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A SURVEY ON MULTIMODAL TRANSPORTATION SYSTEM

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ABSTRACT

Human mobility within an urban usually happens over a multimodal transportation network. For that reason, when studying, analyzing transportation systems one should not consider each mode of transport separately but one should look to it as multimodal transportation system with relations and dynamics between its components. In order to do any analysis related to transportation a model reflecting the multimodal nature of the system is needed. The objective of the research is to develop a GIS data model for a multimodal transportation system combining different modes in one network that allows different modal combination in route planning.

Keywords: Multimodal Transport System, Transport System, GIS, Etc.

I. INTRODUCTION

People move continuously in space from origins for a purpose or to engage in an activity at destinations. Trips are made using different means of transport that can be motorized or non motorized modes of transport. Motorized likes cars, trains, buses and non motorized are basically walking & cycling. Trips are seldom made by only one mode of transport what is known as unimodal trips. City development is closely related to urban transport development. In the modem city, travel modes develop form the original foot mode too many ways. With the popularity of motor vehicles, travels by car become the most popular way. But there are also many problems, such as traffic jam, environmental pollution and so on. It shows that the rational development of multi-modal travel has become urban transport development trends. In order to solve urban traffic problems, we should encourage using high-capacity public transport, and promote development of multi-modal travel.

Advanced Traveler Information Systems (ATIS) are becoming more and more popular in many countries around the world such as United States, Japan, Europe and so on. Traveler information is provided by various means using communication, computation, and sensor technologies and related hardware. Applications can be found through computers, television, radio, telephone, or internet. Intelligent transportation service, however, mostly provided in one transportation modes such as car navigation or separated public and/or private transportation modes through web. More concern should be engaged in routing with more than two transportation modes in one journey, especially for ATIS application. Van Nes, R. has discussed the definition of multi-modal travel, i.e., two or more different modes are involved for a single trip between which the traveler

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has to make a transfer. The purpose of multi-modal route planning is to provide the traveler with optimal, feasible and personalized route between origin and destination (O-D), where the route may utilize several transportation modes including public and private transportations. The existing route planning systems provide bus-subway transfer, car navigation mostly; few have access to walking guidance. The only walking path provided by Google Map has specifically pointed out "this route may be missing sidewalks or pedestrian paths". Without considering walking guidance, it is hardly able to provide viable pedestrian door-to-door travel routes, not to mention the optimization and personalization guidance.

Route planning problem is used to be represented as an optimal problem which is aiming at providing feasible route under certain needs. The optimal solution is defined over a set of evaluation criteria considered by the user during the route selection process. Real-world optimization problems can hardly be expressed with just one criterion. Researches in multi-criteria evaluation for routes concentrate generally in two aspects. One is trying to figure out the possible criteria when people travel out which is often accompany with experiments and grouping the most likely criteria from existing ones to the minimal numbers. Others concentrate on how to utilize these minimal criteria to solve optimal problems.

II. LITERATURE SURVEY

2.1 Multimodal Transportation systems

It is the "combination of traveler modes & kinds of transportation systems operated through various systems". From this definition, it is possible to distinguish the main elements of multimodal transportation system as:

- Travelers
- Different modes of transports
- Different operators

It can also be defined from the perspective of the movement or the trip. According to that it can also be defined as "the use of two or more modes involved in the movement of people or goods from origin to destination.

Fig. 1: Multi Modal Transport Trip (Transfer point is denoted by the bold T)

Multi Modal Transport System (MMTS) relates to single consisting of combination of modes i.e. vehicle modes metro, car, tram, etc.) or service modes (private/public) between which the traveler has to make a transfer. (T) Transfer points are the points that connect the modes' networks together in one larger network and where travelers can change mode. Transfer is the core concept of multimodality and what makes the multimodal system different than considering each mode separately. From that we can say that a multimodal transportation system is a set of choices of modes of transport which travelers can use with different combinations according to their needs and preferences to reach their destination.

Multimodal transportation is seen as one of the solutions to encourage people to use the public transport. The main idea is to complete a part of a trip by car, park in one of the designated park-and-ride parking lots, and continue the trip by using a certain means of public transport. In this way, people living in areas not covered by convenient public transport systems may complete the mentioned "last mile" by utilising their personal vehicles to a point where public transportation system is denser and then continue their trips by the public transport [11].

