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BOOK OF ABSTRACT

A Bayesian methodology for route choice inference based on Bluetooth data

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Abstract—By installing Bluetooth sensors at a specific set of intersections it is possible to detect the passage of vehicles equipped with Bluetooth technology by these points. However, Bluetooth-enabled vehicles are not necessarily detected by every sensor they pass by, because the probability of detection depends on several factors, such as weather, nearby infrastructure, or the speed of the vehicle. To address this lack of perfect information, this study describes a methodology to infer the most likely route used by a vehicle between two successive detections. The methodology consists of three stages. The first stage entails drawing up a graph of the road network and the location of Bluetooth sensors. The second stage consists of using the Bluetooth-acquired data to calibrate the distribution of dwell time at each node and travel time for each edge of the graph defined in Stage 1. The third and final stage consists of convoluting node and edge time distributions between successive detections to obtain an aggregate distribution for each potential route. A Bayesian inference is then applied based on the travel time observed for each vehicle and the set of detections that did not occur, to determine the probability of each route. Keywords—Bluetooth technology, Route reconstruction, Bayesian inference, MAC address)

A low dimensional model for bike sharing demand forecasting

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Abstract— Big, transport-related datasets are nowadays publicly available, which makes data-driven mobility analysis possible. Trips with their origins, destinations and travel times are collected in publicly available big databases, which allows for a deeper and richer understanding of mobility patterns. This paper proposes a low dimensional approach to combine these data sources with weather data in order to forecast the daily demand for Bike Sharing Systems (BSS). The core of this approach lies in the proposed clustering technique, which reduces the dimension of the problem and, differently from other machine learning techniques, requires limited assumptions on the model or its parameters. The proposed clustering technique synthesizes mobility data quantitatively (number of trips) and spatially (mean trip origin and destination). This allows identifying recursive mobility patterns that - when combined with weather data - provide accurate predictions of the demand. The method is tested with real-world data from New York City. We synthesize more that four millions trips into vectors of movement, which are then combined with weather data to forecast the daily demand at a city-level. Results show that, already with a one-parameters model, the proposed approach provides accurate predictions.

A scalable approach for short-term predictions of link traffic flow by online association of clustering profiles

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Abstract — Short-term prediction of traffic flows is an important topic for any traffic management control room. Nowadays, the large availability of real-time data in urban contexts raises not only the expectations for high accuracy of the forecast methodology, but also the requirements for fast performance of the computation engine. These capabilities must be horizontally scalable in modern IT infrastructure to allow application on large size networks. The proposed approach is based on a real-time association of the latest data received from a sensor on the field to the representative daily profile of one among the clusters that are built offline based on an historical data set. To achieve high scalability, the spatial correlations among different sensors are ignored, and for each of them an independent model is built-up. Therefore, each sensor has its own clusters of profiles with their representatives; during the short-term forecast operation the most similar representative is selected by looking at the last data received in a specified time window and the proposed forecast corresponds to the values of the cluster representative. Despite the number of clusters is small (on average, a dozen for each sensor), the fact that the association is done every time new data are coming makes the prediction capable to flexibly adapt to daily fluctuations. The paper investigates the quality of the proposed forecast methodology on a real data set in urban environment. An important ingredient of the methodology is clearly the clustering technique that is used offline. We adopted the Affinity Propagation, because it is an unsupervised approach where the number of clusters is deduced by the data itself and the algorithm has really few parameters to be fine-tuned. Special attention needs to be put in a proper definition of similarity between profiles to make the clustering algorithm and the realtime association work properly. The proposed methodology will be compared with the naïve approach of repeating the same value just received from the field for the whole forecast period. The naïve approach can be used to benchmark other methodologies. Despite its simplicity, the proposed approach allows to achieve high scalability in real productive environments while proving a limited loss of accuracy with respect to more complex forecast methodologies that we tested in other works [2], [3].

A Simulation Tool for Energy Management of E-Mobility in Urban Areas

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Abstract —In this paper we describe a simulation tool developed to study city wide scenarios of e-mobility. The tool is intended to support e-mobility stakeholders in finding effective solutions to facilitate a widespread and sustainable EV adoption in urban areas. The tool includes a suite of integrated models designed to reproduce emobility pattern, charging behaviour and resulting impact on electricity demand at a high spatiotemporal resolution. The suite also includes models to evaluate multimodal mobility approaches and smart charging strategies including the use of renewable energy. The simulation tool has been tested in the metropolitan area of Rome (IT). We have used large scale collections of vehicle trajectory data to calibrate and validate the suite of models. Keywords — Electric mobility, multimodal transport, energy management, smart charging strategy

A Multiple Objective Formulation of An Electric Vehicle Routing Problem For Shuttle Bus Fleet at A University Campus

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Abstract— In the present study, we handle the electric bus routing problem considering a road network that serves a university campus area with colleges, dormitories, social and recreational areas, and etc. We propose a multi-objective formulation using the actual network characteristics together with the power consumption characteristics of light electric vehicles, the electricity consumption rates in areas where state universities are located, and an assumption on fast charging station mounting costs. Aiming to minimize the costs of multiple objectives on vehicle operating, recharging, and fast charging station implementation the integer programming model we formulate finds the least cost set of routes for the vehicles originating from a single depot that serves to all the campuswide student transport demand by not exceeding the driving range without visiting a charging station. We originally consider the intersections existing on the case network as intermediate nodes, in addition to bus stop, and hence, sometimes charging station nodes. Keywords— Battery Electric Vehicles; Vehicle Routing Problem; Environmental Sustainability

A New Strategy For The Diagnosis Of The Bus Headways Using AVL Data

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Abstract— Different properties of transit systems determine the quality of service of a public transportation system and reliability is a significant one. Although there is no single concept of reliability, regularity of the headways of the buses is an important measure. Speed and headway information of buses can be easily extracted from Automatic Vehicle Location (AVL) data with the explained method. This study focuses on a novel measurement using kurtosis of distribution of distance headways among buses along a transit route, which is proposed for identifying irregularities from AVL data of buses during public transportation operations. Kurtosis measurement on headway distribution of 5-minute data can provide online problem detection without using historical data each time step. Trajectories of buses in Istanbul, Turkey of 30 days from April 2017 are analyzed. Approximately, there are 5000 timestamps; therefore, 5000 pairs of GPS coordinates in a bus trip in a day, 4000 bus trajectories in a month, and combined, 20 million data points. In this network, the value 4.0 is used as a threshold of kurtosis measure. Above the threshold, there is always an anomaly in the system. Transit operators can follow the proposed analysis of one-week AVL data in order to calibrate a kurtosis threshold value for their network. The findings of this research are valuable for both policy makers and operators in cities having large-scale bus networks. This brief methodology can be easily followed to create a tool that signals operators for problems without investigating each route perpetually. Keywords—automatic vehicle location, headway, intelligent transportation systems, kurtosis, pattern analysis, public transportation

A real time hybrid controller for regulating bus operations and reducing stops at signals

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Abstract—We propose a hybrid controller which consists of holding and a Driver Advisory System (DAS). It combines the objectives of seeking the regularization of operation and the reduction of stop and go actions at signalized intersections. A simple headway based holding criterion is applied at stops to define the time needed to maintain even spaced headways between buses and additionally a speed recommendation is given to traverse during green indication at the downstream signalized intersection. The controller is tested using simulation for a bus line of the city of Luxembourg and compared to a benchmark scenario, the single application of bus holding, two variants of a Cooperative ITS-based speed advisory system and different levels of transit signal priority. Results show that there are additional benefits compared to traditional holding in terms of regularity while similar performance to strong transit signal priority is achieved in terms of time spent at traffic lights. Index Terms—Public transport , Holding Strategy, Cooperative ITS, Driver Advisory System

A study of a comfortable vehicle motion predictive control with no speed limit reference

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Abstract—In the last decade great advances have been achieved in the development of reliable Advanced Driver Assistance Systems. The feeling of safety in automated vehicles performing trajectory tracking in urban environments has become an interesting field of study, where several strategies have been proposed. However, most of the current approaches employ speed limiters for the longitudinal control of automated vehicles to avoid discomfort due to excessive lateral accelerations in paths with high curvatures. Therefore, smoothness of the path must be evaluated previously in a planning stage before the trajectory tracking task. In this work, a comparative study is carried out with different comfortable predictive controllers based on kinematic model approaches. Moreover, the novelty of including the lateral acceleration as an additional state parameter into the tracking stage to avoid a previous speed limit calculation is evaluated. A comparison of the strategies is accomplished using a simulated test vehicle within a realistic environment developed in Dynacar. For that purpose, the control architecture for the automated driving problem is exhaustively explained and lowlevel control disturbances are considered and modeled to scale into a future real implementation of the vehicle motion control strategies. The performed tests demonstrate effectiveness of the proposed approach. Index Terms—Automated Driving, Model Predictive Control, Motion Planning, Vehicle Dynamics.

A two-stage Metaheuristic approach for solving the Vehicle Routing Problem with Simultaneous Pickup/Delivery and Door-to-Door service

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Abstract— This paper presents a novel approach consisting of a two-stage optimization system to solve the problem of the distribution of goods in urban areas. The optimization problem is subject to some real-life constraints like vehicles' capacity, compatibility between orders and vehicles, urban traffic flows, pickup and delivery sequences. In particular, the Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) is considered. In this work, we complicate the problem adding door-to-door operations typical of urban logistics (VRPSPD-D2D). The proposed optimization algorithm is based on two honey bee-inspired metaheuristics: Artificial Bee Colony (ABC) at the first stage; Bee Colony Optimization (BCO) at the second stage. This approach proposes an efficient way in achieving the main objective of this research work: the minimization of the global transportation cost, subject to the demands of the customers and operational constraints. To test our approach, new instances of the VRPSPD-D2D are proposed, based on the Sioux-Falls City network. Results of the proposed Bee System are compared with two Genetic Algorithm-based approaches. Keywords—vehicle routing, simultaneous pickup/delivery, urban logistics, two-stage optimization, metaheuristics

Accident Lane Prediction Using Probabilistic Inference

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Abstract—In this study a Bayesian Hierarchical Model for predicting the accident lane using the average section speed and density data obtained from a sensor or GPS was developed. With the assumption that speed and density values are normally distributed in an accident situation depending on the lane the accident has occurred, the related parameters are modelled and the probability of occurrence for each lane is predicted. This method can be used in real time traffic services where accidents are recorded by users or detected by other algorithms in order to alert the drivers about the lane of the accident. The awareness to the accident lane can ease the channeling of vehicles to the non-accident lanes and can help prevent the secondary accidents. Keywords— accident lane prediction, Bayesian hierarchical model, probabilistic modelling

Adaptable Anomaly Detection in Traffic Flow Time Series

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Abstract—Analysis of traffic data is an essential component of many intelligent transportation system applications where the quality of data plays an important role. Traffic data collected through sensors (e.g. loop detectors) often contain anomalies due to different reasons such as malfunctioning detectors or anomalous traffic conditions. Regardless of their rooting cause, such data heavily affect the results of the subsequent analysis (e.g. traffic prediction). There are a few barriers that make the anomaly detection troublesome including absence of universal definition of anomaly, change of traffic pattern over time, unavailability of labeled data, use-case driven analysis. In this paper, a new anomaly detection method for traffic univariate time-series is proposed which does not assume labeled historical data yet uses expert feedback to deal with the fluid definition of anomaly. The method is exemplified and evaluated by applying it on real traffic time series data collected through loop detectors installed in an urban road network in Europe. Employing the proposed method as a pre-process of traffic state estimation can increase the accuracy measure as well as ease the learning of different traffic patterns. Index Terms—anomaly detection, traffic flow time-series, loop detectors, clustering

An enhanced evolutionary method for routing a fleet of electric modular vehicles

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Abstract—The adoption of electric vehicles are viewed as an environmental friendly initiative and an economic opportunity because the number of these vehicles in the globe would be over 35 million by 2022. However, planning the routes of electric vehicles for timely delivery of goods, involves to take into account the limited energy which may lead the drivers to detour from the initial plan for recharging the batteries. In this work, the studied vehicles are modular. It means that they consist of an innovative system with one cabin for the driver and one or more modules for the goods. The research problem arising when planning the routes of such a fleet of electric modular vehicles is recent. It is a kind of Vehicle Routing Problem with Time Windows (VRPTW) where the objective is also the minimization of all the costs but with some adding constraints linked with the recharges and the nature of the vehicles which are composed of modules. Therefore, the best current methods dedicated to the VRPTW and its variants have been investigated. In this work, we propose to hybridize the population based evolutionary schema with two possible procedures: a local search operator and a variable neighborhood descent. An experimental study is conducted to compare the approaches and show the effectiveness of using the electric modules for freight delivery. Index Terms—Urban logistics, electric modular vehicles, vehicle routing problem, evolutionary algorithms

An Integrated Decision Making Framework For Vehicle Selection in Shuttle Services: Case of A University Campus

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Abstract—One of the most significant activities of life is transportation. An efficient transportation network has many health benefits on a society, such as making work and essential services, recreation facilities, and shopping centers accessible by people and allowing people to contact each other. However, the continuous increase in demand for transportation and consequently the use of vehicles using conventional fuel types, such as fossil fuels, causes serious problems on the environment. Alternative energy sources such as electricity, natural gas, propane, ethanol, methanol, biodiesel and hydrogen, some of which are similar with the traditional fuels and some of which require completely different vehicle properties, are considered as alternatives to gasoline and diesel fuels. As of today since there is a wide variety of vehicle options, including hybrid and electric vehicles, for users the decision on the type of vehicle to be preferred is certainly a challenging task for the purchasers. During the decision-making process, all options should be carefully evaluated in terms of advantages and disadvantages, where Multi Criteria Decision Making (MCDM) can be a helpful tool for decision-makers in this challenging process. In the present study, with the ultimate motivation of aiding the decision making process for renewing the shuttle bus fleet -that is currently composed of all internal combustion engine vehicles- serving to a university campus, we concentrate on the problem of selecting the most suitable vehicle for a mediumscale settlement's road network. Keywords—multi-criteria decision making, AHP, TOPSIS, electric vehicles, hybrid vehicles, internal combustion engine vehicles

An Online Training Tool for Better Understanding the Operation and Significance of ITS

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Abstract—Developments in the fields of Intelligent Transport Systems (ITS) and Cooperative ITS (C-ITS) are continuous and new innovative technological solutions for the provision of more accurate and trustworthy feedback are employed on a regular basis. The last decade, the European Union has funded more than 140 million euros for research in innovative ITS and C-ITS technologies through the HORIZON 2020 funding mechanism.Taking into account the significance of ITS and C-ITS technologies, in the frameworks of the CAPITAL project, an ITS knowledge database has been introduced in order for a common framework to be provided for the deployment of ITS and C-ITS. The ITS knowledge database is presented in the form of Massive Open Online Courses (MOOCs) through the CAPITAL Online Training Platform, developed in the standards of other online training platforms. The solution of MOOCs has been chosen due to the fact that more and more platforms, either university platforms or not, are already introduced for providing educational programs.The ITS knowledge database consists of nine independent topic studies, with each one aiming to describe the current state of the art of ITS and C-ITS. The aforementioned topic studies are the following: *Introduction to ITS and C-ITS.*ITS and C-ITS user services.*TMC and roadside technologies for ITS.*Communication technologies for ITS and C-ITS including relevant standards.* Impact assessment of ITS and impacts of selected ITS and C-ITS systems*Financial incentives, business models and procurement models for C-ITS deployment.* Cost-benefit analyses of ITS services.*Guidance in deploying ITS and C-ITS.*Data protection and privacy.

