IMPACT OF THE ICT ON THE MANAGEMENT AND PERFORMANCE OF INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract: Intelligent Transportation Systems (ITS) modelling, planning, and control are research streams that, in the last years, have received a significant attention by the researcher and practitioner communities due not only to their economic impact, but also to the complexity of decisional, organizational, and management problems. Indeed, the increasing complexity of these systems and the availability of the modern ICT (Information and Communication Technologies) for the interaction among the different decision makers and for the acquisition of information by the decision makers, require both the development of suitable models and the solution of new decision problems. This presentation is aimed at showing the new attractive researches and projects in the field of ITS operational control and management in Europe. In particular, it points out the key solution of using effectively and efficiently the latest developments of ICT for ITS operational management.

1 INTRODUCTION

The term Intelligent Transportation Systems (ITS) is used to refer to technologies, infrastructure, and services, as well as the planning, operation, and control methods to be used for the transportation of person and freight. In particular, Information and Communication Technologies (ICT) are considered to be the key tools to improve efficiency and safety in transportation systems. Indeed, the advent of ICT has a tremendous impact on the planning and operations of freight transportation and on traffic management systems. ITS technologies increase the flow of available data, improve the timeliness and quality of information and offer the possibility to control and coordinate operations and traffic in real-time. Significant research efforts are required to adequately model the various planning and management problems under ITS and real-time information, and to develop efficient solution methods.

In recent years, the European Union has sponsored several projects targeting advancements of different transportation systems. On the other hand, ITS topics are considered relevant and attractive research areas.

In Section 2 the paper recalls the most important European Projects in the fields of ITS and intelligent freight transportation. Moreover, Sections 3 and 4 present the research advances in two crucial sectors of ITS: the management of Urban Traffic Networks (UTN) and of Intermodal Transportation Networks (ITN), respectively.

2 EUROPEAN PROJECTS IN THE FIELD OF ITS

A basic project on ITS is CESAR I & II (Co-operative European System for Advanced Information Redistribution) that proposes an Internet communication platform that aims to integrate services and data for unaccompanied traffic and the rolling motorway traffic management. Moreover, in the field of railway system management, CroBIT (Cross Border Information Technology) is a new system that provides the railways with a tool to track consignments and integrates freight railways along a transport corridor providing total shipment visibility. A maritime navigation information structure in

European waters is established by MarNIS (Maritime Navigation Information Systems) that is an integrated project aiming to develop tools that can be used to exchange maritime navigation information and to improve safety, security and efficiency of maritime traffic.

In addition, several projects focus specifically on efficient freight transportation. For instance, Freightwise aims to establish a framework for efficient co-modal freight transport on the Norwegian ARKTRANS system. One of the main objectives in Freightwise is establishing a framework for efficient co-modal freight transport and simplifying the interaction among stakeholders during planning, execution and completion of transport operations. Moreover, the project e-Freight is a continuation of Freightwise to promote efficient and simplified solutions in support of cooperation, interoperability and consistency in the European Transport System. E-Freight is to support the Freight Logistics Action Plan, which focuses on quality and efficiency for the movement of goods, as well as on ensuring that freight-related information travels easily among modes. Furthermore, in the Seventh Framework Program (FP7-ICT Objective 6.1), the SMARTFREIGHT project wants to make urban freight transport more efficient, environmentally friendly and safe by answering to challenges related to traffic management and the relative coordination. Indeed, freight distribution management in city centres is usually operated by several commercial companies and there is no coordination of these activities in a way that would benefit the city. The main aim of SMARTFREIGHT is therefore to specify, implement and evaluate ICT solutions that integrate urban traffic management systems with the management of freight and logistics in urban areas. Finally, EURIDICE (European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics) is a project sponsored by the European Commission under the 7th Framework Program seeking to develop an advanced European logistics system around the concept of ‘intelligent cargo’. The goal is networking cargo objects like packages, vehicles and containers to provide information services whenever required along the transport chain. The project aims to build an information service platform centred on the individual cargo item and its interaction with the surrounding environment and the user.