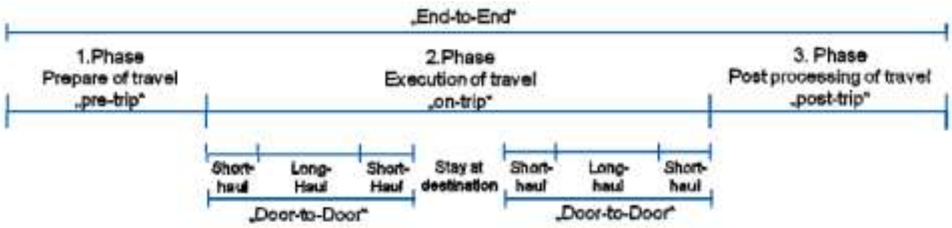

Fig. 2: Phases of Business Trip

Multimodal trips can be divided to into three sections as in Fig.2. The first route section is the way from the starting point (e.g. place of work) to a transport station (e.g. airport). Usually this section of the journey is a short-haul section. The subsequent main section is the longest distance (long-haul, e.g. airport-airport), in the travel chain which is done using the main mode of transport (e.g. airplane). The last section is like the first route section a short-haul to the final destination. The coverage of all partial sections between start and destination is referred to as "door-to-door". The distance covered in the subsections is not necessarily in accordance with accumulating time or expense [12].

2.2. GIS (Geographic Information Systems)

Among all the supporting technologies of transportation and navigation, Geographic Information Systems (GIS) always plays an important role. GIS as a powerful tool for geospatial data management; visualization, presentation and analysis are widely used to model transportation networks. Most of commercial GIS software contains packages which solve the conventional route planning problem, but without taking into account the integration of multiple transport modes. Also, some of route planning systems are making efforts to integrate more transportation modes, e.g. Google Maps added "Walking", "By public transit", and "Bicycling" options besides "By car" in its Get Directions function for some areas but still the route planning is performed separately for each mode, i.e. one mode at time. For that a mode that integrates all the modes of the transport system of an urban area in one network is believed to be capable to define routes between origins and destination, over the network, making use of different modes in order to find the route with the least cost.

23 Concept for a multimodal business travel portal: Identification of a holistic business travel process and the required functional building blocks:

This technique covers a multimodal for business trip. They divided the trip into three phases: pre-trip, on-trip, post-trip. The *planning phase (pre-trip phase)* for business trips – in contrast to tourism travel – takes only a few hours or days. In this phase, decisions regarding means of transport or accommodation will be made on the basis of more or less intensive information gathering. The scope of information gathering is determined by the duration of the trip, the distance and the number of destinations to be visited. The *on-trip phase* starts with the actual departure, defined by leaving the apartment or workplace. The on-trip phase is characterized by taking place mainly outside of the habitual abode. This phase consists of at least transportation (round trip within a day) and possibly accommodation at the destination. The post-trip phase consists of billing and reimbursement of travel expenses. The expenditures paid by corporate card should automatically be detected by the cost accounting system. Cash payments and payments with a private credit card must be recorded manually. In the case that no accounting system is available all spending would need to be captured manually.

In order to define the building blocks of a holistic business travel assistant use cases which typically occur before, during and after a business trip were created and analyzed. The services range from route planning to the travel expense accounting [1].

2.4 In-Vehicle Application for Multimodal Route Planning and Analysis

The authors developed a solution by combining web services, vehicle data and integration with an in-car infotainment system. to guide a user to public transport transfer spots. Their solution offers optimal park-and-ride transfer points, which will benefit the driver during the whole trip. They developed an android application for multimodal route planner. The main components of this applications are routing algorithm, Smart Device Link proxy library. The routing algorithm will calculate an optimal transfer points and the proxy library is used for communicating with IVI system and navigation modules to guide the user. Smart Device Link component provides various information about the vehicle, such as current fuel consumption, odometer data, engine speed, vehicle speed, current heading and Global Positioning System (GPS) position (vehicle speed, heading and GPS position may be obtained from a smartphone if some of the data are not available from the Smart Device Link component, though using phone's GPS is not preferred).

2.5 Multi-Modal Transportation Optimization of a Local Corridor

The objective of this technique is to re-design a multimodal transport system which will safely integrate motor vehicles, bicyclists and pedestrian traffic. Traditional traffic engineering emphasizes on optimizing vehicular traffic movements and pedestrian and bicyclist traffic movements are considered as constraints. The focus of this research is to develop a way to maximize the capacity of existing right-of-way for all three traffic movements simultaneously, using a common metric of person-trips [3].