An Open Toolbox for Integrated Optimization of Public Transport

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Abstract—Public transport networks are a vital factor in the development of urban and peri-urban mobility. Their design is the main contributor to their possible success. Determining line planning, timetabling and vehicle scheduling is a complex set of tasks, which are interconnected in many ways. The development is typically tackled by hand, incorporating multiple objectives, in a time-consuming way. Within each task, decisions require multi-objective optimisation. These planning steps are usually carried out sequentially to simplify matters. However, research has shown that integrated approaches lead to superior solutions. On the other hand, integrated approaches increase computational complexity. We report on a toolbox which can seamlessly integrate the three tasks (line planning, timetabling, vehicle scheduling). A general framework formalises all relevant information and ensures the exchange and interoperability between intermediate solutions of the three separated problems. Then, we formulate the three problems to iterate between the planning steps within an approach inspired by the eigenmodel structure [1]. We refine existing approaches to minimise costs and travel time jointly. Thanks to the extensions and framework we may shrink the size of the problems without loss of optimality. The eigenmodel can significantly reduce complexity, while the extended formulations for line planning, timetabling and vehicle scheduling allows consideration of all relevant limitations. We report a study in the region of Bern, Switzerland. The solution computed for a network of regional buses significantly decreases the demanded effort of the planners. The added value lies in the improved quality of the solution and the shorter response time, enough to support interactive optimisation. Keywords—Integrated Optimization, Public Transit, Planning, Line planning, Timetabling, Vehicle scheduling

Analysis and Prediction of Disruptions in Metro Networks

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Abstract—Public transport disruptions can result in major impacts for passengers and operator. Our study objective is to predict disruption exposure at different stations, incorporating their location-specific characteristics. Based on a 13-month incident database for the Washington metro network, we successfully develop a supervised learning model to predict the expected number of disruptions, per type, station and time of day. This supports public transport authorities and operators to prioritize what type of disruptions at what location to focus on, to potentially achieve the largest reduction in disruption exposure. Our clustering results show that start/terminal and transfer stations are most susceptible to disruptions, mainly due to operations- and vehicle-related disruptions. Keywords—clustering, exposure, prediction, vulnerability

Analysis of Urban Traffic Network Vulnerability and Classification of Signalized Intersections

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Abstract—This work studies urban road traffic networks and discusses ways to assess the importance/criticality of urban links and nodes. A series of indicators are defined that are useful to evaluate spatial and temporal features and identify congestion hot spots. One way to do this is by utilizing concepts from graph theory (e.g. connectivity, efficiency, betweenness). These indicators are based on the structure of the network (graph) and do not require any traffic data. On the other hand, one could utilize historical traffic data (e.g. flows, densities, average speeds) in order to evaluate the importance of an urban link or node to the overall performance of the network. Such an analysis could capture congestion dynamics, spill-backs, and queue propagation in the network. Here, we combine both approaches mentioned above to come up with a classification (or ordering) of the different links and nodes inside a zone. This classification can then be used for real-time traffic control purposes, e.g. a city can choose the intersections that need to be instrumented and reduce the operational cost of online traffic management. Finally, we discuss the correlations between the different indicators that are investigated and how can one take this into account in the decision making process. Index Terms—urban traffic congestion; graph theory; simulation; intersection classification; congestion hot spots.

Applying Traffic Conflicts to Analyze Safety of Conventional and Autonomous Vehicles

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Abstract— Surrogate measures of safety attract revived interest thanks to the advancements in traffic observations techniques and the growing need for rapid safety evaluation. This paper briefly introduces the latest method of analyzing traffic conflicts caused by some sort of failures to estimate the expected frequency of crashes. It can be applied to conventional and autonomous vehicles. The Lomax distribution of drivers' response delays to failures is derived from the causality mechanism with application of the counterfactual approach. The Lomax distribution belongs to the family of extreme value (exceedance version) distributions. The proposed method delivers a consistent and logical framework, intuitive interpretation of the results and conceptually sound and practical way of setting a proper threshold separation between conflicting road users to address the primary concern among traffic conflict experts and users. From this perspective, the proposed method is less restrictive and more appealing than the early proposed extreme value distributions. The fundamentals of the method are briefly explained and an example application to analyzing road departures in a driving simulator presented. The results confirm the expectations derived from the concept of the method. The paper also discusses an application of the method to analyze safety of autonomous vehicles. The data needed for the analysis and expected to be collected in autonomous vehicles are identified. The envisioned applications include estimating the crash probability to better interpret the gravity of near-crash situations experienced by autonomous vehicles, optimization of navigation system's response to threat by minimizing the crash probability, and identifying and estimating the risk factors among others. Keywords— safety analysis, surrogate measures of safety, traffic conflicts, crash frequency, Lomax distribution, road near-departures

Assessment and classification of selected ITS in Poland

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Abstract—The work presents a review of selected Intelligent Transport Systems (ITS) in Poland. In the vast majority of the 29 cities that have been classified by the Central Statistical Office in Poland as the largest cities in terms of population, the ITS already exist. In article selected the ITS in cities with the largest population and where the system was implemented comprehensively i.e. it was implemented as one integrated system. In the case of the already built urban ITS systems, the assessment of the implementation was carried out, among others, on the basis of earlier assumed indicators. These indicators were usually limited to a relative reduction of travel time in the area covered by the project, calculated separately for individual and public transport. Due to implementation of the priority for public transport assumed a stronger effect of reducing the travel time by public vehicles than the individual one. The values of the travel time reduction were planned at around 5-10%. Post-implementation descriptions of systems also indicate qualitative indicators, such as reducing the number of stops, obtaining traffic improvement, increasing safety and a more efficient response to the occurring events. In connection with the above, the authors have compiled the essential functions and roles of selected systems as well as obtained quantitative and qualitative indicators of implementations. The article also presents the classification of the particular ITS, which was implemented on the basis of the obtained data and which includes, inter alia, the cost of building the system, population, implemented subsystems and the number of intersections with traffic lights covered by the ITS system. This compilation allows to see existing correlations between selected parameters and to determine trends and dependencies of individual values. Another important element of the work is the analysis of Key Performance Indicators (KPI) for selected ITS. These indicators allow to determine the values achieved through the use of ITS systems and monitor their current effectiveness. The indicators are, among others, recommended by the EU in order to uniform and standardize the assessment of the effects of implementing ITS road systems. As a result of literature research selected KPI that are possible to be calculate from available data and referred those KPI to selected projects and implementations of ITS in Poland. The authors also pay attention to the need for changes in the approach to the implementation of ITS systems or applications, which should take into account the needs of end users of the system. The association of the consumer with the values offered by ITS allows for the determination of a long-lasting and effective strategy for the implementation and development of systems. Keywords—intelligent transport systems, ITS classification, ITS effectiveness, Key performance indicators

Automating Ticket Validation: A Key Strategy for Fare Clearing and Service Planning

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Abstract— Sustainability in transportation is a fundamental element to consider in the urban planning process, since transport has direct effects on the environment of a city and on the well-being of the citizens. To achieve a sustainable mobility environment, an efficient public transport framework, in which different means and companies coexist, is essential. An integrated fare system thus needs to exist, along with an agreement among the service providers for ticket revenue sharing (clearing), avoiding creating a barrier to the adoption of public transport, since users can be overwhelmed by many tickets and several purchase methods. To combine the needs of users and providers, developing a system to simplify user experience, while at the same time collecting precious data for service monitoring and planning, we focus on creating a flexible ticket validation using three different technologies (QR codes, GPS and Bluetooth). The contributions of this work are: i) greater flexibility in ticket validation obtained by using multiple technologies; ii) the novelty of a gamification layer applied to mobile ticketing; iii) the identification of a method for obtaining clearing-related data. The adoption of multiple technologies introduces different benefits: to the users, who will be able to complete trips on multiple vehicles without worrying about ticket compatibility; to the companies who will be free to choose among the multiple options, and not forced to adopt a single technological solution. The main expected result is the collection of key validation related information, which will be exploited mainly for clearing purposes and possibly even in real time for optimizing fleet management. Keywords—Bluetooth, gamification, GPS, public transport, smart ticketing, sustainability

Autonomous Mobility-on-Demand Real-Time Gaming Framework

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Abstract—Simulation frameworks for autonomous mobilityon-demand (AMoD) systems are currently implemented as roundbased games, where the real-world simulation time effectively stops until the fleet operator and users finish their decisionmaking processes. As such, these decisions, which take time to complete in the real-world, are unrealistically treated as instantaneous in the simulation. This work presents a real-time gaming framework for AMoD simulations that creates asynchronous processes to compute fleet operator decisions and delayed mode choice decisions of users (after they receive real-time information), while continuously updating the system state, i.e. moving vehicles and performing boarding processes. The framework enables a multiplayer game with multiple AMoD operators using different policies and pricing strategies to compete against each other and public transportation for on-demand travelers. The framework is applied to numerical experiments in order to simulate the effect of non-instantaneous operator and user decision-making and then to study two operator policies only available in a framework with non-instantaneous decisionmaking processes. The first strategy involves forecasting the future system state when the operator decision will probably be applied. The second policy sends a vehicle to the assigned request even if the corresponding user has not confirmed service with this operator yet. Index Terms—mobility-on-demand, real-time simulation, async framework, agent-based simulation, real-time mode choice, multiplayer game

Big Data and Emerging Transportation Challenges: Findings from the NOESIS project

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Abstract— In the last years many Big Data technologies have been applied to the transportation sector all over the world. Despite existing and future promising applications, critical factors which lead to a successful application and value generation from Big Data technologies in transport are largely unknown. The European Union(EU) Horizon 2020 (H2020) NOESIS project aims at identifying critical features leading to the successful implementation of Big Data technologies and services in the field of transport. In order to accomplish that aim, key challenges of Big Data utilization in the transport domain, need to be initially identified. The scope of this paper is to present the research findings on the major Big Data in Transportation challenges. The NOESIS challenges describe the major transportation areas and sub-problems that could benefit by Big Data. Firstly, a literature review was conducted in order to obtain the main areas (challenges) within the transportation domain which have the potential of greater exploitation through Big Data methods. 10 initial focus areas were identified from reviewing the state-of-the-art in Big Data and transportation research. Secondly, findings from the literature review were discussed and validated during a workshop with experts on Big Data in Transportation, increasing those challenges to 13. For each of the focus areas, corresponding sub-problems have been also identified.: The findings of this paper contribute to the exploitation of Big Data within transportation in two ways: i) it provides the necessary literature review and experts' discussion for identifying the transport domain areas in which big data technologies could be successfully applied and ii) it identifies sub-problems linked to each of the challenges that big data could help to improve transportation. As a result, it is believed that this work initiates a first step towards enhancing the socioeconomic impact of transportation investments using Big Data.Keywords—Big Data, Transportation, Challenges

Big Data fusion and parametrization for strategic transport demand models

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Abstract— Ever more observed data on destination and mode choices made by travelers is becoming available from e.g. GSM and ANPR data. For strategic transport demand modelling, this means that instead of estimating synthetic models and calibrating them on the limited set of available observations for a single study period definition, different data sources are fused to a 'common operational picture' of the total travel demand for many different study period definitions and this fused data is parametrized to a synthetic model for application in model forecasts. Three issues arise in the data fusion step. Firstly, inconsistencies between data sources and/or observations need to be detected and removed. Secondly, different data sources need to be weighted and normalized, often without (comparable or usable) reliability measures available. Thirdly, the data fusion problem is underspecified: the level of spatial detail of the transport models. This paper proposes and demonstrates a method that solves all three data fusion problems by use of a multi-proportional gravity model to fuse all data into a single set of travel demand matrices. This set of demand matrices can be directly used in operational applications or parametrized to be used in tactical and strategical applications using a bi-level optimization method that is also described in this paper. The methodology is used to conduct OD matrix estimation using GSM data, observed modal splits, trip frequency distributions and synthetic trip generation, but can be used to fuse and parametrize any data source that relates to (aggregates of) mode-origin-destination combinations. Keywords— data fusion, transport model, demand model, gravity model, big data, parametrization

Calibrating Route Choice Sets for an Urban Public Transport Network using Smart Card Data

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Abstract—Identifying the set of alternatives from which travellers choose their routes is a crucial step in estimation and application of route choice models. These models are necessary for the predication of network flows that are vital for the planning of public transport networks. However, choice set identification is typically difficult because while selected routes are observed, those considered are not. Approaches proposed in literature are not completely satisfactory, either lacking transferability across networks (observation-driven methods) or requiring strong assumptions regarding traveller behaviour (uncalibrated choice set generation methodologies (CSGM)). Therefore, this study proposes a constrained enumeration CSGM that applies the non-compensatory decision model, elimination-by-aspects, for choice set formation. Subjective assumptions of traveller preferences are avoided by calibrating the decision model using observed route choice behaviour from smart card data, which is becoming increasingly available in public transport systems around the world. The calibration procedure also returns two key insights regarding choice set formation behaviour: (i) the ranking of different attributes by their importance, and (ii) the acceptable detours for each attribute. To demonstrate the methodology and investigate choice set formation behaviour, the tram and bus networks of The Hague, Netherlands are used as a case study. Keywords—route choice, choice set generation, smart card, public transportation, The Netherlands

Calibration Procedure for Traffic Flow Models of Merge Bottlenecks

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Abstract—Travel times and delays on freeways are highly dependent on the discharge rate of the bottlenecks. Consequently, it is important to model the traffic flow at bottlenecks as accurate as possible. However this is not straightforward in merge bottlenecks as the traffic flow is impacted by the acceleration, deceleration, and lane changing maneuvers induced by the merging vehicles. The interaction of these factors results in a reduced discharge rate when the bottleneck is congested compared to the discharge rate observed when the bottleneck is uncongested. This phenomenon is often referred to as capacity drop. Therefore, a traffic flow model of merge areas must reproduce the capacity drop phenomenon features including: (i) magnitude of drop in the outflow, (ii) when and how the capacity drop occurs, and (iii) how and when the bottleneck can recover nominal capacity. This can be achieved by a model able to reproduce capacity drop and the correct imputation of its parameters. Here we tackle the imputation of parameters aspect by proposing a calibration procedure that ensures the aforementioned aspects of capacity drop are captured. The procedure, based on the Multi-Objective Differential Evolution (MODE), does not require any information about the calibrated model and therefore is applicable to different models. The output contains multiple solutions in contrast to the usual single solution in single-objective optimization. Therefore, it returns multiple combinations of parameters that can reproduce the field measurements with similar level of accuracy. Unlike single objective approach, defining weights is not necessary. This is beneficial even when the ultimate goal is to find a single solution. The practitioner can inspect the model outputs of each parameter set and pick the one that suits better. Also, the multiple solutions can be used for further analysis and applications such as parameter and output uncertainty. The procedure is tested against field data of a bottleneck in which capacity drop is consistently observed based on data of 16 days. The following implementations of link transmission model (LTM) are calibrated: (a) standard LTM with no extension (capacity drop is not captured), (b) LTM with outflow reduction based on the upstream queue (density); (c) LTM with outflow reduction based on on-ramp flow, and (d) LTM with outflow reduction based on on-ramp flow and queue. In all cases the algorithm output approximate the Pareto Frontier or trade-off curve between downstream outflow and density errors. As expected, the errors are smaller as additional features are added to the model (from case (a) - no feature - to case (d) - two features); however, among the models with one additional feature ((b) and (c)), considering ramp flows had lead to smaller errors. With the multiple solutions, time-dependent upper and lower bounds of density, outflow, and travel times can be obtained by applying the model for all solutions given expected demands. Therefore a possible application is the estimation of lower and upper bounds of travel times.

