Dynamic Management of Traffic and Public Transport at the level of an Integrated Management Center of Urban Mobility

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Abstract
The Integrated Urban Mobility Management Center will ensure the takeover, centralization and offering of information and solutions in real time for all types of urban mobility problems: traffic management, public transport, bike sharing, ticketing, etc.; as well as information on the environment: temperature, pollution, high toxicity alerts, providing public information (weather data, travel times and routes, air quality, etc.) and secure / private information (on traffic accidents, ways of intervention, diversion of transport routes, additional means of transport, integrated solutions according to scenarios and legislation). Preliminary studies on European directives for urban mobility and emergency situations as well as national regulations. Approach: Analysis of the links between the command centers and the information provided for information processing in the Master Center – information system architecture, data sources, storage, processing, data utility, error handling, choosing / generating post-processing solutions to solve the problems encountered using predefined scenarios or using algorithms for generating solutions according to the legislations in force. Results: Creating scenarios for the integration in the Intervention Solutions of the Master Center, providing the two types of information: public and private (secured) reducing CO2 emissions, increasing urban mobility by using public transport means and alternative mobility, increasing road safety, improving response times in case of an event by integrating communication with the Inspectorate for Emergency Situations.

Keywords: Master Center, CO2 reduction, alternative mobility, safety.

1. Introduction
You might be surprised at the fact that, when you stroll through a typical medieval town in Europe with its surprisingly narrow streets compared to today's standards, a tourist guide might explain a curious fact: people used the size of a rider and their horse to determine how tall and wide they were (people often crossed the street using beams above, arches or bridges). Whether the rider's arms could be spread out without touching the walls on either side indicated that the measurement was correct.

As towns and cities have developed, as have our economic and social progress, it has always been our mobility that determined their development. Innovations and structural changes have shaped the history of transportation, which takes us quicker and farther to our destinations. Several cities, including Venice, Amsterdam and Hamburg, began building their internal canal networks in the 15th Century, allowing river traffic between the different parts of the city to occur. These canal networks have been important in explaining the development of urban mobility.

Industrial development and globalization were stimulated by the development of an internal canal system. As a result of the development of railway networks in the 19th century, economic development was further stimulated, and large numbers of people were able to travel quickly and inexpensively [1]. International passenger and goods transport was influenced by the motor vehicle, road and motorway construction, and the advent of air transport during the 20th century. Motor vehicles' explosive growth in developed countries undoubtedly influenced the design and functioning of towns and cities; to the point that cars became more important than people. As a result of sustainable urban mobility, a new paradigm is emerging. Increasing motor vehicle traffic in cities led to a focus on finding the best way to move around. Promoting public transportation was the obvious solution. In comparison with personal vehicles, buses, trams, trains, and subways are much more efficient in using limited city space. As a result, they can accommodate a much greater number of passengers per trip than private vehicles. The solution was to create incentives for more sustainable forms of urban mobility in order to reduce citizens' reliance on their own vehicles. Traffic flow and people's health can both be improved with this measure. A change in perspective was generally accompanied by increased restrictions on car usage: parking restrictions in city centers, restricted access for air pollution prevention, etc. [2].

In the third phase, the concept of sustainable mobility was further developed and questions were posed such as: “Is your journey necessary?”. The debate centered on the fundamental objectives of transport policies. People moved constantly around the city to access goods and services. But what if those goods and services were more accessible and didn't require us to go get them [3]?

As a result of recent research, a group of sociologists and technologists have challenged this bounded approach to transport by studying change from a broader perspective of 'socio-technical systems', which integrates technology, social practices and business. Brand [4], for example, argues that the synchronization between technology and business practices contributes to changing behavior patterns; in contrast, Geels [5] said that the introduction of oil-based vehicle mobility systems at the beginning of the twentieth century resulted in a wide range of interests and organizations reuniting as a result of the development, adoption, and diffusion of this new socio-technical system than were thought to be relevant 'transport interests' during previous centuries.

To examine traffic's total management, this paper considers it as a single system [6],[7]. Methods of general optimization, sensing, technology, and processing of data. People and goods move from one place to another via all types of transport (bike, trains, inland water navigation, air transport, emergency transport) in one single system supported by transportation infrastructure, transportation services, logistics, or control elements. Single refers to all types of movement (from pedestrians to autonomous vehicles). With predefined optimization rules and hierarchically defined interconnected vehicles, the transportation management controls the single transportation system as a whole. As a solution, smart technology may be able to solve the problem (through the use of available technologies and theories), whereas intelligent technology may provide a different solution, based on the specific circumstances and characteristics. The paper outlines a method to bridge the gap between the solutions developed for the various elements (like junction control, smart parking, and optimizing the changing of means of transportation at multi-modal transport centers) and the management of the overall system. Ultimately, the purpose of this paper is to present a vision and concept of managing the total transportation system by defining the concept, the methodology, and the sub-models necessary to support the smart city vision of the future.

