ABSTRACTS

22nd Euro Working Group on Transportation Meeting

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Abstracts

**Wednesday 18th September, 2019**

**Session W11: Land Use and Transport Interactions**  
Room: VS208. Chair: Yos Sunitiyoso

**Zone-Specific Interaction Modeling of Pedestrians and Cars in Shared Spaces**  
*Fatema T. Johora and Jörg P. Müller*

In shared space environments, different types of road users share the urban space and frequently interact with each other, e.g., to negotiate priority. Instead of traffic rules, their interactions are governed by social protocols such as courtesy behavior and by informal rules like the rule of the road. Modeling the movement behavior of road users in shared places is crucial to evaluate the safety and efficiency of such environments. Based on the observation that this behavior differs based on environment topology, in this paper, we investigate two types of shared space topology: intersection zones and road zones. We use real-world data to investigate how road users behave differently in different shared space zones and model zone-specific movement behavior of road users. We validate our model by simulating various zone-specific scenarios involving pedestrian-to-pedestrian, multiple cars to pedestrians and also car-to-car interactions. The results indicate that our simulation model produces realistic behaviors.

**Do Businesses Expect Benefits from the Existence of Metro Stations in Their Area? a Case Study in Thessaloniki, Greece**  
*Andreas Nikiforiadis, Anastasia Roukouni, Socrates Basbas and Katerina Chrysostomou*

It is a fact that a new or an improved transport system has great impact on land uses and real estate prices. While there are many studies, which examine the effect of a new urban public transport system on the values of neighboring properties, little effort has been done for the identification of the benefits of businesses. The present paper attempts to identify parameters which have significant impact on business revenue, as well as to quantify that impact. For the purposes of the study, a questionnaire-based survey took place, addressed to business enterprise owners and professionals in the areas of ten under-construction metro stations. The collection of the data followed by their statistical analysis, which concluded with the development of an ordinal regression model. The results indicate that that more benefits are expected by businesses which are located close to the metro stations, in areas with limited parking availability and especially by restaurants/cafés/bars. Models of that type can be very useful in cases of implementing alternative funding methods, such as Value Capture, in which it is necessary to estimate the benefits that all the parties will gain, in order to recover the appropriate proportion for financing the project.

**Inferring Urban Mobility and Habits from User Location History**  
*Guido Cantelmo, Bogdan Toader, Constantinos Antoniou and Francesco Viti*

Retrieving exhaustive information about individual mobility patterns is an essential step in order to implement effective mobility solutions. Despite their popularity, digital travel surveys still require significant amount of inputs from the respondent. As a consequence, samples are still relatively small in sizes and data are collected during a relatively short period of time – between a few months and a year. Driven by these motivations, the approach proposed in this paper uses mobile phone location history to automatically detect activity location without any interaction with the respondent. The proposed methodology uses raw location data together with a special indexing technique to calculate the probability of performing a certain activity in a certain location. Then, a heuristic rule improves this estimation by considering the value of the information over time (i.e. some time of the day carries more valuable information). Finally, GIS data about the number of facilities located in a certain area is downloaded in real-time to further improve the overall estimation. Results of this exploratory study support the idea that the proposed approach can reconstruct complex mobility patterns while minimizing the number of active inputs from the respondent.
Session W12: Safety and Security
Room: VS217. Chair: Riccardo Rossi

Gap-Acceptance Behavior at Roundabouts: Validation of a Driving Simulator Environment Using Field Observations
Riccardo Rossi, Claudio Meneguzzer, Federico Orsini and Massimiliano Gastaldi

A general procedure for the validation of a driving simulation environment for the analysis of gap-acceptance behavior was developed in this study. It allows to test whether a synthetic indicator of gap-acceptance behavior (the mean critical gap) shows significant differences when computed on the basis of field observations versus observations collected in the simulated environment. If such differences are not significant, driver behavior can be considered similar in the two contexts, thus supporting validation of the driving simulation environment. In order to demonstrate its effectiveness, the proposed procedure is applied to the case of a three-leg roundabout located in the Veneto region (Italy). The results show that the mean critical gap estimated in the field and the mean critical gap estimated in the virtual environment are not significantly different. The proposed procedure can be applied in various contexts in which gap-acceptance behavior is a central element in terms of safety and operational performance of the traffic system under analysis.