Can ICT influence choice behavior? The role of mobile applications supporting Bike-Sharing Systems

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Abstract—It is commonly accepted that Bike-Sharing Systems can significantly contribute to the promotion of cycling and therefore of sustainable urban mobility and this is why more and more cities are introducing such systems in their mobility systems. One of the most important and unexplored parameters for their success, is the proper utilization of technology. The paper investigates whether a mobile application that provides several advanced services to users could help increase the level of the system's use. To provide an answer, a questionnaire survey has taken place in Thessaloniki, Greece addressed to both existing users of the bike-sharing system operating in the city and to other residents who are potential users of the system. The respondents were asked to identify what services they consider useful to be provided by an application. They were also asked to state if a mobile application that would provide such services would motivate them to use the system more often (existing users) or to become members of the system (potential users). A decision tree has been developed to classify users based on the likelihood of shifting to or using more the bike-sharing system. The results show that people aged between 18 and 54, who are not currently users of the system, are those most likely to be attracted to the system due to such an app. On the other hand, people over the age of 54, who work as private employees or are retired, are considered unlikely to be affected by such an app. Car usage frequency, education and income also appeared to have an impact on people's decision to use the system more often due to the app. Keywords—bike-sharing systems, cycling, mobile application, ICT, classification tree

Capacity Building Strategies for further growth of the ITS Sector in Europe

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Abstract— Intelligent Transportation Systems (ITS) and Cooperative ITS (C-ITS) constitute one of the most rapidly growing sectors, regarding transportation research and its implementation in the wider European territory. The European Union invests in the ITS sector through the Horizon 2020 funding program; in the framework of which more than 24 projects are active for the 2014-2017 period with total funding of €140 million. Despite the significance of ITS and C-ITS in the European territory, there is the general assumption that some fundamental knowledge gaps exist in the fields of ITS and C-ITS. These fragmentations in knowledge lead to delays in the development and dissemination of new ITS and C-ITS technologies.In order to tackle the fragmentations derived from the knowledge gaps of ITS and C-ITS stakeholders, a variety of strategies exist and are applied worldwide, under the term Capacity Development Strategies. For each individual case of knowledge fragmentation, and based on each case's special needs and requirements, different strategies are applied. The strategies proposed in this study try to bridge all the existing fragmentations in the ITS and C-ITS dissemination process, by providing all the necessary elements and knowledge to the stakeholders, for identifying the appropriate solution. The proposed capacity development strategies are categorized based on the 5 Know-How levels of the stakeholders as well as on the type of the organization (public authorities and ITS/ C-ITS stakeholders).Different strategies are also applied according to the area of responsibility and to geographic terms, for each public authority and/or stakeholder (local and national level authorities). The analysis and identification of the Capacity Development Strategies realized in this paper is based on the analysis and results from a survey conducted among European ITS and C-ITS stakeholders regarding observed knowledge gaps among stakeholders in the ITS sector.
Keywords—ITS, C-ITS, Capacity building strategies

C-ITS Pilot in Dresden – Designing a modular C-ITS architecture

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Abstract—Cooperative Intelligent Transport Systems (C-ITS) have seen increased interest in recent years, with several ongoing activities and first practical implementations. While clearly V2X-communication will play a significant role in all C-ITS deployments, several key components, such as the wireless communication technology and the message formats, are still evolving. This calls for a modular approach when designing C-ITS infrastructure, especially when considering a real world urban environment. Such environments are characterized by heterogeneous traffic light hardware and traffic management systems. This paper focuses on the modular architecture of the C-ITS pilot in Dresden. For example, a highly flexible communication stack is developed for this special purpose. It fully supports the message types standardized by European Telecommunications Standards Institute (ETSI) on the one hand, while on the other hand allowing the rapid implementation and test of novel message types and contents. This went hand in hand with the development of a modular roadside unit, enabling the rapid implementation of service applications on its central processing unit. In combination with a cloud-based backend, a real-time C-ITS service platform with a hybrid communication concept is developed. This paper presents a modular architecture and best practice guidelines based on experiences of the C-ITS pilot in Dresden. First results of research topics, such as latency measurements, are shown. The ongoing C-ITS deployment in Dresden is part of the initiative “Synchrone Mobilitat 2023”, which aims at advancing Intelligent ¨ Transport Systems. Focusing on automated and connected driving in urban areas, the research and development projects under its umbrella initiate scientific and technological developments and provide comprehensive test facilities. Automated and connected driving in urban areas requires not only simulations and test drives on test sites but also enormous testing effort under This work is funded by the German Federal Ministry of Transport and Digital Infrastructure (BMVI), project HarmonizeDD, and by the federal state of Saxony and the European Regional Development Fund (ERDF), projects REMAS and SYNCAR. real traffic conditions. The Dresden Testbed offers outstanding conditions for the multitude of test kilometers and the experience of different traffic scenarios. Index Terms—V2X, automated and connected vehicles, communication in ITS

Collecting data on Risk Perceptions and Observed Risk in Smart Cities

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Abstract— Throughout the world, bicycling as a transport mode has seen a significant increase over the past decade. Transportation agencies promote bicycling as an alternative transportation option, since it can provide health benefits, reduce carbon emissions, and alleviate congestion. It is imperative then that transportation agencies develop and support an appropriate infrastructure to encourage the continued growth of bicycling. Lack of quality infrastructure is a major impediment to bicycle usage as past research has shown. Factors such as presence of bicycle infrastructure, in the form of bicycle lanes, paths, or cycle tracks, pavement conditions, and roadway safety have been identified as features that could encourage bicycling. Cyclists tend to avoid areas that could pose unsafe conditions and could eventually reduce bicycle use as a transport mode. It is therefore imperative for agencies to identify such locations either with objective or subjective means in order to improve infrastructure and thus encourage cycling. Moreover, social networking and new transportation resources such as bike sharing can be used to supply the lack of traditional crash data in the analysis of bicyclist safety. In this study, two different surveys are used to explore risk perceptions and observed risk that can be collected by social group surveys and probe data from cycling tracking (e.g. Strava) and observation (e.g. video recording). Participants were asked to score a series of intersections and routes in terms of perceived safety problems in the city of Catania, Italy, using a 4-point Likert scale. Observed risk was measured during riding tests with an instrumented bike identifying traffic conflicts in the same routes and intersections by video recording and analysis. A spatial analysis of perceived and observed safety was carried out in order to evaluate correlations and capability of both procedures to identify and classify locations with high risk conditions for bicyclists. The study provides evidence on the possibilities to collect information both from users' pools and probe data that are becoming more and more available in smart cities. Such information can be used as surrogate measure of safety to identify dangerous locations in the urban road network to supplement the limited crash involving bicyclists. Keywords—cycling, poll, traffic conflict, perceived risk, observed risk

Combining Speed Adjustment and Holding Control for Regularity-based Transit Operations

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Abstract— Vehicle bunching often occurs in highfrequency transit systems leading to deterioration of service reliability. It is thus necessary to control vehicles during operations. Holding control is a common solution for this situation, but it may result in longer vehicle running times. Speed adjustments can potentially contribute to more regular operations while preventing prolonged trip times. This paper proposes a control strategy, which combines these two strategies to maintain the regularity of transit operations. The findings based on simulation study for trunk bus services in the Netherlands suggest that combining the two strategies implies both the positive and negative attributes of each control. Keywords—control strategy, speed adjustment, holding control, bunching

Communication system for Intelligent Road Signs network

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Abstract—The way of providing the end user with an accurate data regarding the current road conditions is one of the very important components in the area of Intelligent Transportation Systems (ITS). In such cases one of the possibilities is to display the adaptive content on a dedicated road sign. The most important issue in the process of building the trust between the road signalling infrastructure and the end user is the information importance and its value. The ongoing NCBiR project - InZnak - aims to introduce a new type of the road signalling subsystem which relies on intelligent road signs equipped with variety of sensors and adaptive led displays. Sensors feed the autonomous algorithms with data necessary to take decisions how to react to current road conditions. The proposed system typically consists of a few road signs communicating with each other and exchanging measured data: weather conditions, road surface condition, traffic volume, avg. vehicle speed, detected road events, etc. On the basis of the information exchanged between road signs, each of them runs the autonomous algorithm to process that data and produces the current image of road section driving conditions. The InZnak project focuses on the problem of the traffic control using intelligent autonomous road signs. The process of the speed limit determination is often complicated and in many cases it is defined by numerous legal standards. In general speed determination should take into account not only the technical aspect, but also social and legal aspects which makes this process especially difficult. This paper presents the of the InZnak communication system architecture with the deployed prototype and its current status of integration.

Keywords—intelligent road sign, traffic moderation, intelligent transport system

Comparative study on the effectiveness of various types of road traffic intensity detectors

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Abstract— Vehicle detection and speed measurements are crucial tasks in traffic monitoring systems. In this work, we focus on several types of electronic sensors, operating on different physical principles in order to compare their effectiveness in real traffic conditions. Commercial solutions are based on road tubes, microwave sensors, LiDARs and video cameras. Distributed traffic monitoring systems require a high number of monitoring stations. In order to improve the accuracy of traffic monitoring, several modalities, complementing each other, may be used in the monitoring stations. In this paper, we propose a multimodal approach to traffic monitoring, using sensors and signal processing algorithms developed specifically for the described task. The aim of the work described here is to test each modality in a real-life scenario, assess their accuracy and to evaluate their usefulness for multimodal traffic monitoring stations. The modalities described in the paper are: Doppler sensor with custom signal processing, video analysis based on cameras and neural networks (employing deep learning algorithms), audio monitoring based on an acoustic vector sensor developed by the authors, as well as LiDAR and Bluetooth as supplementary means of traffic monitoring. Additionally, road tubes and a commercial video-based monitoring system were used in order to provide reference data. Consequently, we are able to present in this paper a comparative study on the effectiveness of traffic sensors operating on the basis of different principles of work.
Keywords— traffic measurement; multimodal analysis; signal processing

CoNL route choice model: numerical assesment on a real dataset of trajectories

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Abstract— This paper proposes a numerical assessment of the performances of the CoNL route choice model [1] on a big-size network (Regione Campania). The CoNL is a particular specification of the CoRUM model [2]. Currently, its performances in terms of choice probabilities have been investigated only on some toy networks, by comparing route choice probabilities with reference to target Multinomial Probit choice probabilities. The paper provides also a discussion about different aspects of the CoNL for route choice: the possibility to take into account also non-efficient path, the computation time of the two versions of the algorithm for building the CoNL structure, and the possibility to adopt some different specifications for computing the structural parameters of the model. The comparison is based on a dataset of 195 trajectories on 145 different o-d pairs, tracked with the aid of an Android application. The trajectories have been collected through the smartphones of travellers moving within the network of Regione Campania (Italy). The results show the superiority of the CoNL route choice model in reproducing observed route choices when compared with other commonly used route choice formulations. Keywords—Route choice, CoRUM, CoNL, correlations

Data-Driven Bus Crowding Prediction Based on Real-Time Passenger Counts and Vehicle Locations

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Abstract—The paper addresses the bus crowding prediction problem based on real-time vehicle location and passenger count data and evaluates the performance of a data-driven lasso regression prediction method. The problem is studied for a highfrequency bus line in Stockholm, Sweden. Prediction accuracy is evaluated with respect to absolute passenger loads and predefined discrete crowding levels. When available, predictions with realtime vehicle location and, in particular, passenger count data significantly outperform predictions based only on historical data, with accuracy improvements varying in magnitude across target stations and prediction horizons. Index Terms—public transport, bus, crowding, prediction, AVL data, APC data

Decentralized vehicle-mounted safety logic for secondary railway lines based on GNSS Positioning and Integrity Monitoring

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Abstract—Railway operation is based on various safety critical control and signalling operations which are conventionally realized by stationary infrastructure. Acquisition, maintenance and operation of these components are generally very cost-intense and compromise the future of railways lines with low traffic volumes. These so called secondary railway lines are essential to satisfy mobility requirements especially in rural regions and differ from conventional main routes as they provide several operational characteristics (e.g. single-laned) which enables simplified, decentralized administration of route setting and train movements. In the work presented, a general overview of a vehicle-mounted safety logic concept which includes a detailed description of the essential probabilistic multisensor GNSS based train position estimation module is suggested. The localization and tracking is performed by adopting an Extended Kalman Filter (EKF). Additionally, a Fault Detection (FD) Receiver Autonomous Integrity Monitoring (RAIM) for safety critical applications is used to ensure integrity of the estimated positions. The GNSS parts of the developed localization and integrity module are validated using a real world Software Defined Radio (SDR) recorded GNSS-RF-dataset which is played back in a laboratory environment enabling reproducable validation cases with different GNSS receivers and algorithm parametrizations. Index Terms—Railway Safety and Control, Railway Signalling, Secondary railway lines, Multisensor GNSS Positioning, Integrity Monitoring, RAIM, SDR Record & Playback

