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Decision Support Systems in Transport Planning

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Abstract

In this paper, decision support systems as a tool in transport planners' hands will be presented through a literature survey. Different classifications of decision support system examples in transport planning area will be given in order to better understand the relationships and differences in various modes and scales.

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Keywords: Decision Support Systems (DSSs); intelligent transport systems; smart solutions;

1. Introduction

Decision support systems (DSS) are computer technology solutions that can be used to support complex decision making and problem solving. Shim et al. (2002) list the components of a classic DSS tool design as [1]:

(i) sophisticated database management capabilities with access to internal and external data, information, and knowledge,

(ii) powerful modelling functions accessed by a model management system, and

(iii) powerful and simple user interface designs that enable interactive queries, reporting, and graphing functions.

Modern transport planning professionals are no longer capable of solving ever developing problems by using traditional methods. Instead, contributions from other fields of science, such as artificial intelligence, optimization

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algorithms and some advanced statistical analyses, in addition to modern technologies, such as, GIS, Intelligent Transport Systems (ITS) and smart solutions are the tools in modern transport planners' hands.

2. Decision support systems in transport planning area

Use of decision support systems help mainly the professionals of transport planning, urban planning, public-policy planning, public transport operating, service industry and logistics but also individual users of transport systems. Monitoring of traffic conditions, listing all possible travel alternatives or calculating fares are now a part of transport users' daily life. User friendly interfaces in web applications and smart devices in transport decisions not only help individuals but also pave the way for the formation of smart societies.

Zak (2010) classifies DSSs and adjusts them to transportation as [2];

(i) Modal focus, that allows to distinguish among different transport modes.

(ii) Size and scope, that splits transportation – oriented DSS-s into: single user, small network and/or group oriented, and centralized enterprise.

(iii) Conceptual focus, that splits transportation – oriented DSS-s into communication – driven DSSs, data – driven DSSs, document – driven DSSs, that primarily facilitate management, retrieval and manipulation on unstructured information collected in different documents and their handling in a variety of electronic formats, model – driven DSSs, and knowledge – driven DSSs.

(iv) Problem solving approach, that divides transportation – oriented DSSs into: passive systems, and cooperative systems.

(v) Organizational level, at which the decisions are made and time horizon associated with them, that divide transportation – oriented DSS-s into: strategic DSS-s that handle decision situations at the highest organizational level, associated with long – term objectives of the transportation organization/ system; tactical DSS-s that support middle and higher level managers of a transportation company / system dealing with mid- term planning and control and operational DSS-s that support lower level managers in their day-to-day (short – term) managerial activities.

(vi) Subject scope and focus, that define precise areas of application of transportation – oriented DSSs; this criterion allows to distinguish the following categories of computer systems for transportation: fleet management systems, including: fleet composition systems (fleet sizing and vehicle type selection systems), fleet replacement systems, vehicle repair and maintenance systems, vehicle and consignment tracking and monitoring systems, vehicle routing and scheduling systems, transportation processes management systems and supply chain management systems with customized transportation solutions, freight forwarding systems, fleet accidents management systems, electronic fuel dispensing and consumption control systems, transportation personnel management systems, including crew assignment and crew scheduling systems, personnel training and career development systems, crew recruiting systems.

(vii) Underlying decision – making methodology which splits optimization based transportation oriented DSSs (single and multiple objective); simulation based transportation oriented DSSs; game theory based transportation oriented DSSs; data mining/exploration based transportation oriented DSSs; hybrid methodology transportation oriented DSSs.

(viii) Character of the data handled by the DSS, which lets us recognize deterministic and non-deterministic transportation oriented DSSs;

(ix) Time variability of the data handled by the DSS; this criterion results in recognizing static and dynamic (time dependent) transportation oriented DSSs.

(x) Internet utilization during decision making processes allows us to define online and offline transportation oriented DSSs.

(xi) Way of communication with the user, that lets us distinguish between passive, single phase DSSs and interactive DSSs.

