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Methodological and technical aspects of models for digital management of transport systems

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***Abstract*. The digital transformation of transport systems is a priority area worldwide and aims to improve the quality of the services offered, as well as the processes of planning and management of work and traffic in transport. Digitization allows in a qualitatively new way to compile basic technological documents, as well as to manage specific transport and business processes. Through such management, the transport of passengers and cargo becomes faster, more efficient and safer. The main problems in the construction of the new digital platforms are related to hardware and software collateral. This article discusses methodological and technical aspects of digital transport management models using new technical and technological solutions of specific business processes and systems management models. The specifics and main directions on which to work to improve the implementation and development of digital systems in transport are outlined.**

Keywords: Building Information Modelling (BIM), Digital management, Digital transformation, ITS – Intelligent Transport Systems, Sustainability

I. INTRODUCTION

The transportation industry is the bloodline of modern society and the basic industry for the development of the national economy. Transport infrastructure is the key to the formation of transportation capacity and the basis of economic and social development. In last decades economy has grown rapidly, infrastructures have developed vigorously. Accordingly transport infrastructure has also made great achievements under development and construction. Extensive operation and management will accelerate the depreciation and loss transportation infrastructure, the high-quality asset. In order to achieve the sustainable development of transport infrastructure, scientific and effective management techniques are essential. The degree of intellectualization of transport infrastructure plays a key role in transportation safety, efficiency and interaction between transportation modes. The intelligent transportation system is the future development direction of the transportation system and one of the key measures to solve of problems. Establishing a real-time, accurate and efficient evaluating systems that functions in a large-scale and all-round way is the development direction of intelligent transportation systems. Accumulate rich experience to achieve the ultimate development goal of an informative, intelligent and humanized transportation system [1].

The current situation of transport infrastructure management is explored, data sources and characteristics of basic transportation information are discussed in the article. In order to give full play to the value of transport infrastructure data, three goals for digital management of transportation infrastructure are discussed: network-level, full life cycle and multi-source information fusion management. The new challenges brought by the digital management of transport infrastructure in the era of big data are analysed [2], [3].

II. MATERIALS AND METHODS

A. Overview of transport infrastructure management

Transport infrastructure management requires the management of basic information, usage characteristic, maintenance records and other information of traffic facilities. It's includes static and dynamic data, as well facility attribute data and operational records. Such information covers a long period of time, including engineering, economy, service and other factors. Therefore, has many objects, wide range of types, a long period, high liquidity and all make management difficult.

The rapid development of information technology in recent years, the level of digital management has been improved in the transport infrastructures. The collection, analysis and maintenance of transport infrastructure data are the core of the management system's role [4].

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Using GIS, BIM, graphic recognition, Wi-Fi, 4G, 5G and so on sensors and different technologies, the collection of transport infrastructure data is becoming faster and more accurate, maintenance of service more convenient. The development of information network technology, such as development of Web, PC, Cell phone clients, allow managers to conveniently query asset information, perform information maintenance anytime and anywhere. The fuzzy comprehensive evaluation, neural network algorithm etc. provide methods for analysis. So more accurate and reliable transport infrastructure information models can be established. Grey prediction model, decision three, genetic algorithm etc. provide great solutions for comprehensive maintenance of transportation facilities. Based on development of these technologies and method for analysis, it's particularly important to collect accurate and comprehensive infrastructure data. All obtained data can also play a great role in decision making. Implementation of the digital management is very feasible and necessary [5], [2], [6].

B. BIM background

Building Information Modelling (BIM) is a process developed in the 70s in the USA to create and manage information and digital representations of physical and functional characteristics. The tools used in BIM have different nature and comprehend databases, 3D models and even things like contracts. Further development and refinement across last decades along with technological progress, becoming more popular and recognized worldwide nowadays. It's not just a 3D software, but rather an entire, very different approach. Transportation infrastructure is one of the many applications of BIM, especially in current times and globalized world, characterized by an ever-increasing transportation demand related to economical and demographical changes, along with transport infrastructures complexity. In recent years approach is getting extended to Smart Cities and Intelligent Transport Systems (ITS), which makes sense given the complex and multidisciplinary nature of these infrastructure. This paper will introduce a brief description of the BIM in relation to ITS, moving then to more technical details [7].