Dependability of V2I Services in the Communication Network of the Intelligent Transport Systems

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Abstract— Intelligent Transport System (ITS) applications are focused on improving road safety and creating new transport services. To realize the potential of ITS applications, data exchange should be efficiently carried out through direct communication over short distances both between vehicles (V2V) and between vehicles and infrastructure (V2I). High demands are placed on ITS performance indicators. These requirements are increasing especially in the context of the new mobility patterns using autonomous vehicles. The ITS big data processing can be centralized or distributed. The centralized approach utilizes the power of cloud computing. In contrast to cloud computing, intelligent data processing with faster responses and higher quality can be provided by fog computing. Fog computing is a horizontal, system-level architecture that distributes computing, storage, control and networking functions closer to the users along a cloud-to-thing continuum. Implementing fog computing in the dynamic environment of ITS to provide real-time big data analytics is facing many challenges that are not covered by previous research studies. The article analyzes the availability of V2I services in distributed communication network of ITS with fog-based architecture from reliability point of view. The dependability of V2I services for end users of smart vehicle in fog operating ITS is defined. The mathematical model of the reliability of a separate dedicated service in fog-based ITS for end user applications in the real conditions of operation is developed. Keywords—reliability, availability, intelligent transport systems, fog architecture, V2I communications

Deriving on-trip route choices of truck drivers by utilizing Bluetooth data, loop detector data and variable message sign data

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Abstract—On important truck-dominated motorways, a large share of traffic consists of trucks. Our hypothesis is that these trucks do not always make optimal routing decisions which cause inefficiencies in the traffic system. Therefore, route choice of truck drivers is of interest to both transport planners and traffic management authorities. The objectives of this paper are two-fold. First, this paper models on-trip route choices of the truck drivers. Second, we assess the inefficiencies of those routing decisions. This paper utilizes Bluetooth data, loop detector data, and variable message sign data to model the route choices of truck drivers. To the best of our knowledge, this is the first time that Bluetooth data have been used for the estimation of route choice models of truck drivers. The trucks are inferred from Bluetooth data by applying a Gaussian mixture model-based clustering technique. We apply both a binary logit model and a mixed logit model to derive the route choices of truck drivers on a case study between the port of Rotterdam and hinterland in the Netherlands. The predictive performance of the model is tested by conducting out-of-sample validation. The model results indicate truck drivers significantly value travel distance, instantaneous travel time and lane closure information en-route. The estimate of travel distance varies significantly among truck drivers. While 38% of truck drivers do not take the shortest time path, 48% of truck drivers do not choose the system-optimal path. These inefficiencies imply that traffic management solutions have the potential to improve the performance of truck-dominated motorways. Index Terms—on-trip, en-route, route choice, truck driver, binary logit, mixed logit, bluetooth, loop detector, variable message sign, truck-dominated motorways, freight corridors

Designing the conditions of road traffic in the cities taking into account the human factor

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Abstract — During organization of road traffic it is important to take into account the mechanism of action of emotions that determine the entire indicative activity of the driver. The magnitude of emotional stress is influenced by the speed of the vehicle and its position in the traffic flow, as well as the characteristics of traffic organization. This applies to the placement of road signs, pointers, traffic lights, etc. The article aims to investigate the emotional state of the driver during the route. In order to conduct the research the electrocardiography ECG Holter monitor with electrodes was used. Neulog was implemented to record the galvanic skin response. The registration of the vehicle speed in synchronization with ECG and galvanic skin response in real time was held with the help of VideoVbox recorder. It has been established that the driver, as a rule, automatically adjusts to some level of emotional tension that is optimal for him, and the speed of the car's movement acts as a regulator of this level. Therefore, on the road sections where ergonomic requirements are not met, the driver compensates for the possible increase in emotional stress by a corresponding decrease in speed. Moreover, the more difficult is the certain part of the road for the driver, the bigger is this decrease in speed. If the driver passes these areas without reducing the speed, then this leads to an increase in the level of emotional tension. Prolonged emotional stress is a source of fatigue and changes the drivers reaction time.Keywords— driver's functional state, galvanic skin response, heart rate, human factor, conscious and subconscious activity

Development of Intelligent Road Signs with V2X Interface for Adaptive Traffic Controlling

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Abstract – The objective of the project INZNAK carried out in a consortium of Gdansk University of Technology, AGH University of Science and Technology and 2 commercial firms is to develop a conceptual design and to make research tests of a new kind of intelligent road signs which will enable the prevention of the most common collisions on highways, resulting from the rapid stacking of vehicles resulting most often from accidental heavy braking. A range of products will be developed, including intelligent road signs: standing, hanging and mobile ones, displaying dynamically updated driving speed limit, determined automatically, through an embedded electronic module, enabling multimodal measurement of traffic conditions. Solving a number of research and construction problems, such as: effective and independent of weather conditions traffic monitoring based on simultaneous analysis of several types of data representation, a development of a method of calculating gradients and histograms of vehicle speed for various types of road situations or traffic topologies. Moreover, creating a platform for self-organizing reliable wireless connections among road signs equipped with innovative displays and power supplies and carrying out prototype tests are carried out. As a result, advanced conceptually products for increasing road safety for which there is a market demand around the world are being prepared for the future implementation.
Keywords – road signs; traffic analysis; signal processing; renewable electricity; wireless data transmission; Vehicle-toeverything

Does ride-sourcing absorb the demand for car and public transport in Amsterdam?

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Abstract—The emergence of innovative mobility sevices, is changing the way people travel in urban areas. Such systems offer on-demand service (door-to-door or stop-to-stop, individual or shared) to passengers. In addition to providing flexible services to passengers, past studies suggested that such services could effectively absorb the demand for private cars thereby reducing network congestion and demand for parking. This study investigates the potential of a ride-sourcing service to absorb the demand for public transport and private cars for the city of Amsterdam. Results indicate that a ride-sourcing vehicle could potentially serve the demand currently served by nine privately owned vehicle and that a fleet size equivalent to 1.3% and 2.6% of the total public transport trips, are required to provide doorto-door and stop-to-stop times comparable to those yielded by the current public transport system. Results from the modal shift indicate that most PT trips are substituted by active modes and most car trips are substituted by ride-sourcing service. Index Terms—ride-sourcing, agent-based simulation, public transport, demand responsive service

Effects of user adaption on traffic-responsive signal control in agent-based transport simulations

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Abstract—All traffic-responsive approaches have in common that they directly influence waiting times of travelers (users) at intersections and, thereby, influence user reaction, e.g. route choice. On the other hand, users route choice directly influences sensor data and, thereby, the signal settings controlled by trafficresponsive signals. Thus, the interference of route choice and traffic-responsive signals constitutes a combined problem. This work focuses on a detailed simulation-based analysis of the effects of route choice on the performance of different traffic-responsive signal algorithms implemented in an inner-city area of a realworld scenario. It Is found that the effects of induced traffic matter a lot, especially for the inner-city area: A significantly higher number of agents travel through the inner city, increasing travel time, delay and noise levels in this area (in comparison to the case without user adoption), whereas overall traveled distances decrease, i.e. more direct routes are used and by-pass routes around the city become less congested. Furthermore, the effects of different levels of saturation on the interaction of route choice and signal control are analyzed. Index Terms— induced traffic, user adaption, route choice, traffic-responsive signals, agent-based transport simulation, realworld application

Estimating empirically the response time of commercially available ACC controller under urban and freeway conditions

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Abstract— Research on Advanced Driver Assistance Systems (ADAS) and technologies that are expected to be involved in automated driving attracts lately a lot of interest from engineers and modelers. Adaptive Cruise Control (ACC) is one of the first automated functionalities available for privately owned vehicles and the deployment of such systems in public transport networks is constantly increasing. The impact of such controllers is still under investigation and there is a lot of discussion regarding their ability to positively affect congestion and pollution. In simulation studies regarding the impact of ACC on traffic flow, one key parameter is their response time. This parameter, usually takes low values, based on the controller's theoretical ability to respond instantaneously. In the preliminary results presented by the authors in [1] based on an empirical approach, it seems that this hypothesis is not valid. The present work builds on this conclusion presenting further results on two more commercially available controllers and testing their response in both urban and highway driving conditions under normal driving behavior without critical situations regarding the safety of the vehicle's passengers. The deployed ACC systems are primarily designed for safety and comfort. Adding on top of that the delays due to the interoperability of various vehicle systems, the final response time, that an observer would see, is very close to the human reaction time and this work shows that in some cases is even higher and by no means instantaneous. The findings here refer to normal driving conditions. Traffic simulation,, connected and automated vehicles, Adaptive Cruise Control, Response Time

Exploring Demand Patterns of a Ride-Sourcing Service using Spatial and Temporal Clustering

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Abstract—On-demand transport has become a common mode of transport with ride-sourcing companies like Uber, Lyft and Didi transforming the mobility market. Recurrent patterns in prevailing demand patterns can be used by service providers to better anticipate future demand distribution and thus support demand-anticipatory fleet management strategies. To this end, we propose three steps for extracting such demand patterns from travel requests: (1) constructing the origin-destination zones by spatial clustering, (2) composing the hourly and daily origindestination matrix, and; (3) temporal clustering to extract the dynamic demand patterns. We demonstrate the three step approach on the open-source Didi ride-sourcing data. The data consists of travel requests data for November 2016 from Chengdu, China amounting to approximately 6 million rides. The analysis reveals pronounced and recurrent and thus predictable daily and weekly patterns with distinct spatial properties pertaining to ride-sourcing production and attraction characteristics. Index Terms—ride-sourcing, spatial clustering, temporal clustering, demand patterns, taxi data

Fuzzy surrogate safety metrics

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Abstract— Road safety is one of the most significant performance indicators in traffic networks. Automation technologies can provide significant opportunities for improvement. However, evaluating the risk involved in using these technologies is not a trivial task. One of the existing tools in traffic safety evaluation are the surrogate safety metrics (SSM), which can be a suitable mean for evaluating the level of safety of different technologies. Nevertheless, existing SSMs have been mostly developed for conventional vehicles and have important disadvantages of comparing their behavior to the behavior of automated vehicles (AVs) or connected automated vehicles (CAVs). A distinction can be made between SSMs, dividing them in active or passive safety metrics. Active safety metrics such as TTC identify situations where there is an imminent danger and responses are necessary. Passive metrics such as DSS (Difference between Space distance and Stopping distance) identify unsafe situations where evasive action may not be immediately necessary. In this light, two new SSMs for rear end collisions have been developed, based on fuzzy logic, the passive fuzzy surrogate safety metric (PFSSM) and the active fuzzy surrogate safety metric (AFSSM). Results of this work show that PFSSM and AFSSM are robust indicators in classifying a situation to be totally safe, certainly unsafe or even a little risky, corresponding to the spectrum of different behaviors. The novel fuzzy safety metrics are tested on synthetic trajectory data, to showcase their advantages on evaluating the safety level of longitudinal movement. Keywords—automated vehicles, road safety, fuzzy logic, surrogate safety metrics, traffic simulation

Game theory and cooperative-competitive performances in real time traffic signal settings based on floating car data.

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Abstract—The future of traffic control and management includes new technologies such as "connected" and "autonomous" vehicles. Connected vehicles will allow new traffic signal control systems that will be able to use information on vehicle positions (Floating Car Data, FCD). The use of FCD in traffic control systems can be beneficial by increasing sustainability of transportation in terms of fuel consumption reduction, reduced pollution and increased safety. However, not "connected" vehicles might not benefit or might even be damaged by the introduction of such systems. This paper intends to explore how an FCD-based adaptive traffic signal would impact different categories of vehicles in terms of cooperative-competitive performances. Game theory can be applied both in the implementation of algorithms and in assessing driver choices to participate in a cooperating and/or competitive signal regulation system, so a dedicated laboratory has been developed for testing the regulation algorithms and the interactions among drivers. The Nash bargaining equilibrium was used to implement a control algorithm which was tested with different percentages of "connected" vehicles. Some implementation challenges are discussed and new research directions outlined. Keywords— GNSS, ITS, localization

How Will Autonomous Vehicles Operate in an Unlawful Environment? The Potential of Autonomous Vehicles for Disregarding the Law

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Abstract—The future of urban transport environments is being reshaped by the potential introduction of autonomous vehicles within their networks. The development of such vehicles is implemented within closed and controlled testbeds that simulate the urban environment. The operation of such testbeds assumes that laws should regulate how traffic operates. Another assumption is that autonomous vehicles by design (through their coding) follow the existing regulations and act accordingly. However, there exist societies in which unlawful behavior has become the norm for most of its drivers. In such an environment, the traffic and infrastructure conditions themselves compel drivers to adapt to the current conditions disregarding the law in an effort to travel to their destination in an efficient - and safe - manner. A provision for the unlawful behavior of autonomous vehicles has three major requirements, namely that any such decisions are: a) technically possible b) legally defensible, and c) ethically justifiable. The technical capabilities of autonomous vehicles in making complex decisions have already been studied to some extent. To this end, the purpose of this paper is twofold. Initially, through a preliminary literature review, it is called to explore whether the concept of autonomous vehicles acting beyond established laws is defensible. Moreover, in an effort to explore the ethical justification of such behavior, this paper aims to answer two important questions. Firstly, it ascertains how drivers behave under shifting and unlawful conditions. Furthermore, it assesses whether the potential passengers of autonomous vehicles expect the vehicle to act in a manner similar to that with which they themselves would drive. These two questions form the basis of a questionnaire that is distributed amongst users of the Greek urban transport environment. This questionnaire identifies conditions under which Greek drivers would disregard the law and to what extent. Finally, the questionnaire juxtaposes these findings with the expectations of the aforementioned drivers for autonomous vehicles. Keywords—autonomous vehicles, unlawful environment, traffic regulation compliance, adaptation, survey

Hybrid Choice Model to analyze electric car sharing demand in a university community

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Abstract— Sharing Mobility is characterized by a high digital component able to supply customers with a considerable level of flexibility in urban trips. The study was conducted focusing on the E-go car sharing project, promoted by University of Roma Tre and Enel Energia S.p.A. E-go is an university electric car sharing system. The paper provides a double contribution to the research activity on sharing mobility: i) the exploration of the electric car sharing potential demand among students; ii) the implementation of an Hybrid Choice Model to analyze the role of the pro-environmental attitude on the users' willingness to use car sharing. The analysis has been based on the data collected in a survey among the potential users of the e-go car sharing service. One of the first findings of the study is that the pro-environmental attitude doesn't significantly influence the choice of the users. The authors suggest to the car sharing operators and to the policy makers to take in consideration the results of the study in order to plan promotional strategies and to develop policies aiming at supporting the spread of this service. Keywords—sharing mobility, car sharing, behavioral model, electric vehicle I. I