3. Selected Case Studies

The decision support systems of transportation planners cover a wide perspective, ranging from traffic control centres, passenger movements, public transport management for the scheduling and routing of cargo, automated transport systems, etc.

In this part of the study some selected case studies of use of DSSs in solving transportation problems are presented through literature survey. In these cases, contributions from other fields of science, such as artificial intelligence, optimization algorithms and some advanced statistical analyses, in addition to modern technologies, such as GIS, ITS and smart solutions are the tools in modern transport planners' hands.

Soykan &Erol, [3] use DSSs to solve problems of air transport mode [3]. The addressed problem is airline crew scheduling, which is a part of airline schedule planning. Robust airline crew pairing process refers to the procedure of constructing anonymous crew pairings to cover the given flight schedule in near-optimal way that is less prone to disruptions (or at least easier to recover once disrupted). This process has to deal with complicated specifications of inputs and satisfy a number of different and often conflicting constraints. Also user inputs are often needed in several points in the process to obtain high quality and timely solutions. The researchers present a model-driven Decision Support Framework (DSF) which combines an optimization algorithm and a simulation-based schedule evaluation scheme for automating real-world practical robust ACP problem (Fig. 1).

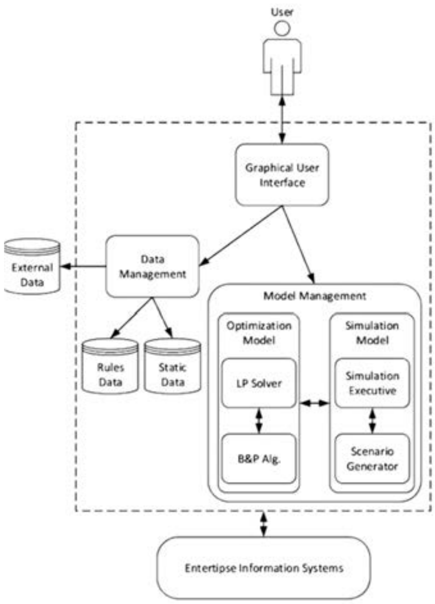


Fig.1. The architecture of the DSF (as a prototype DSS) for airline crew schedule planners [3].

A Branch-and-Price (B & P) approach is utilized as a solution method in which column generation method is applied at each node of the B & B tree. The presented DSF can primarily assist airline crew schedule planners, who have to spend a lot of time and effort creating crew schedules taking into account non-linear cost structure, various amounts of constraints that affect cost and flight safety.

Balas, [4] uses DSSs to solve problems of maritime transport. It proposes a typical investment planning problem with uncertainties and risk parameters that decrease the reliability of cost and income predictions, which coastal engineers are used to face. The case study is from the Iskenderun Pier of Turkey, which is under construction. The superiorities of this proposed simulation-ANN model to other classical investment planning methods were the inclusion of uncertainties in the investment parameters like the change of cargo and costs variables in time, and the determination of project benefit/cost with an improved accuracy. A feasibility analysis model was proposed in this chapter for ports (Fig.2).