2.6 Dynamic Route Selection in Route Planners

This technique has outlined the concept of a user interface for route planners, which provides immediate feedback through an updated route on a map once the user changes the preference weights. The basis for an

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2.8 Multi-Modal Path Guidance Based on the Real Traffic Information

In this approach the author introduces the multimodal path guidance model based on real traffic information. They had built the dynamic trip guidance system based on above system. The system can obtain real traffic information to serve the path planning of trip to reduce the relay and number of stops. Based on the GIS and database, they build the multi-modal urban dynamic traffic guidance system. It will become the development direction of ITS, which can reduce the traffic jam [7].

2.9 The need to model multimodal transportation systems

The models for multimodal transportation systems are used for a wide range of functionalities. They can be used for assessing the current performance of a transportation system like assessing the regional accessibility of a neighborhood. It can also act as a decision support tool for transportation policies such as assessing the overall performance of the transportation system of an area after introducing a new route or line for a specific mode of transport. For example, [10] used a similar model to assess the introduction of more bike and ride facilities at bus stops in Dutch cities. A model for multimodal transport can also help measure the benefits of integrated transport system like assessing the benefits of integrating non-motorized transport with public transport which can only be performed in a multimodal context.

Finally such models can also assist in route planning. Commuters need improved means to solve the problems affecting their journey in a multimodal context aiming to find the optimal route between the source and the target of the trip using different modes of transportation [11]. Providing commuters with path finding options or the optimal route with the least cost as well as the overall travel cost is expected to help in trip planning and route choice. Such information can only be obtained by a model encompassing all modes in one network.

Most of commercial GIS software contains applications which solve the conventional route planning problem, but without taking into account the integration of multiple transport modes. Also, some of route planning systems are making efforts to integrate more transportation modes, e.g. Google Maps added "Walking", "By

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In multimodal transportation system main components can be identified as: modes operating on infrastructure network and travelers moving from origin to destination using these modes. So, logically speaking, three conceptual layers can be defined in a multimodal transportation system.

Physical level: encompassing infrastructure network (streets network, train railway network, metro railway network).

Transportation level: in which elements of modes of transport are defined. Transportation modes operate on infrastructure network. Modes routes are delineated based on existing infrastructure. Train railway is the train route instead of just its physical existence. Roads are detailed to its modal functionalities. Roads represent: bikes lanes, car paths, bus lines and pedestrian sidewalks. Also different stations, stops, terminals and parking are present in this layer.

Movement or trip layer: in which people use the previous two layers to move from origin to destination with different combinations according to their preferences and characteristics. By combining all these components in a GIS model representing multimodal transportation system as shown in Fig.4.