Identification and monitoring of concealed cracks in road pavement using a machine-learning approach

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Abstract— The current methods that aim at monitoring the structural health status of road pavements allow detecting surface defects and failures. This notwithstanding there is a lack in methods and systems that are able to identify concealed cracks (particularly, interlayer cracks) and monitor their growth over time. For this reason, the objective of this study is to set up a supervised machine-learning-based method for the identification and classification of the structural health status of a pavement based on its vibro-acoustic signature. In particular, the vibro-acoustic responses of differently cracked road pavements to the vehicular traffic have been determined. These signatures were collected and analyzed through machine learning (ML) models, to classify the different levels of damage of the pavements under test. Different configurations of the classifiers were tested and compared in order to define the most performing one. Results show the possibility of associating a specific vibro-acoustic signature to a road pavement through the most efficient artificial neural network (ANN). These results are encouraging and represent the bases for the application of the proposed method in real contexts (smart cities) by mean of suitable and well-designed tools for ITS. Keywords—Machine Learning Classifier, Vibro-acoustic signature, Road Pavement, Structural Health Monitoring, Concealed cracks identification and monitoring

Impact of service quality factors on ride sharing in urban areas

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Abstract— Ride sharing offers great potential to decrease the number of vehicles in the street and improve traffic congestion, if the customers are willing to share a ride and accept a certain deviation from their direct travel route. The demand for ride sharing will probably increase with higher user convenience. However, constraints on detour time, waiting time or even amount of time to board and disembark the vehicle, decrease the chances to find shared trips. This paper investigates this trade off by analyzing the impacts of service quality factors on the amount of trips which could be shared, a quantity called shareability. The service quality factors which are analyzed are the detour time, the time the customer is willing to wait to be picked up and the boarding time. A mathematical model that captures these impacts is developed and the model is tested by means of simulations. The results show a good correlation of the mathematical model with the simulated data for all the factors considered. Therefore, we create a relevant model, which could be used by operators to examine the shareability rate that can be reached when offering different quality of service to the customers. Keywords—ride sharing, shareability, service quality factors, on-demand mobility

Impacts of charging methods and mechanisms of zero-emission buses on costs and level of service

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Abstract— To limit global warming and strive for more liveable and sustainable cities, innovative zero-emission (ZE) buses are on the rise all around the world. Different alternative vehicle propulsion methods have been introduced during the last decades. However, for now, only trolley, battery and fuel-cell electric vehicles can be classified as (on the pipe) ZE-buses. This research focuses on battery electric buses, since they are most cost-efficient and – therefore - the most promising option for the (near) future. An important limitation of battery electric buses is however the limited range of operations due to capacity restrictions of batteries. Batteries should be (re)charged before, during and/or after daily operations. Different charging methods, including different charging power systems are available to charge battery electric vehicles. As far as known to the authors, scientific literature focusing on the operations and charging scheduling of electric buses is scarce. In this study, a comparison of different applied charging methods for electric buses is obtained. A ZE-bus station simulation method is developed to assess charging methods and charging regulations with regards to their impacts on a variety of costs and level of service indicators. This simulation-based method is multi applicable, since it is particularly based on general automated vehicle location (AVL) data. To demonstrate our model, a case study at Schiphol (Amsterdam Airport) is performed. This research concludes that the shift to ZE-bus transit is involved with higher costs and passenger disturbances. Investment costs of ZE-buses increase substantially: Most electric vehicles are around 60 to 80 percent more expensive than conventional diesel engine vehicles and additional charging infrastructure investments are required. Benefits of electric operations, including vehicle propulsion cost savings up to 70 percent, are not able to compensate these high investments. The charging method choice contain trade-offs between level of service and (vehicle and charging infrastructure) investment costs. (Slow) depot charging offers opportunities for operations on short distance lines. However, additional vehicles are required in order to replace a vehicle which should be recharged. In this respect, conventional timetables could be complied and the level of service remains unchanged. To prevent fleet overcapacity, vehicles should be recharged fast (with high charging power) along the line. Slight charging related delays could occur, especially when the number of charging systems is not sufficient, and/or the charging times are relatively long. Bus end stations and terminals are suitable as fast charging locations, since charging time could be combined with buffer time there. Finally, dynamic/in-motion charging offers opportunities to prevent charging related delays completely due to combined charging and operation time. This charging method is still in its infancy stage yet, so focus is more on (innovative) static charging methods now. Keywords— Electric buses, charging methods, level of service, investment and operational costs, service reliability

Impacts of Shared Autonomous Vehicles on the Travelers' Mobility

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Abstract - In this paper agent-based modeling was used and simulation of activities were conducted to study the existing behavior of travelers and the behavior of travelers considering shared autonomous vehicles (SAV). In the modeling framework distance, travel time, travel cost, fleet size and capacities of vehicle types were used as main parameters. Additionally, we created user groups (long commute drivers, transit rider, car rider, high class income), who are more willing to use SAV. Simulations of the daily plan of activities were performed using Multi-agent Transport simulation tool (MATSim), which applies the concept of co-evolutionary algorithm. Travel plans of 3000 persons were simulated, and fleet sizes of 20, 50, 100 SAV were examined. The results showed that 1 SAV can replace 8 conventional vehicles with acceptable waiting time ranging from 7-10 minutes and usage of 4-seats (shared trips). The utility function that were used in the study showed that the travel time decreased by 17% and the travel distance decreased by 20% after 100 iterations performed on the existing plans. Moreover, the long commuter and high-income travelers can be served by 20 SAV with waiting time of 10 minutes and trip duration of 20 minutes. In this case 1 SAV can replace 6 conventional cars with acceptable waiting time 10-15 minutes. Keywords: agent-based modeling, autonomous vehicle, optimization, activity chains, utility function

Impacts of vehicle fleet electrification in Sweden – a simulation-based assessment of long-distance trips

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Abstract—Electrifying road transport is seen as one of the key components in decreasing the carbon footprint of the society as a whole. Recent developments in electric drivetrain and battery technology have helped to design vehicles with ranges that make them independent of public charging infrastructure during most sub-urban and commuting trips. Once long-haul trips are planned, however, these vehicles require a dense network of charging infrastructure. In this paper, the impact of a largescale electrification of vehicles in long-distance trips is evaluated by combining an agent-based long distance transport model of Sweden with a detailed model of energy consumption and battery charging. Energy consumption and charging schemes are simulated for different types of vehicles and chargers. In a first application, all vehicle traffic is electrified. Results demonstrate that the daily estimate for energy consumption is in the region of 150 GWh. This equals roughly 40% of the current Swedish electricity consumption. Energy consumption is the highest along in the motorway network connecting the south of the country (Malmo, G ¨ oteborg and Stockholm). Along these motorways, ¨ also the highest demand for charging infrastructure arises. Nationwide, two peak times for vehicle charging seem to exist: One is around lunch time and another in the mid-afternoon. During the first peak, overall energy demand is presumably the highest. Index Terms—Electric Vehicles, Transport Simulation, MATSim, long distance travel, Sweden

Improved OpenLR decoding using a stepwise increased deviation range

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Abstract—Exchanging information regarding traffic network related data, parties traditionally use a set of static references to the actual (road) network. Examples of such static references appear in TMC and DATEX II. These references use lists of road identifiers. The problem with this static road references approach is that the road network is continuously being changed which requires periodic administrative activity for all parties. Dynamic location referencing methods seek to reference locations without requiring a common definition of the road network. Examples of these methods are Agora-C, OpenLR, and Hidden Markov map matching. The challenge that these methods face is that each party can have a network definition that deviates in respect of the geographic location and of other descriptive information. Although the current OpenLR method takes possible deviations into account, its decoding methods can still result in false positives. This paper shows how the OpenLR decoding method can be improved by using a stepwise increased deviation range. Index Terms—OpenLR, map matching

Improving calibration time of traffic simulation models using parallel computing technique

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Abstract—Calibration procedure of traffic simulation models can be a very time-consuming process in case of the large-scale and complex network. In the application of Evolutionary Algorithms (EA) such as Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) for calibration of traffic simulation models, objective function evaluation is the most time-consuming step in such calibration problems, because EA has to run a traffic simulation and calculate its corresponding objective function value once for each set of parameters. The main contribution of this study has been to develop a quick calibration procedure for the parameters of driving behavior models using EA and parallel computing techniques (PCTs). The proposed method was coded and implemented in a traffic microscopic simulation software. Two scenarios with/without PCT were analyzed by developed methodology. Results of scenario analysis show that using an integrated calibration and PCT can reduce the total computational time of the optimization process significantly, in our experiments by 50%, and improve the optimization algorithm performance in such a complex optimization problem. Proposed method is useful for overcoming the limitation of computational time of the existing calibration methods and can be applied on various EAs and traffic simulation software. Keywords—Calibration, Parallel Computing, Genetic Algorithm, Particle Swarm Optimization, Parallel Hybrid GAPSO, Parallel Hybrid PSOGA, VISSIM

Integrating ridesharing services with automated vehicles into macroscopic travel demand models

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Abstract—As the introduction of fully automated vehicles enhances the attractiveness of carsharing and ridesharing systems, cities and regions may want to examine the effects of this development. This paper presents a framework for how to integrate those services in traditional macroscopic travel demand models, which are commonly used to evaluate the impacts of changed transport supply. Addressed topics are (1) the implementation of direct and intermodal ridesharing into the demand modeling process, presenting two approaches for the latter, (2) the bundling of ridesharing trips and (3) the scheduling of automated and shared vehicles. The first approach for integrating intermodal ridesharing includes ridesharing as an additional transport system, which uses the road network and which is integrated in the timetable-based public transport assignment. The second approach uses direct-link connections between traffic zones and suitable public transport transfer stops for the ridesharing feeder trips instead. Using the second approach, preliminary results of a test scenario for the Stuttgart region are presented. Keywords—automated vehicles, ridesharing, on-demand services, macroscopic travel demand model, trip bundling, vehicle scheduling

Introducing Network Softwarization in Next-Generation Railway Control Systems

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Abstract—The advent of softwarization implies a re-thinking of network design and management that positively impacts on service provisioning and maintenance efficiency. In particular, Software Defined Networking and Network Function Virtualization introduce abstraction techniques that are suitable for an easy and efficient deployment of service chain and for the use of general purpose hardware devices. The introduction of these paradigms in the railway domain is challenging due to its strict service and safety requirements, however it represents a promising approach enabling a disruptive improvement of the management systems and paving the way for next-generation railway control systems. This paper discusses and proposes the adoption of SDN/NFV (Software Defined Networks/Networks Function Virtualization) framework in railway control networks. In particular, some possible promising directions of investigation are drawn considering service orchestration and edge-based NFV services. Furthermore, two different applications are described focusing on SDN and NFV, respectively. An improved SDN failure recovery mechanism is proposed and evaluated showing the improvement in terms of recovery time. Instead, the introduction of configurable orchestration systems aiming to dynamically instantiate required services on Virtual Machines directly in the railway peripheral places by means of edge computing solutions for maintenance operations of peripheral assets is described and discussed. Index Terms—Railway management systems, Railway control networks, SDN/NFV, VMs, Orchestration, ERTMS.

Investigating the Influence of On-Street Parking Guidance Strategies on Urban Mobility

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Abstract—Parking Guidance and Information (PGI) solutions are a type of Intelligent Transportation System aimed at helping drivers by suggesting routes leading to facilities with higher parking availability. Current PGIs are mainly limited to multistorey car parks, where this availability information can be easily collected, since monitoring on-street parking availability is still a challenge, requiring very expensive sensor deployments. However, the actual benefits of such investments to provide up-to-date onstreet parking availability data for PGIs has been barely studied. To fill this gap, in this paper, we present the results of an investigation on the influence of different types of on-street parking information on urban mobility. Based on real on-street parking data from San Francisco (USA), we investigated the scenario where a PGI has to support a driver who has not found an on-street parking space at his/her destination, and has to decide on the next road to go. We compared four scenarios for the PGI guidance, based on: (I) actual on-street parking availability information, collected from stationary sensors, (II) static information about the parking capacity of a road segment and (temporary) parking limitations, (III) static information about only parking limitations, and (IV) no information at all. Clearly these different solutions have strong implications in terms of deployment and operational costs. Results show that there is a significant reduction of parking search with more informed strategies, but also that the use of real-time information makes sense only presence of limited parking availabilities. Indeed, whenever the parking dynamics are not very competitive, realtime data offers only a limited improvement over static one. Index Terms—Parking Guidance and Information, Sensor Network, Urban Mobility.

Laboratory experiments to assess the reliability of traffic assignment models

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Abstract—The assignment models, representing the relationship between travel demand and flows on the network, play a key role in almost all applications of both planning and transport network management. Although there are countless specifications for the assignment models, its reliability and dispersion structure are rarely discussed in the literature. Then, this paper addresses the errors that the usual assignment models introduce, both in terms of simulation of the network performances and in terms of OD matrix estimation based on the traffic measures. All the performances are evaluated through laboratory experiments in a controlled environment. The performances of the assignment models are compared with the results of direct estimates, obtained by randomly sampling route choices observations within the population, with variable sampling rates.Keywords—traffic assignment, assignment map, travel demand estimation.

Leveraging GIS Data and Topological Information to Infer Trip Chaining Behaviour at Macroscopic Level

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Abstract — One of the open challenges in transport modelling is to estimate within-day demand flows that reflect the complexity of individual activity-travel behaviour. While disaggregate (Activity-Based) demand models can recreate realistic daily mobility patterns at an individual level, they usually require an accurate knowledge of individual user behaviour (i.e. via travel surveys), which is not always available. As a result, practitioners often turn to aggregate demand models, that have the advantage of being less demanding in terms of data but typically under represent the demand for secondary activities. In this work, we take research on within-day demand modelling one step forward by proposing a framework that combines traditional methodologies with heterogeneous data sources in order to explicitly represent trip chaining at an aggregated level. We show that the combination of web-based crowd sensed data, network data and behavioural constraints allows to capture complex spatial and temporal correlations between demand patterns. The methodology is applied on the classical Gravity model to show how to incorporate within-day dynamics. Yet, any alternative demand model can be adopted. In our case, Generation and Attraction are used to estimate the systematic demand, that is enriched of information about individual activity patterns, and then the impedance function plays a central role in spatially distributing locations of trips using geographic relationships and constraints deriving from space-time behaviour. A case study for Luxembourg City has been presented to show the potential of the methodology: the choice of using data from a different spatial context to account for the temporal dimension has been validated through comparisons with official statistics. The results of simulating a workplace relocation show the advantages of this new approach in representing demand related to secondary activities. Keywords — Travel Demand Modelling, Time-Space Geography, Secondary Activities, Within Day Dynamics, GIS, Network Topology, Synthetic Population

Macroscopic fundamental diagrams for train operations - are we there yet?