Safety Analysis of Unsignalized Intersections: a Bivariate Extreme Value Theory - Based Approach
Massimiliano Gastaldi, Federico Orsini, Gregorio Gecchele and Riccardo Rossi

Application of extreme value theory (EVT) to road safety analysis is gaining interest, thanks to its ability to produce quick and reliable safety evaluations without the use of crash data. Traditionally applied to single collision types and single extreme variables (i.e. surrogate measures of safety), EVT can be further exploited to simultaneously model multiple collision types with the use of multiple extreme variables. In this paper two bivariate EVT approaches are applied for the safety evaluation of a three-leg unsignalized intersection. The first one considers two separate conflict points and a single surrogate measure of safety, the second one considers two surrogate measures of safety collected in a single conflict point. Each bivariate analysis was applied with both classic EVT methods: Block Maxima (BM) and Peak-Over Threshold (POT). The models produced good results, in particular with the POT method, and were able to significantly improve the univariate results when the two estimation datasets were correlated.

Evaluation of Presorted and Presignaled Intersections with Respect to Traffic Efficiency and Traffic Safety
Mirko Barthauer and Bernhard Friedrich

At many intersections, turning drivers have to yield to traffic from the opposite direction and crossing pedestrians and cyclists. Still quite limited understanding of the situation makes this task very demanding for autonomous vehicles. These can be segregated from the flow by means of presignals and be provided with exclusive protected movements. Signal control manages this “presorting and presignaling” system to adapt to the demand. Those changes potentially influence traffic safety and traffic efficiency at intersections and should be evaluated before implementing the system. In a microscopic traffic simulation study, “presorting and presignaling” is applied to a range of existing German intersections. The model is calibrated using headway and vehicle trajectory data. Different scenarios are created by varying traffic demand, signaling aspects, the share of autonomous vehicles and their driving strategies, both for the unchanged and the presignalized intersection. Firstly, the capacity and the level of service are estimated. Secondly, advances in traffic safety are examined using conflict measures like time-to-collision and post-encroachment time. Preliminary results show that typical traffic demand can be served but should go side by side with intelligent traffic management.

Delay Estimation at Urban Midblock Section Influenced by Crossing Pedestrians Under Mixed Traffic Conditions.
Hareshkumar Golakiya and Ashish Dhamaniya
Traffic infrastructures in developing countries are entirely different than developed countries in terms of pedestrian facilities. Pedestrians are not given due weightage and hence pedestrians crossing at urban midblock section is a common phenomenon in developing countries. Such crossing pedestrians not only interrupt the regular traffic but also put themselves at high risk of collision. Traffic stream distracted due to such crossing pedestrians experience delay and ultimately the quality of traffic flow is degraded. The present work is attempted to estimate delay caused to vehicles by crossing pedestrians. The speed models have been developed for different classes of vehicles observed on urban roads in India. The empirical data was collected from fifteen different midblock section with and without effect of crossing pedestrians designated as base and friction section respectively. The developed model further used to plot the speed-flow curves at different degree of pedestrian flow and thereby estimated delay due to crossing pedestrians. It is observed that with the increase in the pedestrian cross flow the vehicular delay increases. The study may be useful for delay estimation at such urban midblock sections influenced by pedestrian crossing for better travel time estimation and give some insight for designing pedestrian facility.

