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The structure of the data flow in integrated urban traffic management systems – the case of TRISTAR system

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ABSTRACT

The purpose of the article is to offer some insight into the data flow architecture in the Tri-City's integrated traffic management system called TRISTAR. To that end selected elements of TRISTAR are identified and described as well as the structure for collecting and exchanging data within different sub-systems. Finally, the article highlights how the TRISTAR system can be extended by adding new elements and modules.in English.

KEYWORDS: Intelligent Transportation Systems, transport modelling,data collection

1. Introduction

The Tri-City's TRISTAR system is one of Poland's few systems to have a dedicated regional architecture. The ITS architecture ensures clear definitions of the system's functional and physical structure, logical links and organisational matters. At present, two ITS architectures are used worldwide. One of them is the so called US ITS architecture used by systems implemented in North and South America. The other is the E-FRAME European architecture. This architecture is used by European and Australian systems as well as Chinese ones. The E-FRAME architecture is also used in Poland, for example for designing the National Traffic Management System, which is a requirement of European law [3]. When building an ITS system it is crucial to use a standardised architecture because it helps to integrate the components. With a uniform logical, IT and technical structure, data can be exchanged between different system components. This ensures that the system stays open to development and enlargement.

Smooth exchange and flow of data between different systems or system components is necessary for efficient transport management.

2. Functional structure of TRISTAR system

The system architecture defines a four-level, hierarchical functional structure (levels of metropolitan, urban, zone and local management). The level of urban management, also called the strategic level or central management layer, covers urban traffic management in the individual cities forming the Tri-City. This level will be responsible for addressing the key demands of the individual cities' transport policies within the Tri-City Agglomeration. The primary function of the central level, which is physically located in the Transport Management Centres in Gdansk and Gdynia, is the integration of all the systems included in the TRISTAR system implementation [8,10]. The main components of the system include the Urban Traffic Management System (UTMS), the Public Transport Management System (PTMS) and Transport Planning System (TPS).

2.1. Urban traffic management system

The Urban Traffic Management System is responsible for traffic management within the city. It includes the Traffic Control System designed to optimise the operation of traffic lights both locally and in the entire area. Using measurement devices (induction loops, video detection), the control system optimises the operation of traffic lights using different mathematical methods (Hill climbing, genetic algorithms, cellular automats). The system is used to change the control objective (to minimise stops, maximise capacity, minimise queue length). Depending on the situation on the roads a specific traffic management strategy will be deployed. The system can optimise control parameters, i.e. offsets and splits of green light in order to minimise the parameter identified in the optimisation objective. The system minimises the so called Performance Index which consists of the sum of three parameters calculated for each signal group. They are traffic volume, number of stops and queue length. By choosing the optimisation objective the user can change the weight (importance) of a parameter and by doing so change the resulting control parameters. While other control objectives can also be added, first they must be studied to understand how that objective will affect the road network. The system helps to calculate traffic parameters at specific points by using data from traffic measurement stations (e.g. momentary vehicle speed, modal split, traffic volume, direction of traffic) and on sections. Section data come from calculations made with traffic models, i.e. BALANCE (based on genetic algorithms) and DRIVERS (based on cellular automats). The models use data from detection that feeds into a road network model developed in the GIS technology and can calculate traffic parameters. The BALANCE control system (balancing adaptive network control method) uses genetic algorithms and helps to minimize the loss of time, number of stops and length of queues in the designated area [1][4]. At the same time the local control system called EPICS takes control over each single junction. The model-based traffic adaptive control method EPICS conducts optimisation based on the current traffic situation via the status changes of the detectors. (a deterministic model similarly to the TRANSYT model has been developed for EPICS). Control optimization in EPICS is performed in two steps. In the first step, stage sequence is fixed (calculations carried out for the next 5 seconds using a modified Branch-and-Bound algorithm). In the second step the fine tuning takes place, i.e. the starting times of the interstages are optimized with one second precision using the Hill-Climbing algorithm. Horizon optimization is provided in 100 seconds forward [6]. Signals at intersections according to the defined weights may be controlled more locally (EPICS) or in the network. BALANCE developed by the German company GEVAS sends traffic signal plans to controllers (at the macro model in the medium- and long-term periods of 5-15 min), the local level can use them as fixed-time programmes or combine with actuated signal programmes. The objective function for the optimization of the BALANCE model can be dynamically created and modified, also using weights that help to create it with a combination of multiple optimisation criteria. For signal programmes the objective function is calculated using the performance index PI, which uses the measured or calculated parameters and their combinations for the signal groups, such as delays, queue length and the number of stops [2]. A component of DRIVERS by the GEVAS company software enables the detection of conditions and disturbances in traffic (it will be possible to extract the data from vehicles in the future) and an immediate demand to change signal settings in response to a change in traffic. By using the cellurar automation models it can also calculate current and make short term (15 minutes) prognoses about traffic conditions in each link of the network model (GIS based model) [7,11].