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Abstract—We discuss the concept and applicability of macroscopic descriptions of operations for railways systems. The concept of macroscopic or network fundamental diagram (MFD or NFD) for vehicular traffic in an urban network has been recently found empirically. The notion of MFD/NFD has been exploited to understand the real-time traffic state and the relevant control actions to keep traffic flow smooth. It has been used predominantly as a monitoring tool in traffic control strategies, which helps mitigate congestion. The railway mode has the same goals of maximizing speed and flow, though it has many substantial differences with vehicular traffic. We investigate the theoretical possibility to derive macroscopic representations of the traffic flow theory macroscopic variables; i.e. speed, density, flow, for railway traffic. We do this with closed formula expression when possible, or with simulation tools when the complex setup does not allow any analytical solution. The implications for applicability of macroscopic representations in railways or railway-like systems are discussed. Keywords—fundamental diagram, moving block, railway signaling system

Measuring cycle riding comfort in Southampton using an instrumented bicycle

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Abstract — The increased environmental awareness and the rising fuel costs make bicycles a more and more attractive mode of travel for short journeys. Considering the future prospect of this mode of transportation and the great advantages that it offers in terms of space consumption, health and environmental sustainability, several city authorities worldwide are presently undertaking schemes aiming at improving cycling infrastructure. The aim of the present study is to monitor the impact of such schemes on the riding comfort of cyclists, as expressed by the, usually lower, quantity and magnitude of vibrations occurring as a result of cycling over pavement defects. Millbrook Road East in the western edge of the city center of Southampton is used as a case study, where vibration measurements are taken by means of an instrumented bicycle during periods before and after a redevelopment scheme involving the resurfacing of the road pavement. The results show a clear overall improvement in cycling comfort postredevelopment, with statistically significant reductions in both the number of high severity vibrations and of their magnitude in “typical” cycling trips taken on the road. However, instances of finishing "snags" in some parts of the surface appear to introduce new minor defects (e.g. around manholes) that are not visible to the naked eye, and these still have some negative effect on the riding experience. Moreover, the study highlights the detrimental impact that widespread pavement defects can have on riding comfort, which affect cyclists of all ages, abilities and styles. Keywords—severity, instrumented bicycle, riding comfort, accelerometer, survey data, cyclists’ perceptions and traffic calming schemes.

Methodology of research on the impact of ramp metering on the safety and efficiency of road traffic using transport models

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Abstract— The methods currently used to assess the impact of Intelligent Transport Systems (ITS) services on traffic safety and efficiency are mainly based on expert assessments, statistical studies or traffic models that need further development. There is no structured, uniform evaluation method to compare the impact of different ITS services and their different configurations. The impact of ITS deployment on the road network adjacent to motorways or expressways is usually not taken into account for simulation studies. The approach presented in the paper takes into account the impact of ITS deployment on road traffic efficiency and safety in areas including major roads and alternative routes. The paper presents a methodology for testing the effectiveness of the implementation of a selected ITS service, which is ramp metering. An approach has been applied in which the impact of ITS services is analyzed with the use of a test road network in macro, meso and microscopic transport models. The evaluation of solutions was carried out on the basis of key traffic efficiency indicators. Surrogate measures were used for the assessment of the impact of ramp metering on road traffic safety. Index Terms— ramp metering, intelligent transportation systems, ITS services, transport modelling, road traffic safety

Mixed hybrid and electric bus dynamic fleet management in urban networks: a model predictive control approach

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Abstract—Reducing pollutant emissions and promoting sustainable mobility solutions, including Public Transport, are increasingly becoming key objectives for policymakers worldwide. In order to jointly achieve these goals, careful consideration should be put on the operational cost and management of PT services, in order to promote the adoption of green mobility solutions and advanced management techniques by operators. In this work we develop a dynamic fleet management approach for next generation Public Transportation systems, considering the instance of mixed electric / hybrid fleet. Our objective is that of investigating to what extent electrification, coupled with optimal fleet management, can yield operational cost savings for PT operators, explicitly considering real-time disturbances, including delays, service disruptions etc. We propose a Mixed Integer Linear Program to address the problem of optimal scheduling of a mixed fleet of electric and hybrid / non-electric buses, and employ it as predictor in a Model Predictive Control approach. Test results based upon a real-life scenario showcase how the proposed approach is indeed capable of yielding a sizable reduction in operational costs, even when considerable disturbances arise from the underlying system. Keywords— Dynamic bus fleet management, e-bus charging scheduling, MILP, MPC

Modeling and assessing adaptive cruise control stability: experimental insights

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Abstract—Adaptive cruise control is a first step towards increasingly automated vehicles, and while ACC offers potential benefits to the traffic stream depending on the ACC design, less is known about the impacts that commercially available ACC vehicles have traffic flow. Therefore, it is of interest to reliably model commercial ACC vehicle behavior so as to be able to better understand how ACC vehicles may influence the emergent properties of the traffic flow. In this article, a set of car following experiments are conducted to collect data from a 2015 fully electric sedan equipped with a commercial adaptive cruise control system. Velocity, relative velocity, and space gap data collected during the experiments are used to calibrate two dynamical models for the ACC vehicle, one for each of two following settings. The models are calibrated via modelconstrained optimization. The main finding is that the best fit models are unstable. To better understand how much the quality of the models would have to change to alter their stability, we calibrate the models with the constraint that they must be string stable and compare both the new model error as well as the calibrated parameter values. We find that the quality of fit for the minimum following setting degrades by 26%, while the quality of fit for the maximum following setting model only degrades by 7%, but requires significant changes in the parameter values. Index Terms—Adaptive cruise control; phantom traffic jams; field experiments; traffic modeling.

Modeling the Effects of Motorway Traffic Control on Driving Behavior in a Microscopic Traffic Simulation

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Abstract—Line control systems on motorways contribute to improving traffic safety and to mitigating traffic breakdowns by means of variable speed limits, lane signals, passing restrictions and warnings. Such control measures are mostly triggered automatically in response to the prevailing traffic and weather situation. Contrary to many other types of traffic control, line control systems have only very rarely been analyzed in a microscopic traffic simulation. One major issue is the calibration of the effects certain variable message sign states have in a given situation. On the one hand, multiple messages and control strategies may overlap, making it difficult to distinguish their individual effects. On the other hand, surrounding traffic and weather conditions must be considered, as well. This paper presents a new approach to model the effects of line control systems on the driving behavior of individual vehicle-driver units in a microscopic traffic simulation. Various influencing factors as well as driver model parameters are modeled as state variables (nodes) of a Bayesian Network, which is trained based on field data from multiple motorway sections across Germany that are equipped with line control systems. This paper describes the modeling methodology, including the calibration and validation process. Furthermore, this paper describes how the model interacts with the microscopic traffic simulation at runtime, and discusses potential use cases of this approach.Keywords—Microscopic Traffic Simulation, Driving Behavior Modeling, Calibration, Line Control Systems, ITS, Bayesian Networks

Modelling of Emergency Vehicles' Route Choice with Use of Trajectory Data

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Abstract—Timing issue is very critical for emergency service. Due to the increasing traffic it has become more and more challenging for emergency vehicles to reach their destinations within a given service period in cities, especially during rush hours. Therefore, there is a need to model routing strategies to support emergency vehicles. Microscopic traffic simulation can therefore be an adequate decision-support tool for route strategies analysis. The GPS positions of 24 emergency vehicles in Brunswick have been tracked over a time period of 5 years. In this paper, the route choice behavior of emergency vehicles is analyzed with the collected trajectory data in Brunswick, Germany. In addition, microscopic traffic simulation is also used to understand the deviation between simulated and real route choices. For this purpose an emergency vehicle model was implemented in the traffic simulation SUMO. The emergency vehicle model allows vehicle in the simulation to violate red traffic lights and force other traffic participants to give way etc. Emergency vehicle drivers have time pressure when they are on duty. Furthermore, the likelihood for emergency vehicle drivers being involved in a traffic accident is significant higher compare to normal vehicles. Therefore, their concern on route choice may be different from that of other normal road users. Besides travel time the other essential route choice factors are also investigated and derived for developing the respective route choice model so that the costs of the simulated routes of emergency vehicles are close to those in the reality. It is expected that the developed model can be transferable and applied in other cities. Index Terms—emergency vehicle, traffic modeling, map matching, simulation

Modelling of traffic with dynamic bus lanes

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Abstract—The idea of dynamic bus lanes (DBL) has been known for years. Many authors tried to estimate the potential benefits of such a solution. The main assumption of the DBL system is to activate exclusive bus lane (XBL) when a bus approaches the segment and deactivate XBL when bus leaves the segment making the lane available to all road users. The new solution requires additional infrastructure like variable message signs and in-pavement lights, informing drivers whether the DBL is active or not. Also, there is a need to use a properly developed ICT system for detecting buses approaching the designated section. One of the popular tools to evaluate a new solution is a microscopic traffic simulation model. Unfortunately, the available software has some limitations. One of them is lack of special modules for simulating the activation and deactivation process of the DBL. The authors of existing publications didn't describe how they solved this problem. Therefore, in this paper the authors propose a new method for modelling DPA control in the PTV Vissim environment. The paper describes two ways to simulate the DBL process – a simplified method and a detailed method.Keywords—Dyamic Bus Lanes, Intelligent Transport Systems, Public Transport, Public Transport Priority, Microsimulation traffic model, PTV Vissim

Motivating the need for an integrated software architecture for Connected and Automated Vehicles technologies development and testing

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Abstract— With the spread of automation in driving, vehicles will have to interact more with the surrounding environment, and consequently the automotive development process will have to contemplate a realistic representation of these elements. This is a critical issue, since in the classic development process used in the automotive field, driver model and traffic environment are represented in a very simplified way. This paper overcomes this criticality through the development of an Integrated Simulation Environment, at the Model in the Loop (MIL) level, which allows the integrated representation of the vehicle dynamic and its automation, of the driver and the traffic conditions. The tool is based on integrated simulation of Matlab / Simulink with the commercial software CarRealTime and with SUMO, an open source microscopic simulator. A series of tests have been performed to prove the need for such a tool, and to show the potential of the instrument. The implemented system allows vehicle, represented with a high level of details, to be tested in realistic traffic scenarios, in which agents and characteristic variables of traffic flow can be varied in order to verify realistically the level of robustness of on-board automation functions.Keywords— integrated simulation; autonomous driving; virtual validation; vehicular communication.

Neural networks trained with WiFi traces to predict airport passenger behaviour

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Abstract— The use of neural networks to predict airport passenger activity choices inside the terminal is presented in this paper. Three network architectures are proposed: Feedforward Neural Networks (FNN), Long Short-Term Memory (LSTM) networks, and a combination of the two. Inputs to these models are both static (passenger and trip characteristics) and dynamic (real-time passenger tracking). A real-world case study exemplifies the application of these models, using anonymous WiFi traces collected at Bologna Airport to train the networks. The performance of the models were evaluated according to the misclassification rate of passenger activity choices. In the LSTM approach, two different multi-step forecasting strategies are tested. According to our findings, the direct LSTM approach provides better results than the FNN, especially when the prediction horizon is relatively short (20 minutes or less). Keywords—airport passenger, machine learning, deep learning, lstm, airport management, activity choice

New Insights into Road Accident Analysis through the Use of Text Mining Methods

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Abstract—Traffic safety is one of the main goals when designing infrastructure or vehicles. Many entities are interested in accident data in order to identify current problems. The accurate recording and analysis of accident data, though, is a time-consuming task. New data mining methods allow for a more efficient analysis of large amounts of (unstructured) data. In this paper, accident data provided by the police department of the city of Munich is analyzed both by classical methods considering only classified accidents, as well as with the help of text mining methods, taking into account all descriptions of the accidents. The results indicate that text mining methods can give quick results identifying main problems at the given locations. Using statistical and machine learning methods for the analysis shows promising results. The results of the automatic classification of accidents into accident types based on a learned classification model using the textual descriptions is highly accurate. Retrieving structured information from the descriptions, though, requires a more concise writing of the accidents reports. We conclude that in future, data mining methods could be used to reduce the workload for police officers for both the reporting work as well as the analysis of road accidents. Keywords—traffic safety, accident data, text mining, data mining

On exploring the potentialities of autonomous vehicles in urban spatial planning

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Abstract—Sustainability is nowadays an overarching concept for transport policy and planning around the world. Focusing on urban areas, the problem of congestion, combined with the need to reduce emissions into the atmosphere and increase road safety, has led national and European administrations to develop initiatives to support the so-called “soft mobility” (i.e., the mobility of pedestrians, cyclists). On the other hand, the introduction of autonomous vehicles will lead to significant changes in the interaction between traffic flow and infrastructure. Given this premise, the aim of this paper consists of modelling the interaction between urban space and autonomous vehicles mobility to explore possible benefits deriving by their market penetration. In detail, a network design problem able to optimally identify which links of the road network can be considered superfluous in an autonomous vehicle scenario and, therefore, can be eliminated to reuse them for the soft mobility is considered. A case study is considered to show the proposed network design approach. Keywords— network design, urban mobility, urban spatial planning, autonomous vehicles

On the substitutability of traffic light and pricing controllers in transportation networks

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Abstract—The maximum level of performance reachable by traffic control policies is directly affected by the locations and the types of controllers employed in the network. We therefore investigate methods to identify locations and types of controllers that guarantee that the highest possible level of performance can be reached, fully exploiting the available network capacity, while minimizing the overall installation costs. This condition is known as full controllability. In this work, based on an existing methodological contribution that allows to determine the optimal number and locations of pricing controllers required to reach the maximal level of controllability in transportation networks, we investigate instances and conditions in which the same results can be achieved through Traffic Light controllers, which represent a more realistic and widespread technology. Due to the different impact of traffic lights and pricing controllers on the network, however, optimal locations for one set might differ from the optimal locations for the other, and consequently replacing pricing controllers by traffic lights is not a straightforward task. Moreover, an enumeration of every possible combination of traffic light position will result in combinatorial explosion. In order to avoid this problematic, in this work we study simple, atomic subnetwork structures, widely occurring in real-life networks, and assess whether it is possible to maintain the maximum level of controllability while replacing pricing controllers with traffic light controllers. This first empirical step acts as the basis to study larger and more realistic transportation networks, therefore helping to develop a general methodology to substitute pricing controllers with traffic lights. Index Terms—transportation network, controllability, pricing, traffic light

On-Line Filtering of On-Street Parking Data to Improve Availability Predictions

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Abstract—Knowing where to park in advance is a most wished feature by many drivers. In recent years, many research efforts have been spent to analyse massive amount of parking information, to learn availability trends and thus to predict, within a Parking Guidance and Information (PGI) system, where there is the highest chance to find free parking spaces. The most of these solutions exploits raw data coming from stationary sensors or crowd-sensed by mobile probes. In both the cases, these massive amounts of data present a high level of noise, which heavily affects the quality of availability predictions. In a previous work we demonstrated that a 2-step approach, based on machine learning techniques to filter out noise, improves the quality of parking availability predictions over raw data. In this paper we propose a further advancement of that approach, by including a technique to perform such noise filtering in realtime, with reduced computational efforts. The proposal has been empirically tested on a real-world dataset of on-street parking information from the SFpark project, and compared against a regression model based on SVR, to perform parking availability predictions. Results show that the predictions obtained with the new on-line approach show a better balance between average and entropy in errors distribution with respect to the use of raw data coming from the sensors.
Index Terms—Parking Guidance and Information, Sensor Network, Urban Mobility.