Session W13: Control and Management of Transportation Systems 1
Room: VS219. Chair: Margarita Martínez

Real Time Charging Decision with Stochastic Battery Performance for Commercial Electric Vehicles
Tejas Ghorpade, Narayan Rangaraj and Tilak Raj Singh

The use of Electric Vehicles for logistics necessitates routing based on battery levels and includes trips to the charging station to maintain sufficient charge. Battery consumption depends on several external parameters, and therefore fixed route solutions may not always remain feasible while execution. This paper mathematically verifies decomposing the Electric Vehicle Routing Problem into initial routing over customers and a recourse strategy for dynamic charging decisions. To accommodate the stochastic battery consumption, a charging strategy comparable to the dynamic inventory control policy is proposed. The optimal solutions are obtained from an exact formulation assuming deterministic battery performance. Two policies based on separate decision parameter for each node or a common parameter over the complete network are applied when battery consumption is stochastic. The vehicle movement is simulated over fixed routes and the battery levels are observed at the decision epochs where the charging decision is taken. The policies are compared with respect to the minimum battery level observed, number of times vehicle is charged and the number of infeasible solutions under Expected and Random Realizations of the battery performance. It is observed that the network-wide fixed parameters give comparable results to the node dependent parameters, using lesser information.

A Simple and Generally Applicable Data Fusion Algorithm for the Short-Term Prediction of Travel Times in Real Time
Margarita Martínez-Díaz and Francesc Soriguera

The relevance of travel time information will remain in future driving environments, as long as it meets accuracy requirements. Current travel time information systems usually rely on estimations obtained from spot-speed methods. Also, direct measurements of travel time are more and more used, according to the increasing penetration rate of the related technologies. However, in none of these cases is the information disseminated that expected from a real-time information system, i.e., accurate predictions of travel time. Researchers and private companies have developed methodologies able to provide such predictions. However, they are not generally implemented in practice because of their complexity or the unavailability of the necessary technology. This paper proposes a method that predicts travel times in real time, while being immediately applicable in most roads. Predictions are estimated from the spatial information given by the vehicle accumulation in each section, which is obtained from input-output diagrams. Previously, the original cumulative curves are corrected from drift by means of an algorithm that fuses the available direct and indirect measurements of travel time. The goodness of the methodology has already been proven by the authors when direct measurements are ITT. Now, its suitability when working with ITT will also be demonstrated.
An Adaptive Signal Control Approach to Enhance Effective Green Times for Pedestrians: a Case Study
Gorkem Akyol, Ismet Goksad Erdagi, Mehmet Ali Silgu and Hilmi Berk Celikoglu

This paper focuses on the optimization of a traffic light in the Kadıköy area –one of the central business districts in the polycentric form of Istanbul city– that is used by excessive amount of pedestrians. In the Kadıköy area of Istanbul, there has been an immense crowd at the coastline in either peak or off-peak hours because of the marine transit terminal. When the Kadıköy-Kartal subway’s terminal station is constructed at the heart of Kadıköy in 2013 without the crowd feasibility and analysis, it has become an inextricable situation for both vehicular and pedestrian traffic. In the studied area, there is also a tram line conflicting with the crosswalk that is specifically analyzed. When the pedestrians have a crossing gap, most of them make the decision of crossing without considering the signal phase. Likewise, when it is a pedestrian clearance phase, there can be situations where all the pedestrians cannot cross the street because of high density and insufficient green time.

Level of Service of Urban Roads Under Mixed Traffic Conditions Based on User Perception
Jithin Raj and P Vedagiri

The objective of the study is to analyse level of service (LOS) of urban roads from the perspective of road users. The Indian mixed traffic constitutes different type of vehicle classes, the behaviour of road users will also change with respect to the vehicle class they use for travelling. Hence the study models the variation of LOS perceptions with respect to different vehicle class travellers on urban roads. Video laboratory method was carried out for the collection of user’s perception data, in which the study participants is shown a series of video clips of various operating conditions and ask them their perceptions of LOS. Socio-economic information and travel habits were also collected from the study participants along with the video clip ratings, for the modelling purpose. Ordered probit model was selected for modelling the traffic operational quality in terms of quantitative traffic and road user characteristics. So this paper focusses on analysing the road users’ perception with respect to different categories of vehicle classes and identify characteristics that determine realistic urban road LOS in mixed traffic conditions. The present study will help the traffic engineers to understand the complex relationship between LOS and road-users, for planning the facilities more efficiently.