In addition, the system supports priority demands sent by public transport vehicles as described further in the article.

The objective of the Advanced Traveller Information System is to inform drivers about the current traffic via Variable Message Signs and Variable Message Boards [9]. Detection devices (ANPR cameras, Bluetooth/ Wi-fi scanners) read the parameters they need to identify vehicles (registration numbers, mac addresses of devices) and assign them unique encoded identifiers. The module for calculating travel time searches for the identifiers as they are detected at the specific measurement stations and pairs them (the module filters out unreliable data and rejects extreme speeds measured in the particular period). Measurement stations set the sections which make up the routes between different parts of the Tri-City. Vehicle travel time data are used by variable message boards and signs to inform motorists about:

- travel time between different points across the Tri-City
- traffic delays detected
- recommended detours.

In addition, ATIS data are used in the traffic incident detection module (notifies the operator about traffic disruptions as a result of an incident) on selected sections of the street network and as an element of Traffic Control System algorithms for choosing a traffic lights programme from the available programme library.

The Weather Parameters Measurements System (WPMS) is an element of TRISTAR responsible for measuring weather parameters. Located across the Tri-City, weather stations provide comprehensive data about:

- condition of roadway;
- type and intensity of precipitations;
- air temperature;
- temperature of roadway;
- strength and direction of wind.

The data are used for informing motorists about hazards (through the ATIS) using VMS and change driver behaviour by e.g. reducing speeds in bad weather. Weather information is also available online. Hazard information (slippery conditions, strong wind) is passed on by text message or e-mail to designated services responsible for road maintenance. Data from the system can be passed on to the Traffic Control System and can be used to minimalize impact of weather conditions into traffic network.

All of these systems are integrated. The master level uses a set of tools for overseeing all the other TRISTAR elements. The system consists of a set of different applications (the VT centre by Gevas shown in Fig. 1. It can monitor all of TRISTAR's devices. The system sends commands to its particular sub-systems (e.g. to traffic light controllers when a programme change is needed). The system also stores information about its operation such as a logbook of device messages and operator activity logbook.

To ensure that the sub-systems and solutions designed in different technologies for data recording in different databases (Oracle, MS SQL, MySQL, etc.) are integrated, a special structure is used called the Integration Database (IBD). It is used for exchanging data between all sub-systems and passing them on for further processing for operational or statistical purposes.

Fig. 1. View of operator's application of the integrated system for transport management [own study]

2.2. Public transport management system

As well as running the traffic management system, the Tri-City also has a system for managing public transport. Within the system each public transport vehicle (buses, trams, trolleybuses) has an OBU on-board computer (On Board Unit) with the necessary components. The main one is a GSM modem for communications with the Traffic Management Centre. Equally important is a GPS antenna that helps to locate the vehicle at any time and an RKZ antenna (short-range radios) for communication between the vehicle and traffic lights controllers. Radio connectivity is used to assign traffic lights priority to public transport vehicles. When a vehicle reaches a designated spot before a junction, it will notify a specific controller at the junction. The controller then makes the decision whether priority should be or can be given in relation to the programmed guidelines. The vehicle and the Centre must communicate in order to determine whether the vehicle is on track with the schedule. The first to use this information are the public operator's traffic controllers. They check actual progress versus the timetable. Once processed, the information is sent to passenger information boards at bus and tram stops. The boards show the actual departure time of upcoming vehicles. In addition, the actual location of the vehicle is used in the travel planner available on the TRISTAR website and fixed travel planners in key points of the Tri-City.