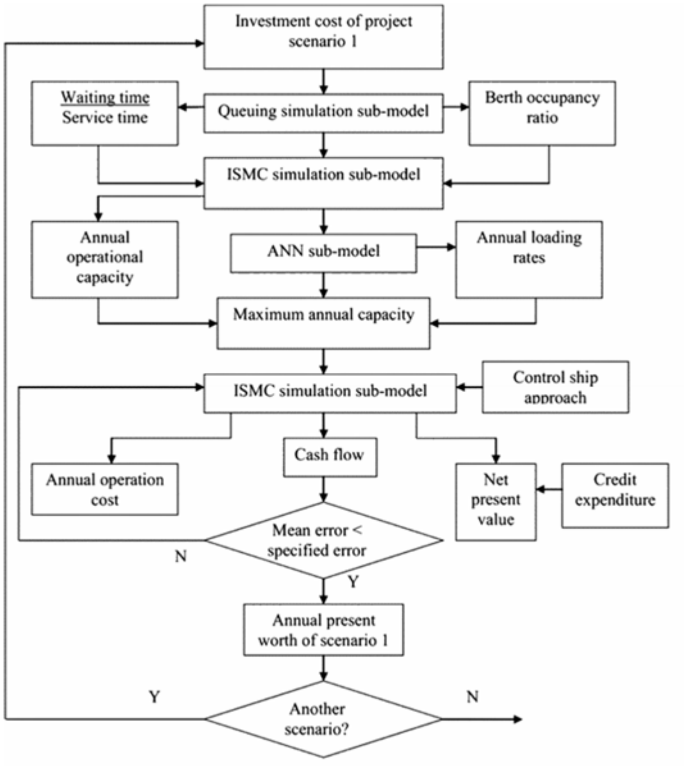


Fig.2. The flowchart of the DSS to calculate feasibility of ports [4].

Three methods were utilized:

(i) Artificial Neural Network (ANN) to determine the rates and capacity of cargo by considering the economic development of hinterland,
(ii) Queuing model to determine the waiting to service time and the berth occupancy ratios,
(iii) Importance Sampling Monte Carlo (ISMC) to simulate ship arrivals/departures from the quays.

The required time to reach the operational capacity in various economic scenarios is determined by the cargo rate predictions of ANN, which is interrelated with ISMC simulation. The artificial intelligence methodology takes the economic developments of the region into account by defining the GNP as one of the input parameters of ANN structures.

Roy et al. [5] review work zones and solve an important maintenance problem in road transport via DSSs [5]. A work zone is the area of a highway where construction, maintenance, or utility work activities that can be identified by warning signs/signals/indicators, including those on transport devices take place.

Work zones also include roadway sections where there is on-going, moving (mobile) work activity such as lane line painting or roadside mowing only if the beginning of the on-going, moving (mobile) work activity is designated by warning signs or signals. The various problems which presaged the increased number of work zones in today’s date also created a myriad of complicated challenges for the various traffic agencies involved in work zone management and estimation. The creation of a work zone changes the road user conditions which then lead to increased number of accidents. The placement, duration and maintenance of work zones are a multi-faceted problem. The highway is not closed, thus work zones can be defined as spatial and temporal restrictions on the roadway which negatively impacts traffic flow conditions. The major concern of most traffic management and planning agencies is the placement of long term. The study describes Extreme Learning Machine (ELM), Minimax Probability Machine Regression (MPMR) and Gaussian Process Regression (GPR) for prediction of work zone capacity.

Ocalir-Akunal [6] presents a case study example to a web based Decision Support System (DSS) for individuals' urban travel alternatives. The case study is from a project prepared for Ankara (Turkey) Municipality, which aims to give individuals the opportunity of choice among all travel alternatives under different criteria, both for public transport riders and car users. A literature survey gives background information from fields of applications of Intelligent Transport Systems (ITS), shortest path problems and web based DSSs. Special emphasis is given to Floyd-Warshall algorithm which is used to solve the shortest travel time between all pairs of points in the case specific problem. In the case study part, the design of the proposed system, its capabilities and examples with screenshots are submitted, to help other researchers design their projects according to the requirements specific for their own cities. The proposed ideas can be applied to the transport net of another city (Fig. 3).