Session W21: City Logistics
Room: VS208. Chair: Antonio Comi

Fast Estimation of Point-to-Point Travel Times for Real-Time Vehicle Routing
Guido Gentile, Lorenzo Meschini, Daniele Tiddi, Agostino Fiorani and Alessandro Attanasi

To provide the optimal allocation of requests to vehicles Routing algorithms typically assume the availability of complete and correct information about point-to-point travel times. In real applications, reliability of travel times is crucial, to avoid compromising the optimality and, more important, the feasibility of vehicle routing solutions, which could affect customer satisfaction or even violate contract terms, jeopardizing the overall service quality. Actually, non-recurrent events and traffic conditions make the estimation and the prediction of such travel times a difficult task, further complicated in real-time applications by the dynamicity of the information and the amount of needed estimates. In this paper we present a complete methodology to achieve an extremely fast computation of point-to-point travel times based on a dynamically updated and forecasted information of traffic conditions on a large network.

Models and Algorithms for Network Design in Urban Freight Distribution Systems
Lucas Guimarães, Bruno Prata and Jorge Sousa

Central areas of large cities offer in general many advantages to their inhabitants. Typically, a large number of products, services, and opportunities are available in those urban zones, thus increasing life quality. Unfortunately, these benefits are associated with increasing transportation activities that can cause serious problems, such as traffic congestion, excessive energy consumption, and pollution.
This paper aims at presenting a new transport system that consists of transporting freight in long-haul passenger vehicles. Two mixed integer mathematical programming models are presented: one for total cost minimization and the other for the travel time minimization. The problem under study was considered as a multi-commodity network flow problem with time windows, multi transport-lines, and multiple vehicles. Three heuristics based on mixed integer programming (MIP) were designed to solve it: size reduction, LP-and-fix, and a combination of these two procedures. The proposed approaches were validated in a case study designed around the intercity passenger transport system, in Ceará, Northeast of Brazil. Several operational scenarios were evaluated, taking into account the available freight capacities. The developed MIP heuristics produced high-quality solutions, in reasonable computational times, with the LP-and-Fix algorithm outperforming the other approaches.

A Classification of Two-Tier Distribution Systems Based on Mobile Depots
Bruno Oliveira, António Ramos and Jorge Sousa

Two-tier distribution systems have been proposed in the context of city logistics to mitigate the negative externalities of urban freight transport, particularly for larger and highly congested urban areas. In this paper, we focus on two-tier urban freight distribution systems based on mobile depots where little or no physical infrastructure is considered and where storage is not permitted. In these types of systems, coordination and synchronization between vehicles are essential, and the main objective is to have vehicles at the transfer locations in a need-to-be basis as a way to minimize their negative externalities. We propose a classification for these systems according to the level of mobility and accessibility of transportation modes operating at the first-tier. Furthermore, we characterize the main components and operational characteristics of the different systems, including the existence of multi-trips, the types of transport modes used, transported loads and the characteristics of the transfer sites (satellites). This work will hopefully contribute for a clearer characterization of two-tier urban distribution systems, to be later used in developing mathematical models for their design and planning.

Urban Freight Vehicle Flows: an Analysis of Freight Delivery Patterns Through Floating Car Data
Antonio Comi, Agostino Nuzzolo and Antonio Polimeni

The assessment procedures of city logistics scenarios require the simulation of freight transport demand and hence the estimation of freight vehicle origin-destination (O-D) flows. These O-D flows can be obtained from the simulation of delivery tours. Therefore, the paper recalls a system of models able to simulate delivery tours using an aggregate approach proposed by the authors and presents such an advancement in sub-model specification and calibration. It uses a two-step procedure for simulating the choice of tour pattern (e.g. single/multiple direct or single/multiple peddling) and the decision of number of stops (trips) made in a selected tour pattern. The data used in this study are from a set of commercial vehicles operating in the Veneto Region (Italy) for which floating car data (FCD) of 60 operating-days were available. The analysis allowed us to investigate the current patterns of delivering tours in the Veneto Region and to point out relationship with socio-economic characteristics and land use of the zone served.