Optimization of Mobility On-Demand Fleet Operations Based on Dynamic Electricity Pricing

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Abstract — The 21st century is characterized not only by a growing need for mobility, but above all by an increasing variety of mobility forms. Individualization, connectivity, urbanization and post-fossil drive technologies will determine the mobility of tomorrow. Technical innovations and changing human needs are becoming the driving force behind novel forms of mobility and innovative business models. But not only the mobility world is changing rapidly. Renewable energies have successfully reached the breakthrough in energy supply, but also pose new challenges, in particular for energy grid operators. More specifically, the renewable energy sources sun and wind are directly connected to planning uncertainty due to their dependence on weather, which leads to frequency fluctuations in the power grid. These fluctuations in turn are the reason for dynamic electricity prices to which especially large consumers can adapt in order to save money. This paper investigates to what extent an operating electric mobility ondemand fleet can adjust to changing electricity prices and whether this adaptation affects the service performance of the overall system. For this purpose, a model is designed, which considers traffic influences in the form of dynamic travel times as well as the passenger and battery management of the vehicles. It is found that a fleet with a charging strategy adapted to dynamic electricity prices can save money at all investigated fleet sizes. Furthermore, it does not substantially affect the service performance of the mobility on-demand fleet. In addition, considerable cost savings can be realized by applying the dynamic charging strategy. The analysis of idle times of the vehicle fleet revealed further potential for optimization, which could e.g. be used for the provision of ancillary services. Keywords — electric mobility, vehicle-to-grid, dynamic vehicle fleet simulation, dynamic electricity pricing, charging optimization

Optimization of rosters in public transport

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Abstract - The article presents the issues of the optimization of rosters in public transport using various optimization methods. The process of preparing the rosters has been described. The general assumptions of the model as well as the corresponding mathematical optimization algorithms were also presented. The results of simulation tests carried out by the authors taking into account the actual data of public transport companies have been presented. Keywords — rostering, work time scheduling, optimization, software, operational planning.

Prescriptive Maintenance of Railway Infrastructure: From Data Analytics to Decision Support

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Abstract — One of the main benefits of the railways digital transformation is the possibility of increasing the efficiency of the Asset Management process through the combination of data-driven models and risk-aware decision support systems, paving the road towards an Intelligent Asset Management System (IAMS). The paper describes the whole IAMS decisional process based on a real railway signaling use case: from field data acquisition to decision support. The process includes data collection, preparation and analytics to extract knowledge on current and future assets' status. Then, the extracted knowledge is used within the decision support system to prioritize asset management interventions in a fullyautomated way, by applying risk-based logics and operational constraints. The target is to optimize the scheduling of maintenance activities, to minimize service disruption risk and optimize both usage of resources and possession times, avoiding (or minimizing) contractual penalties and delays. In this context, a real use case related to signaling system and, in particular, to track circuits, is presented, applying the proposed methodology to an Italian urban rail network and showing the usefulness of the approach and its possible further developments. Keywords— railway prescriptive maintenance, datadriven analytics, decision support, decision automation.

Route Set Generation for Quick Scan Applications of Dynamic Traffic Assignment

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Abstract—Recent years have shown an interest in developing and using quick-scan analysis tools for the evaluation of policy options, such as planning issues, investments in infrastructure or public transport or other measures to cope with the increasing mobility problem. These tools can give a quick and easy insight into the impacts of all kinds of measures, without the large amount of work associated with the use of transport models. The assignment procedure of these tools can be improved and made more consistent with transport models. Therefore, it is needed that the calculation time of standard assignment algorithms is decreased. One possibility is to decrease the size of the route sets used. In this paper, this possibility was investigated for a number of small and medium-sized networks, using a dynamic traffic assignment framework. It was found that a route set in which each OD-pair has a maximum of 4-6 routes is sufficient to get comparable results with the situation with larger route sets. This rule of thumb for the maximum number of routes seems stable if demand increases and is not influenced by the overlap factor, which is an important parameter in the generation of route sets. Further research should focus on the scale factor in the route set generation algorithm and also larger networks need to be studied to be able to come a better founded conclusion about the size of the route set, which can be used in quick-scan tools. Index Terms—route sets, quick-scan tool, dynamic traffic assignment, DTA

Safety Analysis of RCUT Intersection

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Abstract— The safety of intersections on a major corridor is always a concern because of the high-risk vehicle maneuvers intertwined with high operating speed. Significant number of crashes at such intersections is angled-collisions with a high percentage of fatalities and injuries. This is especially true at intersections with a two-way stop-sign control (TWSC) where vehicles on a low-speed, minor roadway must cross or merge into the path of high-speed vehicles on the major highway. The crashes often involve a vehicle entering the intersection from the stop approach and a vehicle travelling high speed on the main approach. While sign and pavement marking may have an impact, they are not considered as effective as eliminating the through and left-turn movement from the minor street. For a signalized four-leg (4SG) intersection, an exclusive left-turn signal phase does promote safety, but it often results in a lower intersection capacity and the excessive delay, particularly during rush hours. One relatively new countermeasure, called Restricted Crossing U-turn (RCUT) has gained significant interest. The RCUT is aimed to reduce the number of conflicting point (thus, reducing crashes and crash severity) and increase intersection capacity. Left-turning and crossing vehicles on the minor road are forced to turn right at the intersection and then making a Uturn a short distance away. Clearly, the RCUT is suitable for an intersection of a major arterial and a minor roadway with significantly smaller traffic volume This paper evaluates the safety benefit of six RCUTs in Louisiana. Unlike the previous studies, this investigation covers both the RCUT intersection only and RCUT system (consisting of the intersection, two U-turns and segments in between). The crash analysis shows a 100% reduction in fatalities, 41.5% in injuries and 22.3% in property damage only crash for the RCUT intersection only, and less impressive reductions for the RCUT system. The review of the original crash reports greatly benefits the investigation on why the crashes increased at few locations, thus, provides the valuable information on how to correct these crash problems through the detailed design and traffic control. The safety improvement plus the high ratio of benefit to cost strongly demonstrate that the RCUT is an effective and economically justified countermeasure on high-speed roadways in both rural and urban areas. Keywords— Intersection safety, RCUT intersection, RCUT system, high-speed arterial, Crash reduction and Design

Safety evaluation of turbo roundabout with and without internal traffic separations considering autonomous vehicles operation

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Abstract— The introduction of autonomous vehicles in road traffic will eliminate the impact of the human factor from the decision-making process of drivers and will push for the introduction of the criteria for road network design, road infrastructure management, traffic modeling and assessment of tools for road safety management. The paper presents a microsimulation approach for the assessment of safety performance of unconventional turbo roundabouts in circumstances where different percentages of connective autonomous vehicles "CAVs" are mixed with conventional vehicles "CVs". Nowadays the turbo roundabouts can be with or without separation in the inner lanes. The formers are present in the Netherlands, Slovenia, Hungary and almost all the states of the Balkan are, while the latter, using only road markings are mainly located in Germany, Poland, Denmark, Czech Republic, Lithuania, Canada, and the United States. The present research work, through analysis of the vehicle trajectories from VISSIM and subsequent analysis of traffic conflicts, analyzed with the Surrogate Safety Assessment Model (SSAM) allows testing the safety benefit of the two layouts of turbo roundabout considering different percentages of CAVs. The results pointed out as the safety level varies at varying of the share of autonomous vehicles in the traffic flow and that considering only the conventional traffic composition the presence of lane separation is effective in avoiding conflicts in the inner lanes, while it becomes less effective at the increasing of the CAVs penetration. In particular, for high percentages of CAVs, the presence of the physical separation does not lead to an increase of safety, a condition that seems to be supported by the fact that autonomous vehicles completely remove the human error from driving. The results suggest again that the microsimulation is a powerful tool for the safety assessment of any road entity based on surrogate measures of safety on the condition to validate the models and use the right behavioral models at the microscopic level for describing the CAVs. The methodology seems to be a promising approach for conventional and unconventional roundabout safety performance evaluation. Keywords—Autonomous Vehicles, roundabout, surrogate measures, traffic conflicts SSAM

Sensitivity analysis of optimal routes, departure times and speeds for fuel-efficient truck journeys

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Abstract—Embedded within the vehicle "routing" problem of determining the order in which customers are served, is the route choice problem of which sequence of roads to use between a pair of pick-up/drop-off locations, and this latter is the focus of the paper. When the objective is something other than travel time, such as fuel consumption, an additional control dimension is that of speed, and in a time-varying context the question of optimal speed determination is no longer a local one, due to potential downstream interactions. This also brings in the possibility to adjust departure times. Recently this problem, of joint route, departure time and speed determination for fuel minimization in a time-varying network, was shown to be efficiently solvable using a Space-Time Extended Network (STEN). In the present paper, we explore the sensitivity of the optimal solutions produced to: i) the fidelity of the within-day traffic information; ii) the currency of between-day traffic information in comparison with historical mean conditions; iii) the availability of historical information on variability for riskaverse routing; and iv) competition from other equally-optimal or near equally-optimal solutions. We set out the methods by which each of these tests may be achieved by adaptation of the underlying STEN, taking care to ensure a consistent reference basis, and describe the potential real-life relevance of each test. The results of illustrative numerical experiments are reported from interfacing the methods with real-time data accessed through the Google Maps API. Keywords— network, route choice, dynamics, variability, fuel

Smart Intersection Management for Connected and Automated Vehicles and Pedestrians

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Abstract - Connected and automated vehicles have the potential to increase both safety and capacity of traffic, especially at intersections. In recent years, many studies about reservationbased intersection control systems that take advantage of the abilities of vehicle to vehicle and vehicle to infrastructure communication, have been published. In these studies, other road users such as pedestrians usually play a minor role or are not considered at all. However, many use cases of automated driving occur in urban environments, where vehicles share the road with pedestrians and bicyclists. This paper presents recent scientific developments about pedestrians at smart intersections and proposes various new control strategies for taking pedestrians into account in automated intersection management systems. In the developed strategies, conflicting trajectories of vehicles are excluded and turning movements of vehicles are not allowed while pedestrians are crossing the street. All control strategies are implemented and tested on a four-leg intersection using a microsimulation software. Results show that it is possible to include pedestrians into an on-demand control while at the same time ensuring that maximum pedestrian waiting times are not exceeded. The level of service for both vehicles and pedestrians can be improved if pedestrians are detected at the intersection and reserve the intersection area they want to cross. However, the most suitable intersection control strategy in order to reduce vehicle delays and pedestrian waiting times varies according to the particular demand scenario.

Solving Traffic Signal Setting Problem Using Machine Learning

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Abstract—We present a method for optimizing traffic signal settings which can be used for both, offline planning and realtime, adaptive traffic management. The method is based on metaheuristics efficiently exploring space of possible settings and evaluating candidate solutions using a microscopic traffic simulation or metamodels of simulations built using machine learning algorithms (e.g., neural networks, LightGBM). We present results of extensive experiments and compare different algorithms and their configurations in order to find the best approach in our use case. Experiments were carried out on a realistic road network of Warsaw (maps originated from the OpenStreetMap service) and showed that LightGBM may outperform neural networks in terms of accuracy of approximations, time efficiency and optimality of traffic signal settings, which is a new and important result. We also show that in terms of traffic optimization genetic algorithms give the best results (comparing to other metaheuristics).

Spatio-temporal Correlations of Betweenness Centrality and Traffic Metrics

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Abstract—Graph-based analysis has proven to be a good approach to study topological vulnerabilities of road networks through specific metrics, such as betweenness centrality. Even though betweenness centrality of unweighted, undirected graphs has been widely adopted to identify critical road segments and intersections, given the very high number of potentially highlytraversed paths flowing through them, congestion and vulnerability are strongly influenced also by static and dynamic context factors, such as road capacity, speed limits, travellers' behaviors, accidents, social gatherings and maintenance operations. In this paper, we perform a comprehensive study on how betweenness centrality (and its modified version based on travel demand), computed on directed, static and dynamic weighted graphs, can be able to capture and anticipate traffic dynamics. Static weights are based on free-flow travel times, derived from the real road network of the agglomeration of Lyon, France, whereas dynamic weights are based on travel times. The latter data, as well as the flows observed on each road segment, have been initially obtained via simulation and successively extracted from GPS taxi trajectories and loop detectors data available for the agglomeration of Lyon. The analysis proves the existence of relevant spatio-temporal correlations of betweenness centrality with traffic flows. Such correlations provide useful information about the characteristics of road networks and the behavior of drivers and justify the usage of dynamic, weighted betweenness centrality for the implementation of next-generation proactive, data-driven urban monitoring systems. These systems are expected to empower urban planners and traffic operators with novel intelligent solutions to reduce traffic congestion and vulnerability risks, therefore contributing to implement the vision of a more resilient and sustainable city. Index Terms—Betweenness Centrality, Dynamic Graphs, Traf

Spatiotemporal Traffic Forecasting as a Video Prediction Problem

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Abstract—In this paper we propose an idea of applying video prediction methodologies for urban traffic forecasting. We state that the spatiotemporal structure of traffic data is similar to the structure of video streams, therefore developed video prediction models could be utilized for urban traffic forecasting after some modifications. Recent advances in video prediction led to development of model architectures that deal with large data in video streams and effectively extract high-level spatiotemporal dependencies. Similar problems were addressed in modern studies of urban traffic forecasting. We discuss analogies between these two application areas and discover key issues that should be solved for successful merging of methodologies. These issues are related to different spatial structures (regular grids in video streams and graph-based data in traffic flows) and different extends of spatial non-stationarity (spatial convolution rules are normally constant over the frame for video processing but have natural spatial peculiarities for traffic flows). The proposed idea is illustrated by a developed model that is based on the video prediction methodology and applied for a real-world urban traffic data. The developed model architecture includes custom graph-based rules for spatiotemporal feature learning and the support vector machine as a predictor. Obtained empirical results demonstrate that the proposed model outperforms other state-of-the-art spatiotemporal models (regularized vector authoregressive models, authoregressive integrated moving average model with exogenous spatial predictors). We consider these results as a successful proof of concept and conclude that application of complex video prediction architectures will be beneficial for spatiotemporal urban traffic forecasting. Keywords—short-term forecasting, urban traffic flows, spatiotemporal feature extraction, data-driven, support vector regression

Statistical Analysis of Temporal Headway Development through Empirical Data in Urban Traffic

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Abstract—Automated vehicles are expected to play a major role in road traffic within the next decades. Thus, it becomes necessary to manage the oncoming partly automated traffic between classical and automated vehicles. In this context, human behavior represents a major source of uncertainty. In order to make different driving behavior as predictable as possible, we chose a statistical approach by collecting empirical data from classical road traffic. For this purpose, a stationary infrared sensor system including multiple measuring units to detect passing vehicles was developed. The involved sensors were attached to lamp posts next to an urban road with a speed limit of 50 km/h. From the generated data set, a statistical analysis of the change in temporal headway between consecutive vehicles is derived. Additionally, an empirically ascertained vehicle speed distribution is presented. Last but not least, a suitable heavy tail distribution is used to fit the underlying data of the occuring temporal headways. All in all, the presented results could help an automated vehicle to merge into the flowing traffic on a major road in an efficient way considering safety, energy, and comfort criteria.