3 URBAN TRAFFIC MANAGEMENT

Traffic congestion of urban roads undermines mobility in major cities. Traditionally, the congestion problem on surface streets was dealt by adding more lanes and new links to the existing Urban Traffic Networks (UTN). Since such a solution can no longer be considered for limited availability of space in urban centres, greater emphasis is nowadays placed on traffic management through the implementation and operation of ICT. In particular, traffic signal control on surface street networks plays a central role in traffic management. Despite the large research efforts on the topic, the problem of urban intersection congestion remains an open issue (Lo, 2001, Papageorgiou, 1999). Most of the currently implemented traffic control systems may be grouped into two principal classes (Papageorgiou et al., 2003, Patel and Ranganathan, 2001): i) fixed time strategies, that are derived off-line by use of optimization codes based on historical traffic data; ii) vehicle actuated strategies, that perform an on-line optimization and synchronization of the signal timing plans and make use of real time measurements. While the fixed time strategies do not use information on the actual traffic situation, the second actuated control class can be viewed as a traffic responsive network signal policy employing signal timing plans that respond automatically to traffic conditions. In a real time control strategy, detectors located on the intersection approaches monitor traffic conditions and feed information on the actual system state to the real time controller, which selects the duration of the phases in the signal timing plan in order to optimize an objective function. Although the corresponding optimal control problem may readily be formulated, its real time solution and realization in a control loop has to face several difficulties such as the size and the combinatorial nature of the optimization problem, the measurements of traffic conditions and the presence of unpredictable disturbances. The first and most notable of vehicle actuated techniques is the British SCOOT (Hunt et al., 1982), that decides an incremental change of splits, offsets and cycle times based on real time measurements. However, although SCOOT exhibits a centralized hardware architecture, the strategy is functionally decentralized with regard to splits setting. A formulation of the traffic signal network optimization strategy is presented in (Lo, 2001) and (Wey, 2000). However, the resulting procedures lead to complex mixed integer linear programming problems that are computationally intensive and the formulation for real networks requires heuristics for solutions. Furthermore, Diakaki *et al.* (2002) propose a traffic responsive urban control strategy based on a feedback approach involving the application of a systematic and powerful control design method. Despite the simplicity and the efficiency of the proposed control strategy, such a modelling approach can not directly consider the effects of offset for consecutive junctions and the time-variance of the turning rates and the saturation flows.

An improvement on urban traffic actuated control strategies is provided in (Dotoli et al., 2006) where the green splits for a fixed cycle time are determined in real time, in order to minimize the number of vehicles in queue in the considered signalized area. The paper gives a contribution in facing the *apparently insurmountable difficulties* (Papageorgiou et al., 2003) in the real time solution and realization of the control loop governing an urban intersection by traffic lights. To this aim, the paper pursues simplicity in the modelling and in the optimization procedure by presenting a macroscopic model to describe the urban traffic network. Describing the system by a discrete time model with the sampling time equal to the cycle, the timing plan is obtained on the basis of the real traffic knowledge and the traffic measurements in a prefixed set of cycles. The traffic urban control strategy is performed by solving a mathematical programming problem that minimizes the number of vehicles in the considered urban area. The minimization of the objective function is subject to linear constraints derived from the intersection topology, the fixed cycle duration and the minimum and maximum duration of the phases commonly adopted in practice. The optimization problem is solved by a standard optimization software on a personal computer, so that practical applications are possible in a real time control framework.