Session W22: Public Transport Planning and Operation 1
Room: VS217. Chair: Miquel Estrada

Feeder Transit Services in Different Development Stages of Automated Buses: Comparing Fixed Routes Versus Door-to-Door Trips
Hugo Badia and Erik Jenelius

The arrival of automated vehicles could significantly reduce the operating cost of mobility services. This fact has encouraged researchers to propose door-to-door services instead of the current fixed routes. However, a comparison between these two alternatives is required in order to identify when (depending on the development degree of the automated vehicles) and where (depending on the characteristics of the area of service) the implementation of each service is the most competitive solution. This research compares the two types of transit services to supply first/last-mile solutions in suburban areas. By means of an analytical approach, the results show that fixed routes remain the most effi-
cient alternative unless the new technology reaches a certain degree of development that allows a high reduction of operating costs. In this case, the applicability of door-to-door services will significantly increase under certain circumstances: small areas of service, short distance trips and high values of time.

Modeling Public Transportation Networks for a Circular City: the Role of Urban Subcenters and Mobility Density
Marcos Medina-Tapia, Francesc Robusté and Miquel Estrada

The concentration of both employment and services in a specific area of a town generates positive effects, but also impacts. Some of them are congestion of a large city center, inefficiencies in public transport systems, and others. Many countries face these impacts in which their cities are large and disperse with a central business district that concentrates the majority of activities. Urban subcenters seek to approach economic activities to peripheral urban spaces. The objective of this research is to analyze and evaluate the feasibility of implementing urban subcenters. The analysis is based on a continuous approximation model that considers a total cost function, including users and agency costs: The model can compare urban structures of different transit modes (subway, tramway, bus rapid transit). The model addresses with mathematical optimization (Karush-Kuhn-Tucker conditions) on a circular city with circular and radial roads. The model is applied to several urban subcenters scenarios, and it is applied to a real case: Santiago, Chile. The results of the modeling show that implementation of subcenters generates interesting improvements in the functioning of public transportation systems. These outcomes will be better if the transit is adapted to optimal urban schemes for obtaining consolidated subcenters.

Model and Solution Methods for the Mixed-Fleet Multi-Terminal Bus Scheduling Problem
Erika Picarelli, Marco Rinaldi, Andrea D’Ariano and Francesco Viti

Public transport services are currently executing or planning a fundamental transition from traditional buses to electric buses. During this transition phase, the public transport offering is fulfilled with a mixed fleet across multiple bus terminals, which poses operational challenges for optimal vehicle scheduling, a problem not yet addressed in literature. As researchers in Transport Engineering and Operational Research at the University of Luxembourg, in collaboration with the Roma Tre University, we support the Ministry of Transport of Luxembourg and Volvo buses by modelling and simulating this transition phase, to help them manage and solve such challenges. In this work we develop a mathematical model of the problem and implement a time-based decomposition framework, through which we can optimize real-life daily instances. This method is tested using the main urban bus lines that connect Central Station, Findel Airport and three other major terminals within Luxembourg City. The objective is applying our approach to a wider set of bus lines of the urban system, providing (near) optimal solutions that explicitly consider the energy constraints arising from electric bus operations, while establishing an advantageous trade-off between delaying trips, to implement quick-charging of electric buses, and performing the same trip with costlier traditional buses.

