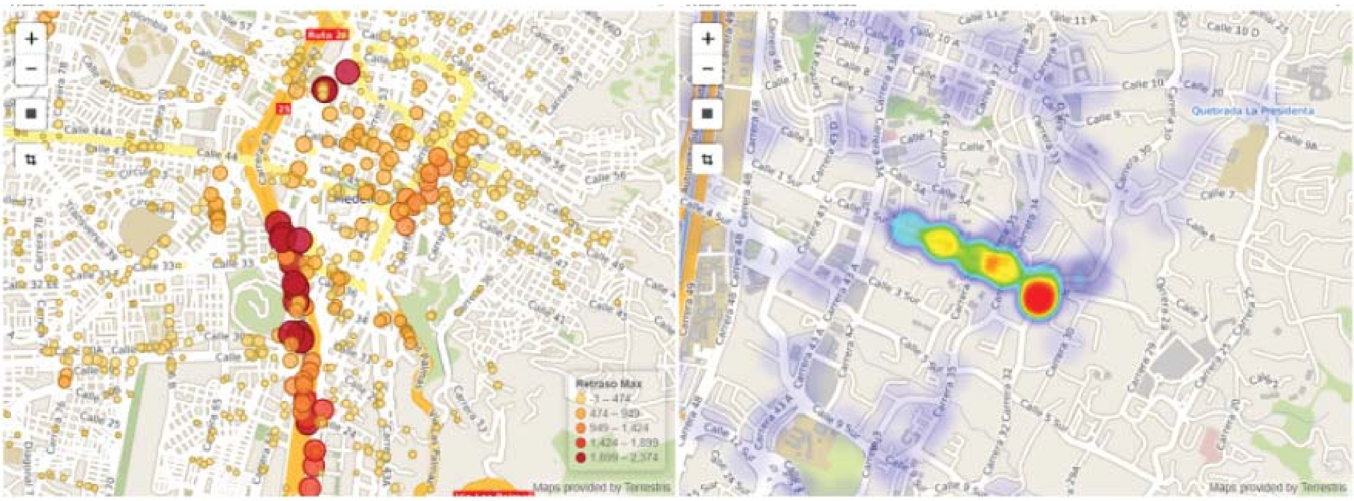

Figure 1. Geo-Referenced Information and Heat Maps

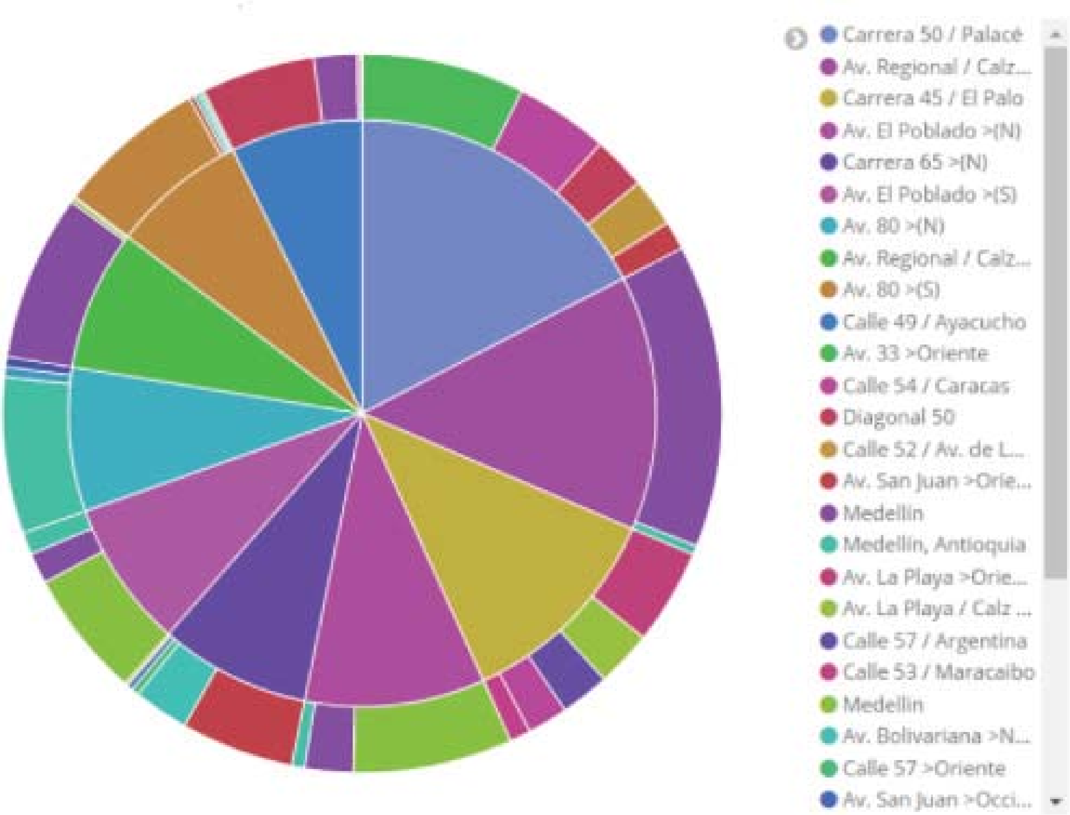

Figure 2. Information classified by Priority and Indicators Level

For the analysis of all this information, a Big-Data system based on a platform called *Elastic Search* has been implemented, which has a set of tools that allows to perform and determine in an integral way the trends, percentages and indicators of different variables associated with the level of congestion of the city roads, based on online data and other historical data.