Stochastic Multi-Vehicle Assignment To Urban Transportation Networks

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Abstract—This paper focuses on multi-vehicle stochastic assignment to an urban transportation network, where paths likely overlap; route choice behavior is modeled through a Probit model, whose application requires Montecarlo techniques. Main aim is to compare two different pseudo-random generators, Mersenne-Twister and Sobol, and four step size strategies for solution algorithms based on the Method of Successive Averages. Keywords—stochastic assignment, multi-vehicle assignment, automated vehicles

Supply characteristics and membership choice in round-trip and free-floating carsharing systems

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Abstract—Carsharing is a car rental system in which members have access to a fleet of cars on a relatively short time basis. Several different types of car-sharing services have been developed such as round-trip and free-floating: the first one is characterized by a more rigid structure because of its stationbased nature, the second tends to be more flexible since a customer can pick up and drop off the car in any public parking inside a wide area. Being a member is the first step users have to take to use this sharing service. This study focuses on the analysis of supply attributes directly linked to territorial characteristics such as parking availability, parking price, distance from the city center, users' trip chain in relation with location of activities and their impact on the membership choice. By using a binary logit model, and a synthetic population of the city of Berlin representing members of both the round-trip and the free-floating service, and through a sensitivity analysis, the study shows how membership is sensible to some of these attributes identifying which supply characteristics impact the user membership choice. Results suggest there are two typical membership profiles and the attributes that lead the choice are different. While a round-trip carsharing member is more willing to drive towards more than one destination and does not always have his/her own car available, the free-floating carsharing member is more apt to use a point-to-point trip scheme driving for more than 15 minutes using the service as substitute of the owned car.
Keywords—carsharing, supply, membership

Taking The Self-Driving Bus: A Passenger Choice Experiment

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Abstract— At the brink of the introduction of self-driving vehicles, only little is known about how potential users perceive them. This is especially true for self-driving vehicles deployed in public transport services. In this study, the relative preferences for a trip with a self-driving bus is assessed compared to a trip with a regular bus, based on a stated preference experiment. Based on the responses of 282 respondents from the Netherlands and Germany, a discrete choice model is estimated as a Mixed Logit model including attitudes towards trust in self-driving vehicles and interest in technology. The results show that currently public transport passengers prefer the self-driving bus over the regular bus only for short trips. This is due to the finding that the value of travel time is about twice as high for the self-driving bus as for the regular bus. Findings from this study further suggest that the popularity of self-driving busses decreases with the presence of a human steward on-board, or if they are operated as a demand-responsive service with fixed routes. People who currently show a strong interest in technology or trust in automated vehicle technology perceive the self-driving busses better than others. The trust-effect is especially strong for women. In general, men are found to be more inclined to choose the self-driving bus than women. Preferences towards automated public transport services are expected to evolve along with the transition from demonstration pilots to their deployment in regular operations. Keywords—Self-driving buses, Automated public transport, Public transport passengers, Stated choice, Mixed Logit, Bus systems

The electric analogue model for analysis and optimization of traffic flows operation in cities

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Abstract—The electric analogue model for analysis and optimization of traffic flows operation in cities has been improved. The method of realization of this model has been proposed. This method is aimed at increasing the capacity of the urban road network on the basis of a definite redistribution of the levels of loading of its sections. On the example of a fragment of the urban road network of the Kyiv City (Ukraine) the main aspects of electric simulation and optimization of traffic flows in cities are disclosed. Keywords—traffic flows, urban road network, electric analogue model, electric simulation

The Potential for Traffic Emission Reduction on Freeways with Dynamic Line Control System analyzed with PTV Vissim

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Abstract—The objective of this research is to analyze by means of microscopic traffic flow simulation whether the integration of traffic emissions in the control criteria of a dynamic line control system can lead to a reduction in emissions. A traffic flow model of a German freeway, equipped with a dynamic line control system, is built and calibrated in PTV Vissim. The current control logic is implemented in Python and integrated in Vissim through the COM interface. The acceptance of the road users towards the displayed speed limits is investigated using measured traffic data from the examined section and is included in the model. Traffic emissions are determined during the simulation and the control logic is adapted. Finally, we performed an emission assessment using HBEFA for air emissions (CO2, NOx, and PM) and RLS-90 for noise emissions. To evaluate the control logics influence on resulting traffic emissions, the existing control logic, as it operates currently, is compared to altered control logics with additional consideration of emissions. An analysis of the emissions shows that the integration of pollution-based control criteria has a positive effect. All air and noise emissions can be slightly reduced by adjusting the control logic, with no significant changes of travel times. This research shows that it is possible to reduce traffic emissions by adapting the control logic of a dynamic line control system. Index Terms—PTV Vissim, HBEFA, RLS-90, ITS, emissions, freeway, microscopic traffic flow simulation, dynamic line control system

The relationship between daily traffic and daily encounters, a micro-simulation study

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Abstract-The safety level of a specific road element can be explained in an analytical way as the product of risk and exposure. The risk is defined as the probability that a unit of exposure is involved in a crash, or in other surrogate safety measures. The most common measure of exposure is the yearly average daily traffic (ADT). The relationship between crashes and ADT is generally not linear, reproducing in some way the well-known safety-in numbers effect. Some recent studies have demonstrated that the use of alternative measures of exposure, such as encounters between VRUs and vehicles at intersections, might have a linear relationship with crashes, allowing to estimate the risk of that specific site just considering the rate of the considered measure of safety. This linear relationship basically moves the safety-in-numbers effect to the relationship between traffic and encounters. In this framework the definition of what an encounter is can be determinant in the definition of the final shape of the relationship between exposure and the considered measure of safety. In other terms, encounters that consider groups of road users might explain the safety-in-numbers effect if every single user of the group is considered to interact at the same way with all the users of the conflicting maneuver that are entering the intersection. In this case, the risk of the first users of the platoon cannot be assumed the same of the following users. However, the previous observational based study was limited to how many different locations that could be studied. By using these studies as a base for a VISSIM model it is possible to simulate the effect of varying levels of traffic and different designs have on the result found by the observational study. This allows this study to further test the hypothesis that by considering only one road user in a group of road users when defining an encounter, the resulting relationship between traffic volume and encounters is non-linear and decreasing, similar to that normally found between crashes and traffic volume.

To model or not? That's the question when everything can be measured

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Abstract—In a world with sensors and cameras almost everywhere you can wonder if classic transport models are still necessary when mobility patterns can be measured continuously.In this paper we will present the progress we made in the past few years by extracting mobility information from Mobile Phone Data (MPD). MPD can be collected continuously, 24-hours a day and every day of the year (24/7/365). Using these data (more than 12 billion location-based events monthly in the Netherlands) both regular and irregular traffic patterns can be determined at local, regional and national scales for any time period, and of course the average working day, which is commonly used for transport policy purposes. MPD-data shows reliable information that can be used for monitoring of traffic, improving the quality of origin-destination matrices (OD-matrices) in transport models but also in direct use determining traffic flows. Regarding the improvement of OD-matrices in transport models, we showed in several studies that the distribution, i.e. the structure of the synthetic OD-matrix of transport models can be improved significantly using MPD-data. For example, MPD data perform much better for OD-relations that are difficult to model with the gravity model due to historical patterns, due to spatial policy, like the Zoetermeer–The Hague-connection. Along interest in the domain of transport planning actual traffic flows obtained from MPD is also of great value in the domain of Out-of-Home (OOH) advertising and for contractors. In the OOH-domain one is interested in the number travelers that pass a billboard location, because the higher this number is the higher the value of this advertising location will be. Clearly, the availability of up-to-date, dynamic OD-data at a national scale is highly beneficial for this purpose. Also, for contractors the need to have up-to-date information about traffic flows. In their planning of road works the need to have information of traffic flows on alternative routes. On primary and secondary roads information on flows are available from counting monitoring programs or transport models. However, the actuality of these data is sometimes a couple of years old. On residential roads actual information is commonly not available. Therefore, also in this domain knowledge of traffic flows on all roads are of great importance. Recently we have made progress in the determination of traffic flows for all roads in the Netherlands directly from MPD-data. Currently, we work on presenting up-to-date traffic flows at national level fully based on MPD in an online

Towards Designing Pre-trip Traveler Information Systems: A Quantitative Evaluation

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Abstract—The progressing traffic collapse burdens the economy, the environment, and the traveler. In order to reduce the monetary, temporal, and individual costs produced by traffic, we need innovative multi-modal pre-trip information systems (IS). Without multi-modal pre-trip IS, planning individual mobility and selecting mobility options is still a pain point for many travelers. Hence, many travelers stick to habitual mobility behavior without weighing up different alternatives. Multi-modal solutions will, however, facilitate individual mobility planning by presenting alternatives proactively and thus reducing the cognitive load of modal and temporal choices. Since the integration of multi-modal mobility services in the everyday life of the end-user is still in its infancy stages, this paper focuses on the customer-centered development of multi-modal pre-trip IS. Thereby, this paper described the implementation and evaluation (n = 174) of pragmatic (i.e., information-based) and hedonic (i.e., pleasure-oriented) features into a smart mirror prototype. The results of our regression analysis shows that both pragmatic and hedonic qualities and the users' experienced need fulfillment significantly predict the users' intention to use the prototype. In conclusion, our implementation and evaluation contributes to the further development of multi-modal pre-trip IS. Our results contribute to our understanding of how to motivate travelers to use multi-modal mobility services and how we can reduce the travelers' cognitive load during the mobility-centered decision-making process. Keywords—pre-trip information, traveler information systems, multi-modal mobility, prototype, evaluation

User throughput optimization for signalized intersection in a connected vehicle environment

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Abstract—Development of connected vehicles has provided different opportunities for traffic management based on highresolution data. However, dominant methods are focused on vehicle-based strategies. The aim of this research is the development of a user-based signal timing (UST) strategy aiming at maximizing user throughput in a connected vehicle environment. The inputs of the proposed optimization algorithm are position, speed, and length of connected vehicles, as well as the number of passengers for each of vehicles, while the output is the optimum green time duration for each phase of signal timing. A microscopic simulation environment is used to collect data and validate the model employed within the algorithm. Then, the proposed optimization problem is solved by genetic algorithm method. The results obtained via UST optimization are compared with a vehicle-based optimization strategy, which is solved by the same algorithm. Results show significant increase in user throughput and share of vehicles with higher number of users on-board when USt is employed. The UST algorithm can be also implemented as transit signal priority strategy and supportive policy for ride-sharing. Index Terms—connected vehicles, signalized intersection, userbased signal timing, traffic control

V2V- and V2X-Communication data within a distributed computing platform for adaptive radio channel modelling

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Abstract—This paper presents findings of the collection and exploitation process of V2X communication data with the aim of developing a measurement data-based radio channel model for the ITS frequency range around 5.9 GHz. Collected under real world conditions, connectivity quality measurements of ETSI ITS G5 communication data form the basis of the presented model prototype. The paper provides insight into the installation and configuration of the communication hardware used. Furthermore, the transmission process of accumulated as well as live data from the vehicles to a big data platform using the IoT message protocol MQTT is investigated. There, the communication data is enriched with other geographically referenced open source data. Finally, the development of a prototype V2X radio channel model using a machine learning process is presented. The model is a helpful instrument for predicting reception qualities in the ITS radio range for previously unknown receiver positions and thus a prerequisite for two exemplary presented use cases.

Walking and bicycle catchment areas of tram stops: factors and insights

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Abstract—Pollution and congestion are important issues in urban mobility. These can potentially be solved by multimodal transport, such as the bicycle-transit combination, which benefits from the flexible aspect of the bicycle and the wider spatial range of public transport. In addition, the bicycle can increase the catchment areas of public transport stops. Most transit operators consider a fixed 400m buffer catchment area. Currently, not much is known about what influences the size of catchment areas, especially for the bicycle as a feeder mode. Bicycles allow for reaching a further stop in order to avoid a transfer, but it is not clear whether travelers actually do this. This paper aims to fill this knowledge gap by assessing which factors affect feeder distance and feeder mode choice. Data are collected by an on-board transit revealed preference survey among tram travelers in The Hague, The Netherlands. Both regression models and a qualitative analysis are performed to identify the factors that influence feeder distance and feeder mode choice. Results show that the median walking feeder distance is 380m, and the median cycling feeder distance is 1025m. The tram stop density and chosen feeder mode are most important in feeder distance. For feeder mode choice, the following factors are found to be influential: tram stop density, availability of a bicycle, and frequency of cycling of the tram passenger. Furthermore, the motives of respondents for choosing a stop further away are mostly related to the quality of the transit service and comfort matters, of which avoiding a transfer is named most often. In contrast, the motives for cycling relate mostly to travel time reduction and the built environment. Three important barriers for the bicycle-tram combination have been discovered: unavailability of a bicycle, insufficient and unsafe bicycle parking places. Infrequent users of the bicycletram combination are more inclined to travel further to a stop that suits them better. Keywords— feeder distance, catchment area, walking, bicycle, tram