2. Materials and methods

The objectives of the study are correlated with the objectives of the strategic documents existing at the level of the municipality, at the county, regional, national and European level, as follows:

- European Green Paper on Urban Transport – "Towards a new culture of urban mobility"[8], the document sets out the main challenges to which urban mobility must respond, the proposed project having an impact on all 5 aspects mentioned: cities with fluid traffic, less polluting cities, smarter urban transport, accessible urban transport, safe and secure urban transport;
- Romania's Transport Master Plan, establishes the guidelines for a sustainable development, one of its estimated results being: "A long-term (sustainable) transport system"[10];
- Integrated Urban Development Strategy 2021-2027. The "Integrated Urban Development Strategy 2021-2027" is a reference framework document that sets clear strategic directions for the future of the city and its citizens, facilitating the taking of important decisions in all fields of activity and it's adapted for every city or area, based on general guidelines.

Identifying the existing deficiencies and carrying out a thorough analysis of the current situation regarding urban mobility, was crucial for establishing optimal solutions for the Integrated Management Center of Urban Mobility. Analysis of existing documents and field visits has resulted in a summary of the main weaknesses of the various systems examined, particularly from the perspective of sustainable urban mobility, and the conclusions have been used to determine the areas for implementation to achieve optimal results. To test the scenery, field study data were entered into a transport model. This was followed by comparative analysis of the output data of the model for the reference year 2020, the first year of project implementation (medium-term forecast – 2024) and for the last year of the sustainability period (long-term forecast – 2029). Implementing an Integrated Management Center for Urban Mobility consists of the fusion data of the subsystems listed below in one command and control center. The system will be able to provide a single interface, front-office and back-office that integrates information from all the subsystems included:

- Intelligent traffic management system;
- Intelligent video surveillance system;
- Infrastructure monitoring system – bridges;
- Public transport management system;
- Intelligent lighting system;
- Road safety system;
- Alternative mobility system;
- Parking management system;
- Electric vehicle charging station system;
- Air quality monitoring system;
- Communication system;
- Monitoring system of the hydrographic network;
- Monitoring systems for utility networks;
- Emergency management system;

- Waste monitoring and collection system;
- Public address system.

The Center will provide the following main functionalities:

- arrangement and endowment of the command center for the integration of data from the other subsystems;
- arrangement of private control centers for systems not currently dispatched;
- integration of data from several subsystems and the distribution of relevant information to them in order to improve individual functioning but, above all, to correlate the actions in an integrated approach;
- integration with the traffic management system;
- ensuring the priority of passage for emergency vehicles and public transport through all traffic light intersections in the municipality;
- implementation of a center for monitoring moving weighing systems;
- implementation of a parking space monitoring center; - integration and extension of the passenger information system;
- ticketing system integration and extension;
- implementation of a road safety system;
- implementation of an emergency management system (integration with CCTV system (existing video monitoring center) and implementation of local emergency management subsystem;
- implementation of an intelligent parking system for private bicycles;
- ticketing integration between all integrated urban mobility solutions;
- implementation of some modules for intelligent control of public lighting lamps;
- implementation of a system for monitoring the charging stations of electric cars;
- monitoring the co2 emission reduction indicators and noise indicators and proposing work scenarios according to the eco-mobility parameters set by the municipality;
- implementation of a system for the monitoring of utilities networks in the municipality (the networks of water supply and sewerage, district heating, gas supply, electricity supply are taken into account);
- hydrographic network monitoring;
- implementation of a system for monitoring waste;
- implementation of an urban mobility software application to facilitate the access of citizens and tourists to the transport system (including charging and passenger information). The application will also act as a travel system for defining optimal routes;
- a centralized IT solution that will ensure: integration of data from all the above mentioned systems, data analysis, generating and transmitting information relevant to each system, support for the decision, analysis of mobility parameters and proposing solutions to improve them, generating estimates and predictions for estimating the future situation (for a short-medium time horizon);
- IT – AI solution for delivering predetermined scenarios for intervention in case of emergency or AI new scenarios based on machine learning capabilities; providing the two types of information: public and private (secured for the emergency authorities) ;
- call center for citizens and tourists.