The data included in the Big-Data system come from different sources, formats and are automatically, repetitively, online or historically generated. According to each type of

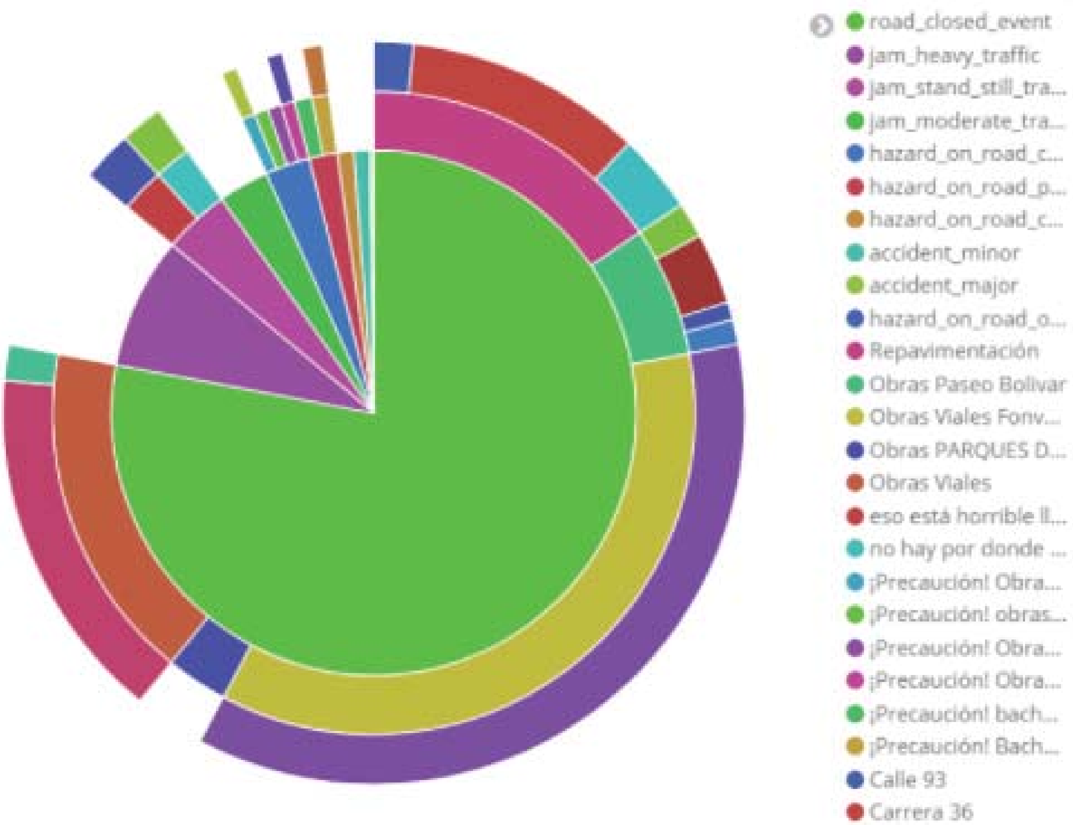

Figure 3. Information classified by Priority and Indicators Level

Figure 4. Sample of Original Raw Data

information source, a software robot must be created that allows the integration and standardization work to match in dates, geo-location and type in order to be able to perform the respective analyzes. The historical data comes from surveys, traffic studies, constructions and works in general that have CSV, Excel and text formats; For this information, it is done in a timely manner and the robot is executed once for each type of source and format. Online data is integrated into the platform through automatic procedures using JSON, OBDC and XML formats. This online data comes from the WAZE community, Timetable platforms, Analytical video sensors and other sources that continuously operate.