Operational Cost and User Performance Analysis of on-Demand Bus and Taxi Systems
Miquel Estrada, Josep-Maria Salanova, Marcos Medina-Tapia and Francesc Robusté

This paper presents the service optimization problem of three different on-demand transit systems operated by taxis and vehicles with semiflexible routes. This problem is aimed at minimizing the total cost of the system that consists of the temporal cost experienced by users and the operating cost incurred by transit agencies. A compact set of estimations of the user performance and operating cost is provided, based on geometric probability. The optimization tool calculates the optimal time headway (or maximal waiting time in case of taxis) and the total cost per passenger served. Moreover, the most efficient on-demand transit service can be easily identified in each demand domain. Results show that taxi systems are only preferable for low demand densities ($\lambda_d < 30 \text{ pax/km2-h}$). In other demand domains, bus systems with low flexibility in the layout present the lowest operating and total cost per passenger. The estimation of unit operating costs allow decision makers calculating the subsidies needed to make the system profitable for transit agencies.
Session W23: Big Data and Machine Learning 1  
Room: VS219. Chair: Dmitry Pavlyuk

Development of an Agent-Based Transport Model for the City of Hanover Using Empirical Mobility Data and Data Fusion  
_Lasse Bienzeisler, Torben Lelke, Oskar Wage, Falco Thiel and Bernhard Friedrich_

The model presented in this work is based on the agent-based simulation framework MATSim. We describe a new approach for the development of a MATSim scenario. In cooperation with the City of Hanover, available data was centrally collected, analysed and clustered. Using data fusion, the dataset was combined and enriched with additional information from open data sources in order to improve the level of detail of the model. In combination with the German mobility survey “Mobilität in Deutschland 2017”, the developed approach is specifically adapted to the regional characteristics of the city of Hanover, but yet transferable to other scenarios.

Applying Machine Learning Methods for Enhancing the Probability of Success in Logistics Tenders  
_Sachin Nataraj, Cristina Alvarez, Angel Juan, Christopher Bayliss, Lluna Sada Trabado and Javier Panadero Martinez_

The concept of logistics tender or request for quotation is gaining importance among the logistics and transportation companies, since many large manufacturers are using this reverse auction system to transport their products worldwide. This paper describes a real-life case in which historical data is used to develop machine learning models able to predict the probability of success in a given tender based on the actual level of some decision variables. Some preliminary results are given, and a discussion on how these models can be integrated into optimization models is also highlighted as potential future work.

Discrete Choice Modeling Using Kernel Logistic Regression  
_José Ángel Martín-Baos, Ricardo García-Ródenas, María Luz López-García and Luis Rodríguez-Benitez_

The Kernel Logistic Regression is a popular technique in machine learning. In this work this technique is applied to the field of discrete choice modeling. This approach is equivalent to specifying non-parametric utilities in random utility models. A Monte Carlo simulation experiment has been carried out to compare this approach with Multinomial Logit models, comparing the goodness of fit and the capability of obtaining the specified utilities.

Towards Ensemble Learning of Traffic Flows’ Spatiotemporal Structure  
_Dmitry Pavlyuk_

Short-term urban traffic forecasting is an important problem of transportation engineering. Many modern forecasting models utilise information about a spatiotemporal structure of traffic flows – relationships between flow characteristics at distant road links that appear with time delays. Accurate identification of this structure is critically important for models’ forecasting accuracy and interpretability. This paper proposes application of an ensemble learning technique for learning the spatiotemporal structure. The proposed ensemble combines three spatiotemporal feature filtering methods that widely used in traffic modelling – travel time-based, which utilises information about road connectivity and travel times between road segments, cross-correlation-based, which uses the correlation structure of dependencies, and a graphical model-based, which discovers conditional relationships between traffic flows. The resulting ensemble is used for specification of features in the spatially regularised vector autoregressive model and applied to a real-world data set (Minneapolis, USA). Extensive experiments demonstrate promising results of the proposed ensemble learning in terms of model forecasting accuracy, robustness of estimated structures and parsimony of resulting model specifications.
A Strategic Multistage Tactical Two-Stage Stochastic Optimization Model for the Airline Fleet Management Problem.
Adrian Serrano-Hernandez, Luis Cadarso and Javier Faulin

This work proposes stochastic optimization for the airline fleet management problem, considering uncertainty in the demand, operational costs, and fares. In particular, a multistage tree is proposed, compounded of strategic and tactical nodes. At the former ones, fleet composition decisions are made, while at the latter ones, aircraft assignment decisions are formulated. Computational experiments are based on a small air network with seven strategic nodes and fourteen tactical nodes (i.e., seasons) where two fleet types are available to be included: Airbus 320, and Boeing 737. These results provide the optimal fleet planning and assignment at both strategic and tactical scopes. Finally, it is shown the superior performance of the stochastic version of this problem against the deterministic one.