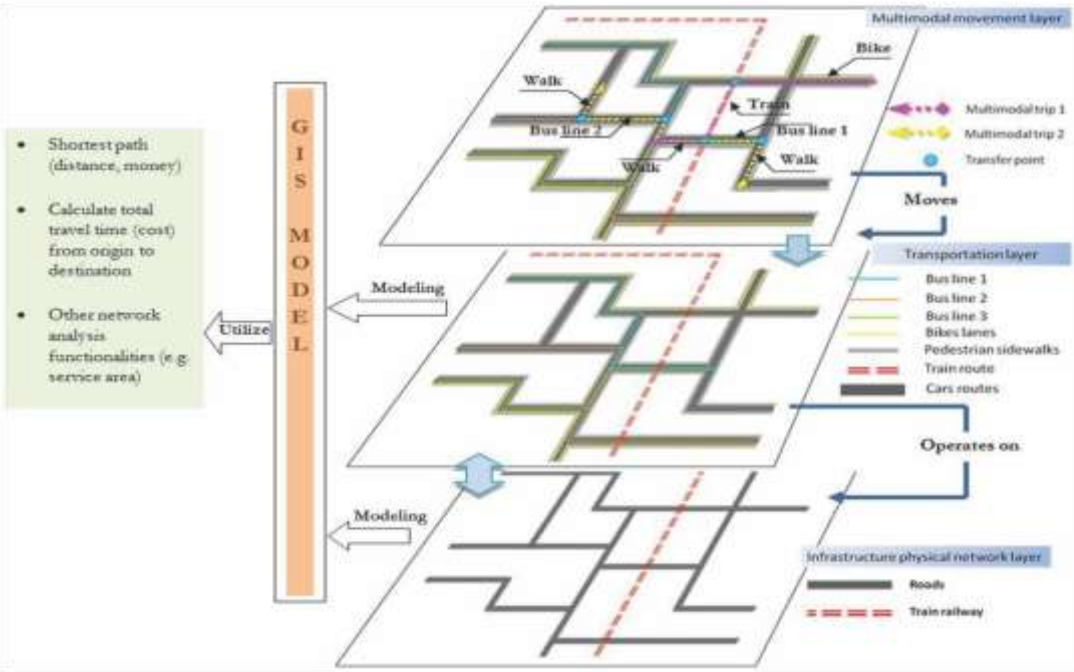

Fig 4. Conceptual representation of a multimodal transportation system

III. ANALYSIS OF SOME MULTIMODAL TECHNIQUES

Paper Name & Author	Basic Concepts	Methodology Used	Parameters	Authors Findings	Our Findings
Fully Agent-based Simulation Model of Multimodal Mobility in European Cities. [12]	In this paper they have introduced a fully agent-based model of multimodal mobility built on top of open-source simulation platform AgentPolis, employing the activity-based modeling paradigm. This paper introduces the most recent and most comprehensive application of AgentPolis platform so far - a large- scale activity-based models of multimodal mobility, covering areas up to thousands of square kilometres and simulating populations of up	Leveraging the fully agent-based modelling approach, they have built large-scale activity-based models of multimodal mobility covering areas up to thousands of square kilometres and simulating populations of up to millions of inhabitants of several European cities.	The fully agent-based modelling approach, large-scale activity-based models of multimodal mobility. AgentPolis, employing the activity-based modeling paradigm.	They have given an overview of the model archi- tecture and implementation details regarding the environment and agent models.	The environment covers transport infrastructure, means of transport and points of interest extracted from multiple publicly available data sources. The synthesis of citizen agent population as well as generation of activity schedules from which an execution of actual traffic is derived are presented in detail.

	to millions of inhabitants of European cities. The models aim to realistically reproduce travel in a multimodal urban transport system in a bottom-up manner, employing the fully agent-based and activity-based modelling approach, where autonomous, self-interested agents schedule their activities (work, shopping, leisure, etc.) and trips in time and space.				
Intelligent Regulation Support System for Multimodal Traffic [13]	This paper presents an interactive, effective and intelligent regulation support system (RSS). The objective is to regulate a disturbed multimodal transport network by assisting the regulators in the evaluation and	An efficient using of multi-agent paradigm through a regulation support system (RSS). Indeed, multi-agent paradigm illustrates some efficient utility in several system architectures. A mathematical formulation is proposed in	RSS	They have developed a multi-model traffic regulation strategy based on a multi-agent system. Unlike other approaches, the model assists the regulators (decisions-makers), proposes them effective solutions and takes into account their preferences.	In order to evaluate the efficiency of the suggested approach, they used some data from a real multimodal transport network.

	the choice of the most efficient decision. In our approach the traffic regulation is obtained thanks to communication, collaboration and negotiation between heterogeneous agents who are able to detect perturbations, analyze, propose and evaluate solutions using choquet integral.	section 3 by defining the space-time regulation horizon, decision variables, criteria and constraints of the regulation problem			
Towards an Integrated Multimodal Transportation Dashboard. [14]	This article proposes a solution for the monitoring of the operational state of multimodal transportation systems in a single dashboard.	Hierarchical LOS Evaluation	Road Traffic, Urban Public Transport, Interurban public Transport	Hierarchical model of LOS was developed and the evaluation inspired by the concept of ontology. For testing purpose they have implemented a prototype of the dashboard that combines the Level of Service (LOS) measures of different transport modes and detail level and permits LOS analysis at	A proposed solution is a dashboard that provides a comprehensive view on the operational state, or Level of Service (LOS), of transportation systems of different types. Such a system is expected to become an essential tool for transport system monitoring and

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				different geographic scale: the entire monitored zone, its areas and sub-areas.	management, supplying the necessary information for strategic and emergency planning to the authorities and other decision makers in the sector.
To switch travel mode or not? Impact of Smartphone delivered high-quality multimodal information. [15]	Travellers' mode switch behaviour with the presence of high-quality Smartphone delivered multimodal information (SMMI) seems to have rarely been addressed.	Modelling method, Data collection method,	Smartphone delivered multimodal information (SMMI),	This study investigated commuters' en-trip mode decision about switching from 'auto' to 'park-and-ride' (P + R) under high-quality SMMI that provides travel time for both modes, delay for auto, cause of delay, P + R cost and comfort level of rail transit. It is based on a stated preference survey of Shanghai travellers. A binary logit model was developed to identify contributing factors that affect mode switching decisions	The developed mode switch model may be incorporated within a dynamic multi-mode transportation simulation model to estimate switching rate and forecast traffic demands on alternate modes under given delay scenarios and assess network-level impacts of SMMI. This will help transportation agencies make better decisions on SMMI deployments.

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