4 INTERMODAL TRANSPORTATION NETWORKS

Intermodal Transportation Networks (ITN) are logistics systems integrating different transportation services, designed to move goods from origin to destination in a timely manner and using multiple modes of transportation (rail, ocean vessel, truck etc.). In the related literature several papers analyze ITN operations and planning issues as container fleet management, container terminal operations and scheduling. With the development of the new ICT tools, these operative and planning issues can be dealt with in a different way. In fact, these new technologies can effectively impact on the planning and operation of ITS. In particular, ICT solutions can increase the data flow and the information quality while allowing real-time data exchange in transportation systems (Crainic and Kim, 2007, Ramstedt and Woxenius, 2006). As mentioned in (Giannopoulos, 2004), numerous new applications of ICT to the transportation field are in various stages of development, but in the information transfer area the new systems seem to be too unimodal. In the application of ICT solutions to multimodal chains, an important and largely unexplored research field is the assessment of the impact of new technologies before their implementation, by a cost-benefit analysis (Zografos and Regan, 2004, Crainic and Kim, 2007). This research field offers numerous research opportunities: for instance, a not well explored case is that of coordinating independent stakeholders in the presence of uncertainties and lack of information on the stakeholders operations and their propagation within the intermodal chain.

An efficient ITN needs to synchronize the logistics operations. Therefore, information exchange among stakeholders is essential and ICT solutions are key tools to achieve efficiency. Nevertheless, the increasing complexity of these systems and the availability of the modern ICT for the interaction among the different decision makers and for the acquisition of information by the decision makers, require both the development of suitable models and the solution of new decision problems. Moreover, ITN and their decision making process are complex systems characterized by a high degree of interaction, concurrency and synchronization. Hence, ITS can be modeled as Discrete Event Systems (DES), whose dynamics depends on the interaction of discrete events, such as demands, departures and arrivals of means of transport at terminals and acquisitions and releases of resources by vehicles. DES models are widely used to describe decision making and operational processes. In the domain of ITN, the potentialities of these models are not fully explored and exploited. In particular at the operational level, we recall the models in the Petri net (Peterson, 1981) frameworks (Danielis et al., 2009, Di Febbraro et al., 2006, Fischer et al., 2000) and the simulation models (Boschian et al., 2009, Parola and Sciomachen, 2005).

In this presentation we mention two papers (Boschian et al., 2009) and (Danielis et al., 2009) that point out the role and the impact of the ICT applications in the field of the ITN management and control. In particular, paper (Danielis et al., 2009) focuses on the ICT solutions that allow sharing information among stakeholders on the basis of user friendly technologies. To this aim the authors single out some performance indices to evaluate activities, resources (utilization) and output (throughput, lead time) by integrating information flows allowed by the use of ICT tools. A case study is analyzed considering an ITN constituted by a port and a truck terminal of an Italian town including the road-ship transshipment process. The system is modeled and simulated in a timed Petri net framework considering different dynamic conditions characterized by a diverse level of information shared between terminals and operators. The simulation results show that ICT have a huge potential for efficient real time management and operation of ITN, as well as an effective impact on the infrastructures, reducing both the utilization of the system resources as well as the cost performance indices.

An application of the ICT tools to the real-time transport monitoring in order to trace and safely handle moving goods is presented in (Boschian et al., 2009). In particular, the authors analyze and simulate a real case study involving an ITN system and the transport and the customs clearance of goods that arrive to the port and the intermodal terminal. The case study is analyzed in the frame of the EURIDICE Integrated Project. The structure and the dynamics of the ITN model is described by the Unified Modeling Language formalism (Miles and Hamilton, 2006) and is implemented by a discrete-event simulation in Arena environment. The task is to provide services for the efficient utilization of infrastructures, both singularly and across territorial networks (e.g., port terminal synchronization with rail and road connections) and to contain the impact of logistic infrastructures on the local communities, reducing congestion and pollution caused by the associated freight movements. The discrete event simulation study shows that the application of the ICT tools allows us to locate goods and the related up-to-date information and to extend it with useful information-based services. Summing up, the simulation results show that integrating ICT into the system leads to a more efficient system management and drastically reduces the system lead times.

5 CONCLUSIONS

The paper presents the new attractive researches and projects in the field of ITS operational control and management. In particular, the key solutions of using effectively and efficiently the latest developments of ICT for ITS operational management are pointed out. The presentation focuses on the most important European Projects in ITS and on two crucial fields of the ITS management and control: the management of Urban Traffic networks and of Intermodal Transportation Networks. In the two cases are emphasized the new results and the challenges of future researches.

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