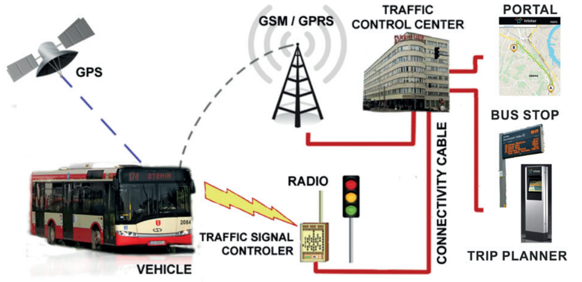

Fig. 2. Flow of data within the Public Transport Management System [own study based on 7]

2.3. Transport planning system

One of the elements of TRISTAR is the Transport Planning System (TPS) based on modelling tools in accordance with the concept of multi-level transport model (MST) [5,11]. As part of CIVITAS DYN@MO, a Gdynia-based project, analytical models were developed that help to optimise transport management in the city.

A macroscopic model of Gdynia was developed using the VISUM software by PTV (Fig. 3). It offers a planning and analytical tool for incidental analyses and helps to understand the effects of e.g. road works on major roads, sports and cultural events on larger parts of the city.

The mesoscopic model was developed in the SATURN package. It supports a variety of traffic distributions. These include deterministic, stochastic and elastic distributions that allow a feedback between the process of traffic distribution in a street network and the demand for transport (which means that reduced demand can be incorporated, if travel costs change). This ensures that the analyses are reliable in terms of availability and capacity of areas.

The microscopic model was developed in the PTV Vissim software. It covers the entire TRISTAR catchment area and has tools for importing data directly from the macroscopic model and simulating the operation of the traffic control system at the local level using the EPICS algorithm. It takes account of the BALANCE area system.

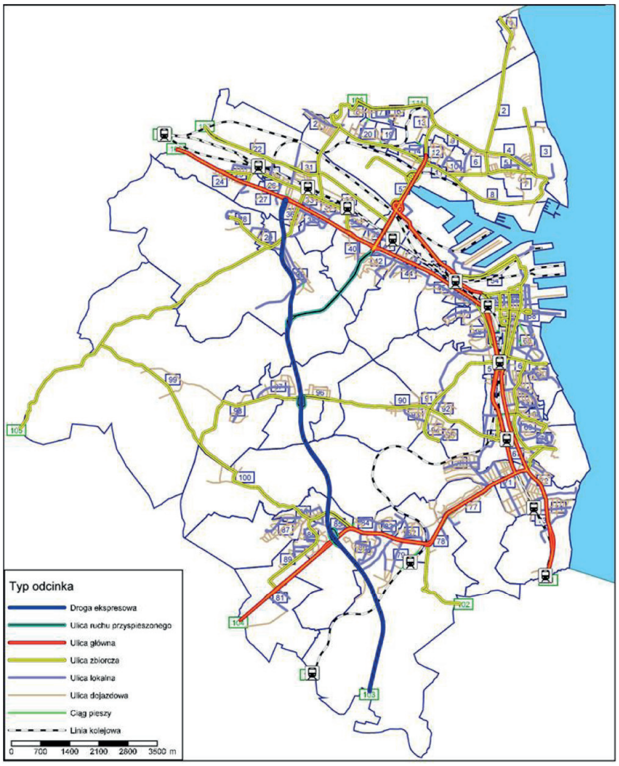

Fig. 3. Macroscopic model of Gdynia [own study]

3. Data flow in TRISTAR system

TRISTAR's IT structure is centralised. The central element of the system is the Integration Database (IBD). It is a complex database for exchanging data between different systems in real time. Communication between the IBD and TRISTAR elements occurs in the duplex system. Each element is able to pass on information to the IBD about its status, as an example. At the same time the central system sends commands as it controls the TRISTAR infrastructure. The job of the IBD is to:

- Pass on information between systems. One such example is the Driver Information System which needs weather information collected by the Weather Parameters Measurement System
- Pass on information to the system about the status of the devices. The majority of ITS devices have their own auto-diagnostics, so if there is an error, the device will inform the appropriate sub-systems and eventually the TRISTAR operator. Tables of Module Activity (TAM) are mechanisms implemented in the database. Their job is to oversee connections with all devices. In case communication with a device goes down, the system will inform the operator.
- Collect data from the sub-systems and pass them on to databases for aggregation and archiving (Date Warehouse).