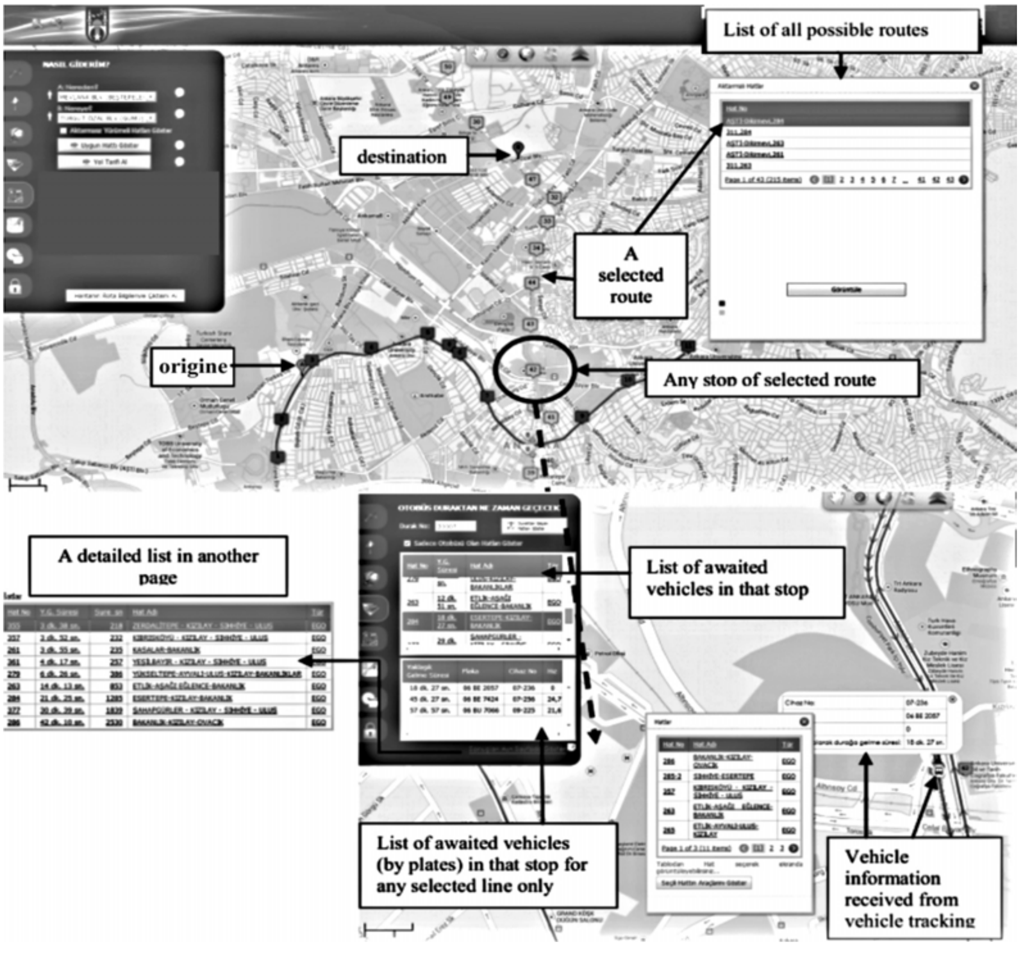


Fig.3. Screenshots from web-based transportation DSS for individuals' travel alternatives.

Akin & Alasalvar [7] model urban growth and expansion based on observed and modelled travel patterns in a study area. In the analysis of interzonal trips using hierarchical cluster analysis (HCA) for 2012 and 2023 as a case study of the province of Sakarya (Turkey). The modelling in this study made possible to analyze the urban structure for different time horizons when O/D travel data are available to understand the interactions over the spatial structure of an urbanized area. The achieved results are useful tools for planners, administrators and policy makers as decision maker to understand the interactions over a spatial structure, and to plan for creating efficient subcentres with more balanced distribution of travel patterns over urban agglomerations. The approach also helps to choose potential areas for future developments.

Murat et al. [8] prepared example to use of analytical hierarchy process (AHP) as a decision support system in the case of (Turkey) for intersection type selection in urban areas. The study is related to higher construction cost of at-grade intersections. The authors gave emphasis on “not signalized intersections”, as the minimum interruptions in traffic flows, average delays, fuel consumption, operating cost and CO emission rates are lower than the others. The analyses that consider operating cost show that preference of at-grade intersections is in the second order. Results of the AHP analysis support also the findings obtained for signalized intersections. Signalized intersections with left turn bay and signalized intersections are also discussed in the chapter. Left turn bays provide an extra space, thus possibility of an accident occurrence can be reduced and also capacity of the adjacent lane can be improved by this way.