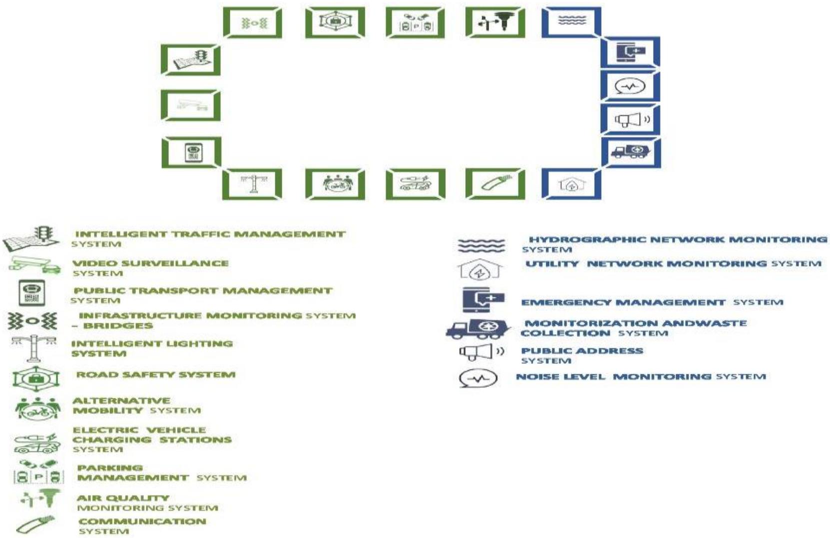

Fig. 1. Integrated Management Center of Urban Mobility

3. Results

The IT solution for delivering predetermined scenarios for intervention in case of emergency or AI new scenarios based on machine learning capabilities will connect all the important factors based on information delivered by all the sensors centralized in the Integrated Management Center of Urban Mobility, based on that scenarios the police, ambulance, firefighters or other factors will improve the response times, because the system will guide them and prioritize the route to facilitate fast intervention; providing the two types of information: public and private (secured for the emergency authorities)

3.1. Private information of the Master Center will provide access to all authorities in the city, creating a user profile that will have certain restrictions depending on its degree of clearance, so that they will have access to the following data:

3.1.1. Traffic management:

- real-time information from intersections: number of vehicles, delays, vehicle blocks, incidents/accidents/events, real-time images from monitored intersections;
- information on the routes most used by different categories of road users ;
- reports on congested points, identifying the cause of congestion ;
- predictions of traffic jams;
- prediction of the impact of certain changes in traffic conditions;
- real-time generation of out-of-weight vehicle alerts.

3.1.2. Prioritization of public transport:

- generating reports on the reduction of vehicle delays through the ranking system (efficiency report);

- transmission to vehicles of information on the speed at which they should travel in order to reach the intersection in green.

3.1.3. Parking:

- information on the degree of use of the monitored parking lots;
- checking compliance with parking space reservations;
- elaboration of proposals for the modification of tariffs from the existing structure of tariff zones, according to the monitored degree of use;
- drafting proposals on moving a certain car park from one tariff area to another, based on the degree of use monitored;
- drawing up proposals on the realization of new tariff zones.

3.1.4. Emergency management:

- emergency assistance via the app;
- planning/management module for events/works;
- possibility of introducing into the system the planned events and works;
- develop proposals on when events/works have minimal impact on urban mobility;
- emergency situations;
- development of predictions and alerts reflecting traffic congestion;
- elaboration of predictions and alerts reflecting the travel request, for each mode of transport, on hourly intervals;
- elaboration of predictions and alerts reflecting on failures (based on historical statistics);
- develop predictions and alerts reminiscent of exceeding the pollution and noise thresholds.

3.1.5. Public transport:

- real-time information on the degree of identity of vehicles;
- real-time information on the loading rate of the stations;
- elaboration of statistical reports on the efficiency of the public transport system (degree of loading of vehicles, waiting time at the station, number of transshipments, etc.) ;
- identifying the causes of delays in vehicles on the route and drawing up proposals to remedy the deficiencies found;
- drawing up proposals on the temporary modification of public transport lines at occurrence of events (unforeseen or planned);
- drawing up proposals on new routes/modifications to existing routes to reduce the number of transshipments, depending on the historical data collected ;
- elaboration of proposals on the addition or reduction, temporary or permanent, of the transport capacity, by days/time intervals, depending on the information collected from the field, in conjunction with historical values;
- proposal to streamline the ticketing system by identifying areas with high travel demand that do not automatic sales of travel titles;
- generating statistical reports on the types of validations used;

- generating reports on the routes used by passengers, available at the time when it will be decided to validate the travel title both when boarding and getting off the vehicle.