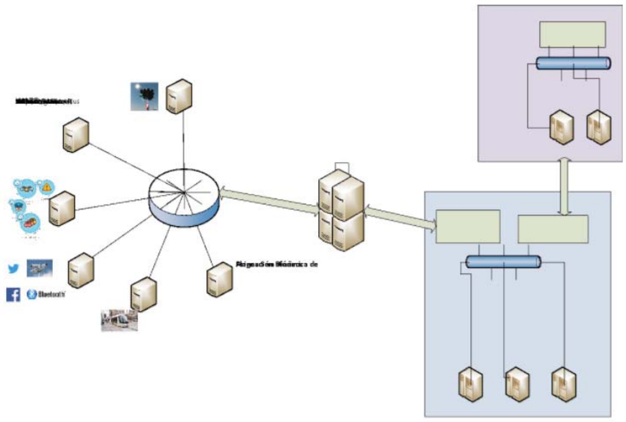

Figure 5. Topological Map of the Platform

5 Results

To assess the impact of the methodology, it was determined, together with the work group, that it should act on the intersection of Calle 54 Oriented and Carrera 65. At this intersection, there is the traffic light controller under number 6555.

Figure 6. Intersection Calle 54 eastbound and Carrera 65.

When analyzing the data stored in the Big-Data platform, the mobility indicators on February 2017 without using the proposed methodology and compared with those of October 2017 with the methodology are the following:

Average delay: 400,587 seconds.
85th Percentile delay: 669,833 seconds.

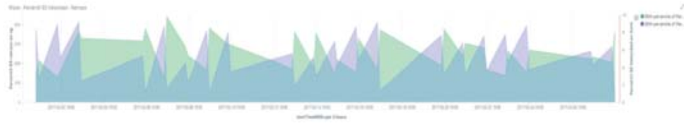

Figure 7. February Data without Methodology

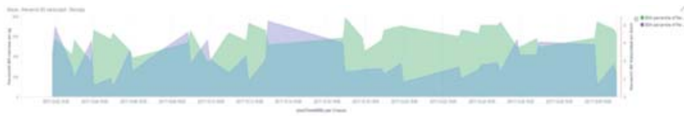

Figure 8. October Data with Methodology

Average delay: 256,334 seconds.
85th Percentile delay: 408,8 seconds.

A users waiting time decreases by 39 %.

The methodology of dynamic allocation of traffic light plans has a positive result in the mobility indicators as follows:

Decrease of Delay using the 85 th percentile of 144 seconds corresponding to an improvement of 39%.

Resumen de Febrero de 2017 - Calle 54 > Oriente										
	Lunes		Martes		Miércoles		Jueves		Viemes	
Rango Horario	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud
06:00-09:00							116	300		
09:00-11:00	98	300	121	300	113	358	99	568		
11:00-14:00					101	300	117	300	106	300
14:00-16:00	525	358	668	358	653	358	744	358	806	568
16:00-19:00	524	317	526	358	584	358	679	358	628	358
19:00-22:00	311	300	336	300	436	300	417	300	466	358

Figure 9. February Data without Methodology

When analyzing the data stored in the Big-Data platform, the mobility indicators on December 2016 without using the proposed methodology and compared with those of the month of December 2017 with the methodology are the following:

Average delay: 462,843.
85th Percentile delay: 677,375.

Resumen de Octubre de 2017 - Calle 54 > Oriente										
	Lunes		Martes		Miércoles		Jueves		Viernes	
Rango Horario	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud	Retraso	Longitud
06:00-09:00	154	212	150	300	89	300	310	300		
09:00-11:00			133	358			219	358	89	300
11:00-14:00									94	300
14:00-16:00	608	303	516	358	500	358	591	358	416	358
16:00-19:00	479	300	371	358	274	303	386	358	427	358
19:00-22:00	376	358	399	358	583	358	574	358	691	358

Figure 10. October Data with Methodology

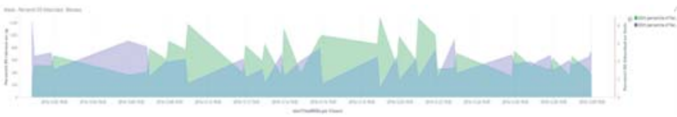

Figure 11. December 2016 without Methodology

Figure 12. December 2017 with Methodology

Average delay: 2991,16.
85th Percentile delay: 511,771.

A users waiting time decreases by 24 %.

The methodology of dynamic allocation of traffic light plans has a positive result in the mobility indicators as follows:

Decrease of Delay using the 85 th percentile of 165 seconds corresponding to an improvement of 24%

6 Conclusions

- The methodology of dynamic allocation of traffic light plans based on data and information obtained from road actors is effective in improving mobility indicators at intersections and corridors where applicable.

- The information generated by actors external to the traffic light system is being more used by the traffic control entities since it determines the use of the roads by the actors in them. Therefore, the traffic light system must be provided with the input and output software modules that allow using this information in such a way that traffic management and the application of different control strategies are carried out with the new information sources dynamically.

- The daily use of the social networks, communities and mobile platforms in the different devices means that each user behaves as a sensor and shares information that is generated online from the different indicators of mobility.

- Big-Data platforms together with machine learning and artificial intelligence tools make the analysis of the data more effective and reproduce more accurately the conditions of use of the roads and the infrastructure of the city.

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