Spichkova & Hamilton [9] developed a methodology to provide smart solutions for sustainable outcomes, so that a transport system becomes a part of a ‘smart city’. In this study DSSs are viewed as a special way of partially designing humans out of the main system actions, particularly if it is assumed that the human will follow the decision recommended by the support system. The proposed web-based DSS, which can be a part of a smart city, is designed for the public transport driver, where the request information for the route is collected from the passengers dynamically in real time. The model can help enabling the reduction of greenhouse gas emission and noise pollution, as well as the saving of fuel costs for the public transport service company. Having a more flexible/dense timetable and possible longer routes as well as subjective shorter travelling times are other possible outcomes of the model (Fig.4).

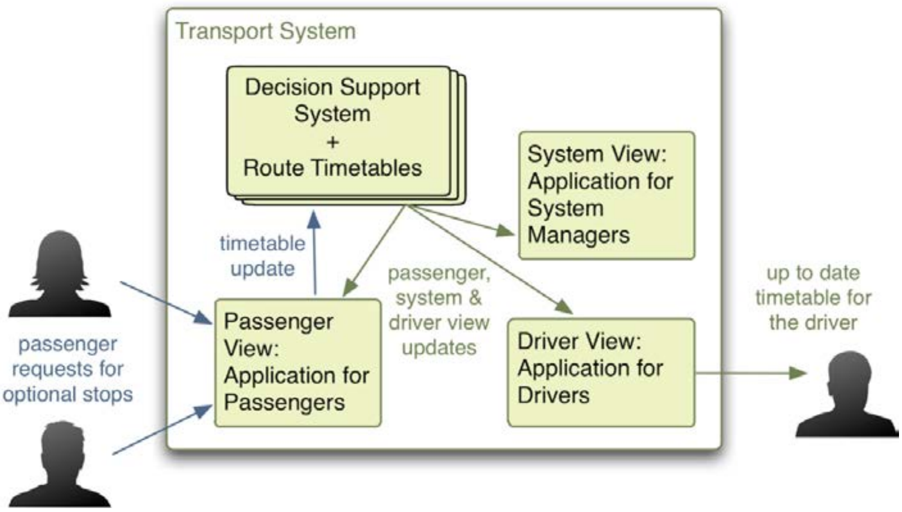
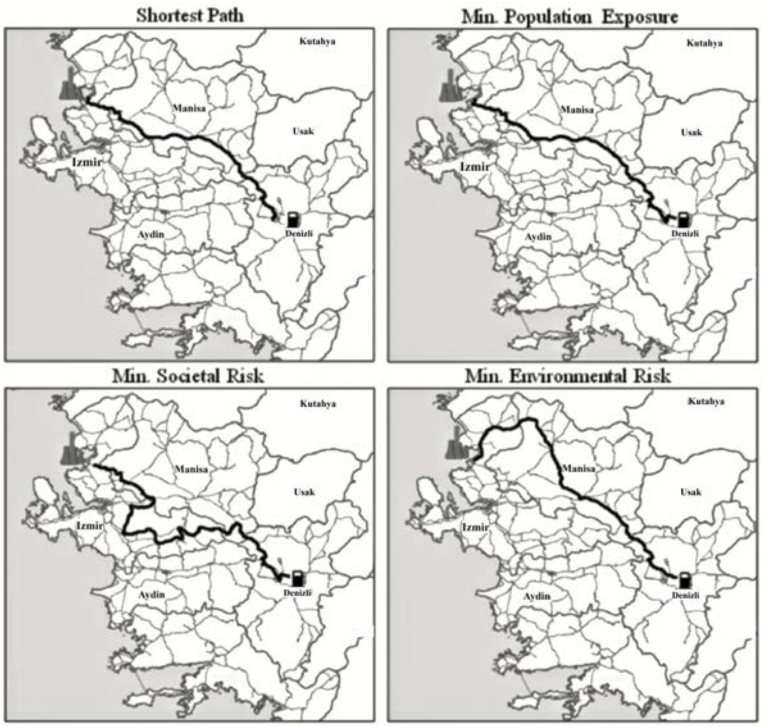


Fig.4. DSS designed for public transport drivers for transport on–demand.