Integration of Airport Terminal Arrival Route Selection, Runway Assignment and Aircraft Trajectory Optimisation
Adrian Barea, Raul de Celis and Luis Cadarso

Incoming air traffic in a given airport can be provided by a great diversity of air routes. However, airports comprise a limited number of runways. The reduction in the number of paths that aircraft can transit takes place in terminal arrival routes, which act as an interface between incoming routes and approach trajectories. This occurrence entails that air traffic has to be carefully managed in terminal arrival routes in order to prevent possible bottlenecks. This work presents an optimisation model that manages not only approach and landing operations, but also terminal arrival routes, deciding on runway assignment, terminal arrival route selection and aircraft trajectory. The proposed integrated model leads to a mixed integer non-linear problem. For its resolution, a Benders decomposition is proposed. On the one hand, the master model deals with runway assignment and terminal arrival route selection, making use of a set of binary variables. On the other hand, the sub-model deals with the trajectory calculation problem, managing a set of continuous variables and minimizing a combination of fuel consumption and delay.

Impacts of Unplanned Aircraft Diversions on Airport Ground Operations
Caterina Malandri, Luca Mantecchini, Filippo Paganelli and Maria Nadia Postorino

When an unplanned disruption causes the temporary closure of an airport, incoming flights are rerouted to one (or more) nearby ones. As a consequence, traffic in the alternate airport increases and the efficiency, punctuality and regularity of operations may be compromised. The purpose of this work is to determine the impacts on the alternate airport airside operations due to the presence of diverted flights. If the number of aircraft to be serviced increases, ground handling operators are subjected to an additional workload, probably resulting in delayed departures and knock-on delays. A discrete-event simulation model of both aircraft landing-and-takeoff (LTO) cycles and turnaround operations is built by using AnyLogic. The model is applied to the case study of Lisbon “Humberto Delgado” airport. When the number of incoming flights increases upon a certain threshold, departure delays spread over the day, which should call for emergency actions and contingency plans.

Session W32: Simulation and Optimization of Transportation Systems
Room: VS217. Chair: Umberto Crisalli

Suppressing the Effects of Induced Traffic in Urban Road Systems: Impact Assessment with Macrosimulation Tools - Results from the City of Krakow (Poland)
Arkadiusz Drabicki, Andrzej Szarata and Rafal Kucharski

This paper presents results of simulation analysis of demand elasticity effects arising as a consequence of major road improvements in urban areas. These projects, often desired to bring network-wide benefits, also induce additional traffic volumes which eventually deteriorate traffic congestion. Our objective is to investigate how this might be prevented with additional changes in road network to preserve key gains provided by new road investment. We present results for selected case studies of
major road projects currently underway in the second-largest Polish city of Krakow. We carry out investigation in macrosimulation transport model, and highlight the impact of demand elasticity phenomena - firstly, how it indeed induces traffic volumes which “fill up” the space apparently freed up by new ring road projects – and then secondly, how further reduction of road capacity leads to final traffic congestion relief. As shown in our analysis, certain measures (indicators) might be potentially useful in estimating the “suppression” of induced traffic effect – i.e. related to network travel times and incremental costs of induced traffic. Findings from our study could be used to derive a generic method for evaluating urban road system development scenarios, and be of practical relevance for road investment appraisal process.


*Umberto Crisalli* and *Antonio Polimeni*

This paper presents an assignment model able to reproduce mixed traffic flows made of automated vehicles (AVs) and conventional ones (CVs). In order to apply to large urban networks, such a model is specified in the framework of the meso-simulation approach. First results of a test case application to a network of realistic dimensions are reported to show the capability of the proposed assignment model to support the assessment of future mobility scenarios characterized by the presence of both AVs and CVs.