3.1.6. Alternative mobility:

- information related to the degree of use of bike lanes, relative to the number of cyclists recorded by the system;
- elaboration of reports and proposals for the efficiency of the network of bike lanes (identification of unused lanes, streets with a significant number of cyclists on which no dedicated lanes are arranged, etc.);
- elaboration of reports and proposals for streamlining the location and equipment of bike sharing stations;
- elaboration of reports and proposals for streamlining the location and equipment of private bicycle stations.

3.1.7. Public lighting:

- monitoring the operation of the system in order to provide safe routes for passengers (with the generation of alerts in case of damage);
- generating proposals regarding the thresholds and time intervals considered in dynamic street lighting;
- possibility of generating alerts for the lighting system regarding the number of pedestrians and the identified crossings, in order to activate the appropriate lighting plans;
- possibility of generating alerts for the lighting system regarding cyclists present on the bike lanes, for their proper lighting.

3.1.8. Electric vehicle charging stations:

- provision of statistical information related to the use of stations;
- possibility of directing to charging stations (by integration with a geographical support).

3.1.9. Noise and air quality monitoring:

- generating dynamic pollution maps, with graphical representation suggestive of the identified problems and proposing solutions for remediation. predictions will be generated based on historical data and solutions will be proposed to keep levels below alert thresholds;
- generating dynamic noise maps with graphical representation suggestive of identified problems and proposing solutions for remediation. predictions will be generated based on historical data and solutions will be proposed to keep levels below alert thresholds.

3.1.10. Utility monitoring:

- Generating information on works with an impact on mobility.

3.1.11. Hydrographic network monitoring:

- information on the hydrographic network;

• generating alerts for intervention.

3.1.12. Waste monitoring:
• providing support for targeting for recycling.

3.2. Public information **provided for citizens will be:**
3.2.1. Used for private vehicles:
• network delays, based on detectors that collect real-time data, the history made and the planned events ;
• position, the number of parking spaces available at that time, with the possibility of booking the parking space and the payment of the tariff according to the desired duration.

3.2.2. Used for public transport:
• he opportune routes, considering both the length of the route and the possibility of prioritization along the route;
• appropriate vehicles, taking into account:
• specific preferences (e.g. ramp for people with disabilities, possibility of charging mobile devices, or other facilities selected by the user);
• the degree of loading, known in real time, also taking into account the demand at the stations through which the vehicle is to pass until it reaches the proposed boarding station;
• the appropriate embarkation station, taking into account:
• ease of reaching it;
• degree of congestion (of the station and of the vehicles to reach the station);
• the necessary facilities (e.g. automatic for the sale of tickets);
• the estimated time of arrival at the station of the vehicles, estimated both according to the position of the vehicles and based on other relevant data collected by the system (e.g. the existence of large queues of vehicles in front of the bus);
• the appropriate destination station, taking into account the way of continuing the journey;
• purchasing the travel ticket directly from the app, with multiple validation for attendants and selecting the most advantageous fare for travelers.

3.2.3. Used for bike-sharing:
• selection of the appropriate stations (with bicycles available at pick-up and with available seats in the drop-off station);
• booking the bicycle and making the payment directly from the application.

3.2.4. Used for pedestrian routes
The accessibility of the routes will be taken into account (e.g. for people with locomotor disabilities, no routes involving stairs will be selected) and the safety conditions (number of historically recorded incidents, appropriate lighting, etc.):
• provision of information on the resulting charges for each route;
• providing information on the degree of pollution achieved for each route;

- providing information on the route regarding the movements to be made next (e.g. get off the public transport vehicle at the next station);
- real-time update of route-to-follow information based on real-time data collected in the mobility operational center;
- possibility to upload subscriptions in the app;
- possibility of payment in a single action for all charges involved in the selected trip;
- generating alerts for the necessary actions (e.g. a subscription uploaded to the app is due to expire, the time for which the parking was paid, etc.).

3.2.5. Collection of anonymous data of:

- the routes followed;
- means of transport used;
- the selection criteria of the user, from the variants of the routes offered, with the possibility of estimating the reasons for which a certain route was chosen;
- actual delays, compared to estimates originally provided.

According to the present system, which is outlined and validated from a technical perspective, alternative urban transport solutions will be integrated to facilitate people's access to workplaces, service providers, or other areas of interest, reducing travel times, transportation costs, reducing pollution and energy consumption, decongesting traffic, and improving safety as a result.

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