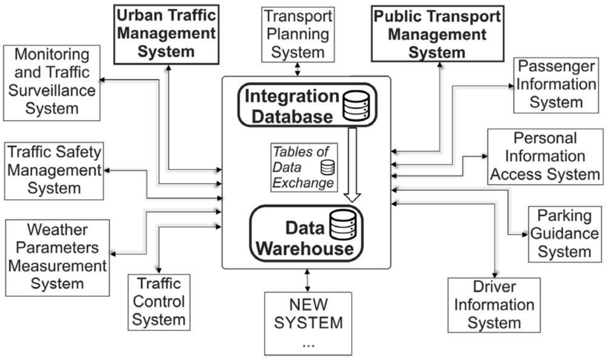

Fig. 4. Flow of data between sub-systems. [own study based on12]

To ensure that the systems are integrated (data produced in different formats) and can work together if new elements from new manufacturers are added, Tables of Data Exchange (TWD) were introduced. They contain subsequent information about system states and subsequent values of system characteristic parameters that are measured or calculated [12]. If new devices are added that differ from the existing ones and produce data in a different structure, they must come with a mechanism that allows the data to be added to the existing TWD with a set data structure. Thanks to its flexibility, this solution can read and record data in any TWD by any sub-system. If new sub-systems are added, information can still be read from the existing TWD, but a new TWD will be required for storing information made available to other systems. The idea of data flow and where the sub-systems are located is shown in Fig. 4.

4. Extensions to TRISTAR

The Tri-City's TRISTAR does not have all the systems in place that were originally planned for the entire Metropolitan Area. The modules to be added include a module for detecting overloaded vehicles (a system for weighing heavy goods vehicles) and a module for directing trucks to car parks. Because of the Tri-City's seaside location, these modules are extremely important. The conurbation's two major and dynamically developing ports generate a lot of heavy goods traffic. Using solutions for enforcing HGV regulations is key for road safety, road infrastructure management (overloaded vehicles damaging the infrastructure) and for the economy (eliminating unfair competition). The ability to direct trucks to dedicated car parks will be helpful with improving traffic in areas close to the ports.

In the case of the first system, the city of Gdynia already has a WIM (Weigh In Motion) device, developed in the pilot project CIVITAS DYN@MO. It will serve as a basis for enlarging the whole system. By integrating it with Tristar system, it will be possible to send data to the other parts of the system, adding to their functionality. One of the systems that can benefit from the data is ATIS. Weigh-in-motion stations are equipped with cameras that recognise registration plates (ANPR) and vehicle features (ARTR). That way any violations by a truck can be fully documented. By using information from the system, for example registration plates data, we will be able to extend the area covered by road traffic information (travel time) which is sent via VMS devices and the website. In addition, vehicle numbers and modal split information can be sent to the traffic management system and the related traffic control system.

Recently, part of CIVITAS DYN@MO, the Gdansk University of Technology has been working on an algorithm for Automatic Traffic Incident Detection (ATID) using data from the traffic control system. To that end junction detector data will be used as well as data about the signal displayed on the signalling devices. Statistical tools and neural networks are used to develop the algorithm. It will help to detect junction incidents and inform system operators. The information will also help to step up action to minimise the consequences. As a result, rescue services will be able to get to the accident scene faster and traffic disruptions will be managed more effectively.

In terms of data flow, for both existing and new data, TRISTAR can incorporate new elements. The incident detection system will be complemented with a function that will direct rescue services to the accident scene based on up-to-date traffic information. TRISTAR's implemented mechanisms can send information in real time about the best (fastest) route and control parameters can be changed to accommodate emergency services.

The next possible example of how the system could develop is to implement solutions that will support communication between the infrastructure and vehicles using it. One of the possibilities is sending data about changing traffic lights to the vehicle. Another possibility is to send up-to-date information about traffic to vehicle satellite navigation systems with suggestions of a new route, if there has been an accident.

5. Conclusion

The architecture play essential role in developing ITS systems. Thanks to it system can be open for new functionalities and solutions. Architecture enables integration of different ITS systems. Need of interoperability of ITS systems brought about creation of international architectures such as US ITS architecture and E-FRAME, that are now used worldwide. Thanks to centralized IT architecture of TRISTAR system, all the subsystem can be connected with each other. Connection between subsystems give possibility to develop of new functionality of the system and its components (exp. WIM ANPR cameras can be used to calculate travel time for ATIS system). Free data flow between subsystems can improve functionality of ITS system. Traffic is very complex process, lots of different factors have impact on traffic reliability efficiency and safety. System development that can take into account many of different parameters can make it more useful and bring more profits for transport systems users.

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