Niţă & Niculae [10] analyse the connectivity of the Natura 2000 protected areas network for terrestrial mammals in the Alpine Biogeographic Region from Romania by evaluating the spatial distribution of Sites of Community Importance in the Region and assessing the functional connectivity of the protected areas network on two scenarios: with and without the impact induced by the roads network. The analysis includes a number of 125 sites and the distribution of 17 species of terrestrial mammals, protected under the Habitats Directive, each having different dispersion distances and different home-range sizes. The protected areas crossed by the transportation infrastructure are considered to be disconnected. The achieved results for the case study area opens a horizon in discussions about the adverse effects of transport on environment.

Gamberi et al. [11] prepared a multi-objective optimizer for multimodal distribution networks [11]. The authors discuss the effective design of multimodal distribution networks (DNs) from a multi-objective perspective. Three of the most relevant optimization drivers are jointly considered looking for the multi-objective optimal network configuration. The operating cost function stresses the importance of effective DNs to save money making the retailer/end-user full price convenient, the carbon footprint looks for environmentally sustainable DNs able to mitigate the impact on the climate change and to reduce emissions due to production, storage and shipment activities. Finally, the delivery time function forces to speed the distribution process to promptly supply the market demand. The tri-objective model is behind an optimizer decision support system (DSS) supporting the planner in the steps to design an effective supply chain network. The application is exemplified through a case study taken from the fresh food industry. Particularly, the peculiarities of food produces are considered to update the general multi-objective model, e.g. produce perishability. The data are from Italian producers distributing products to multiple European countries. Short and long shelf life products are studied to highlight differences in the most effective shipping strategies. The key outcomes stress opposite trends between operating cost and environmental impact on one side and the time objective function on the other.

Karabulut & Ocalir-Akunal [12] prepared a tool for GIS based risk analysis for transportation of dangerous goods on road (the RAGISADR). The proposed model has been developed to evaluate the environmental risks of transportation of dangerous goods on road. In this chapter a risk based decision support model is used as a tool for route decision making of fuel products. The relevance of the model as a decision support tool is demonstrated through a case application to a road network in a region in western Turkey. The priority weights of each environmental criterion are calculated by using Analytical Hierarchy Process (AHP). The most convenient route according to the criteria set is determined after assessing the outcomes of the risk analyses models (Fig.5).



Objective	Distance (km)
Shortest Path	270
Min. Population Exposure	297
Min. Incident Probability	398
Min. Societal Risk	431
Min. Environmental Risk	332

Fig.5. Results from the RAGISADR [12].

4. Conclusion

During the last three decades, the use of computers has contributed a lot to the practice of transport planning. In addition to gaining the ability to build up more complex models in order to analyse collected data, some new approaches, which take human behaviour into consideration, have been added to transport planners' tools. Increasing use of computers gives transport planners possibilities to handle much more data with increasing precision in very limited timeframes. This modern perspective in decision-making in transportation planning is mainly fed by scientific approaches of systems thinking, GIS, information systems and artificial intelligence. The results of any analysis regarding any transport decision can be easily visualized and presented to decision maker. A single solution is usually replaced by a set of solutions with a comparative list of advantages and disadvantages. Use of decision support systems help mainly to professionals of transport planning, urban planning, public-policy planning, public transport operating, service industry and logistics but also individual users of transport systems. Monitoring of traffic conditions, listing all possible travel alternatives or calculating fares are now a part of transport users' daily life. User friendly interfaces in web applications and smart devices in transport decisions not only help individuals but also pave the way for the formation of smart societies.

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