C. Information modelling and ITS

ITS comprehend a multitude of technical devices and processes interconnected into network, aimed to control and optimisation the different types of transport and their mechanisms. For example, ITS applied to road transportation is the ensemble of connected sensors designed to optimize traffic flows, in combination with Connected Autonomous Vehicles (CAVs). Other examples of ITS include Intelligent Road Intersections (IRI), Smart Roads and so on. ITS work with large amounts of data stored and exchanged between vehicles, surrounding infrastructure and electronic devices etc. All these aspects can be implemented in models in order to have a well-organized and well-working system, either in a design phase, or in working phase or for maintenance. The interconnection between Geographic Information System (GIS), ITS and BIM can be achieved by modelling data thanks to the use of Unified Modelling Language (UML) and Model Driven Architecture (MDA). Different system architectures can be developed for structuring and manipulating BIM models, along with 3D geospatial information, collection of points and any data that can be collected by smart sensors in places; one of such systems considers four different layers: data pre-processing, data systematization and storages, system interface, and front-end data manipulation; data integration is achieved thanks to the development of an UML. This method allows reconstructing and geo-referencing 3D BIM models, along with data storage and visualization; the final outcome constitutes what is called a Precinct Information Modelling (PIM). Thematic models considered in this system included: Building, Vegetation, Sensor, City Furniture, Land Use, Transportation, and Terrain [6], [8], [9];

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D. Main difficulties faced by management of transport infrastructure

At the present the main difficulties faced by the digital management of transport assets are: 1) Insufficient historical data on transport infrastructure management. 2) Transport infra management involves many types of data so processes of integration and application are difficult. 3) Transport infra management is usually based on projects. The different platforms are difficult to exchange and share data. The advancement of comprehensive management of regional route networks is hindered [11], [12].

E. data sources for transport infrastructure management

There are four main sources of basic transport data: design information, facilities collected, manual collected and network collected data [2].

A. *Design information data:* The basic data mainly include the electronic topographic maps of different proportions, the design and constructions documents etc. The basic geographic information maps are used in general for surveys of water systems, survey control, survey of residential, coast and shelf. A large number of multimedia, exchanges and contract reports are also contained.

B. *Facilities collected data:* Now there are more various monitoring facilities. For example, widely used sensor systems including Fiber grating, piezoelectric material, shape memory alloys etc. Also have high-definition cameras, weather monitors, radar detectors etc. The camera technology, laser scanning, infrared temperature field photography and geological radar detection technologies are used. The automation of process is efficient and no manual errors.

C. *Manual collected data:* In some cases, the detection equipment can't directly collect info, so the detection of mechanical equipment and data export required manual additional operations. Nowadays the automation is high and manual collection is getting down.

D. *Network collected data:* In the Internet age people's lives are increasingly dependent on the Internet. The development of the mobile Internet applications such as precise location positioning, terminal perception, cloud processing and computing. Data fed from user phones by road is also useful information resource.

F. New systems under the digital management of transport infrastructure

A. Network-level management

Currently commonly used transport infrastructure management systems are mostly project-level. That is the scope of management is only a single specific project. The management cycle is the project operation life cycle. At the different stages of project, the different systems will be used due to different responsibilities, which will lead to the fragmentation of information. For different projects the information is even more fragmented. Even if the geo locations are close or adjacent, organisation rules, languages, data processing methods are different due the different management systems. Project level management can lead to loss information between projects and even the various stages of the same project, which hinders the exploitation of the potential of data in asset management. The network-level transport infra management can solve these problems. The network-level manage and analyses the historical and real-time data. The evaluation and forecast models are used for analysis and decision making. The limited maintenance funds are allocated more effectively and reasonably [13].

The calculation logic structure of the system is shown in the Fig. 1 The system evaluates judges whether the planned investment is satisfied. Finally, the feasible maintenance plans are got and the plans are not unique.

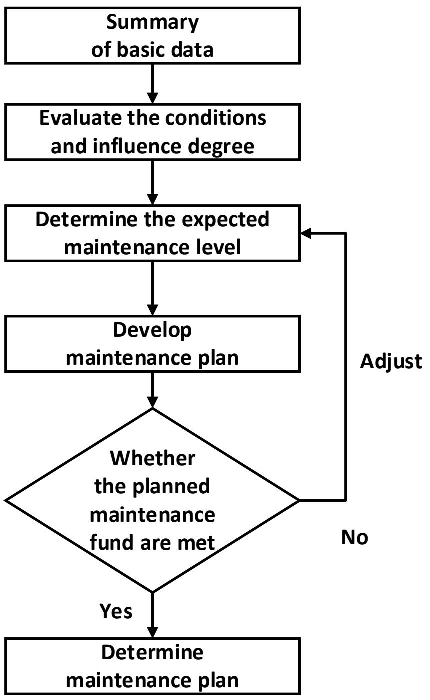

Fig.1 Network-level management procedures for transport infrastructure

B. Full-lifecycle management

In the fully-lifecycle transport infrastructure there are many participants. Most only involve part of the process and the type of data generated are complex and diverse. There are problems of poor data communication, data delay and even data islands. To a large extent these lead to low level management and efficiency. Development of informatization in full swing to improve the efficiency and effectiveness of information exchange, it's necessary for transport infrastructure to establish a platform for effective management and sharing of full-lifecycle data.

The full-lifecycle of transport infrastructure can be divided into three stages: design, construction and operation. The information between various stages is still interrelated and ensuring the effectiveness of info communication. The digital management platform of transportation infrastructure should have unified and integrated characteristics as shown in Fig. 2

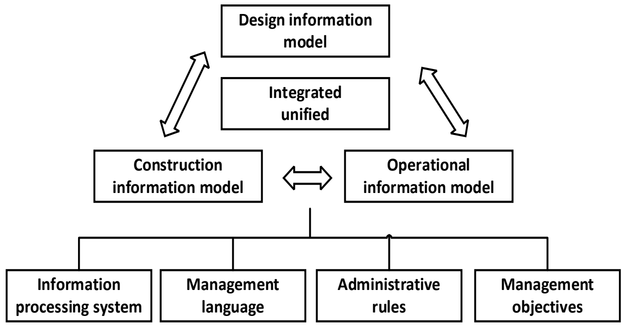

Fig.2 Transport infrastructure management model based on the whole life of the project

Establishing a digital management platform for transport infrastructure and building a database that stores and manages the entire life cycle data that runs through design, construction and operation is an effective way to realize the full life-cycle of management. The overall idea is shown on Fig. 3

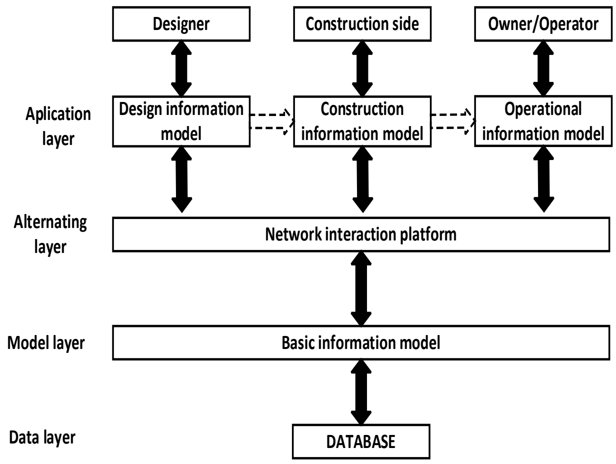

Fig.3 Full life cycle transport infrastructure management platform structure

C. Multi-Sorce Information Fusion

Multi-source information fusion refers to the comprehensive processing of information from different sources, so as to obtain more unified and rich information. With development of Internet and Wi-Fi technologies there are more channels for information acquisition. It's realized that information integration can improve the accuracy and comprehensiveness of the evaluation and understanding. The multi-source information fusion technology has developed rapidly [5].

In transport infrastructure management, through the integration of information, the geological and hydrological data, historical construction, maintenance data related to facility can be obtained quickly and directly. The application process of multi-source distributed data is shown in Fig. 4. The effect of multi-source information fusion is not a simple accumulation, but 1+1 >2, which can fully tap the potential data.

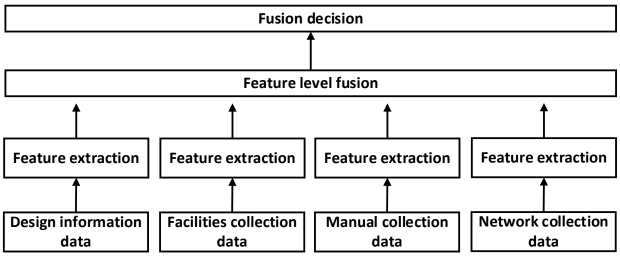

Fig.4 Schematic diagram of multi-source information fusion technology

The transport infrastructure digital management platform assists in scientific maintenance decision-making by reasonably summarizing and storing transport infrastructure information, realizing the sharing of asset information.

III. CONCLUSION

In the last decades, transportation systems have witnessed a demand growth, caused by factors like an increasing local and international mobility, globalized trades and mainly improvement of economic conditions. The complexity of transportation systems has therefore getting more significant than previously, generating high transport volumes and huge amounts of related information. The application of BIM process to transport infrastructure can facilitate their management, as BIM allows the creation of realistic 3D models which can be enriched with technical data; BIM also allows sharing this information among stakeholders of different backgrounds. ITS technology like radars, sensors, and automated devices interconnected within a network, permit much easier management operations and the creation of detailed databases which can be implemented into models. The integration of BIM, GIS and ITS lead to powerful models which can be used for tasks such as monitoring infrastructure's safety, controlling an Intelligent routes and flow. This information can be viewed and analyzed in real time and quickly shared and analyzed, afterward shared among technicians and professionals, and it's relatively easy to consult thanks to the accuracy of 3D models. Future research might be directed towards the implementation aspect of BIM, GIS and ITS, also searching for new applications, methods of data processing and finding solutions to make these technologies more accurate, widespread and cost-effective [14], [15].

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