Network-Wide Emission Effects of Cooperative Adaptive Cruise Control with Signal Control at Intersections

*Mehmet Ali Silgu*, *Ismet Goksad Erdagi* and *Hilmi Berk Celikoglu*

In this paper, we analyze the relation of penetration rate of vehicles with Cooperative Adaptive Cruise Control (CACC) and three parameters, i.e Total Time Spent, Number of Stop-and-Go Movements and Total Emission, in three test networks, which have different levels of complexity and different traffic control strategies. Our analysis shows that the possible effects of CACC on environment and traffic in near future is distinguishable. We further discuss the compatibility of existing urban traffic control management strategies with CACC.

Regional Dynamic Traffic Assignment for MFD Traffic Models and Bounded Rational Drivers

*Sergio Batista* and *Ludovic Leclercq*

In this paper, we propose to extend the regional dynamic traffic assignment framework for Macroscopic Fundamental Diagram traffic models discussed by Batista and Leclercq (2019), to account for bounded rational drivers. We consider drivers with indifferent preferences and with clear preferences for more reliable travel times. Monte Carlo simulations are used to account for explicitly calculated distributions of trip lengths as well as the regional mean speeds. The Method of Successive Averages is used to calculate the regional network equilibrium. Preliminary results considering bounded rational drivers with indifferent preferences are discussed.

Session W33: Demand and Choice Modelling

Room: VS219. Chair: *Francisco G Benitez*

Land Use Inference from Mobility Mobile Phone Data and Household Travel Surveys

*Noelia Caceres, Francisco G. Benitez* and *Luis Miguel Romero*

The mobility data derived from mobile phones may provide hints regarding land-use. Activity zones, be residential or productive, feed the global mobility once acting as origin and/or destination of trips. This research presents an approach to characterise the predominant activity of the sectors of a case of study, the metropolitan area of Malaga (Spain), using mobility patterns. The methodology is tested and compared with the socio-economic information provided by the Official General Statistics and Economic Information in order to quantify the reliability of the approach.
Passenger Centric Train Timetabling Problem with Elastic Demand
Ricardo García-Ródenas, María Luz Lópezc-García, Julio Alberto López-Gómez and Luis Jimenez Linares

A widely used taxonomy for train timetabling models, classifies them according to the point of view used, in: i) operations centric models and ii) passenger centric models, which tries to maximize customers satisfaction. This work proposes a passenger centric timetabling model based on machine learning techniques. The proposed model uses the concept of strategy of a passenger as a set of lines to satisfy his/her particular origin-destination trip. A demand forecasting model has been developed based on kernel functions and it allows the estimation of the number of passengers in each strategy of the network, taking into account the existing correlation between strategies. The resulting model captures the elasticity of demand with respect to the characteristics of the designed timetable such as price, travel time, arrive time, etc.

A Dynamic OD Prediction Approach for Urban Networks Based on Automatic Number Plate Recognition Data
Jing Liu, Fangfang Zheng, Henk J. van Zuylen and Jie Li

OD flows provide important information for traffic management and planning. The prediction of dynamic OD matrices gives the possibility to apply anticipatory traffic management measures. In this paper, we propose an OD prediction approach based on the data obtained by Automated Number Plate Recognition (ANPR) cameras. The principal component analysis (PCA) is applied to reduce the dimension of the original OD matrices and to separate the main structure patterns from the noisier components. A state-space model is established for the main structure patterns and the structure deviations, and is incorporated in the Kalman filter framework to make predictions. We further propose three K-Nearest Neighbour (K-NN) based long-term pattern recognition approaches. The proposed approaches are validated with field ANPR data from Changsha city, P.R. China. The results show that the observed OD flows can be accurately predicted by our proposed approaches. Which prediction method performs best depends on the quality of the available data: for regular, periodic OD matrices the Kalman filter is better, for irregular OD matrices the pattern recognition, that looks at different time periods in the historical data, gives better results.

Thursday 19th September, 2019
Session T11: Shared Mobility
Room: VS208. Chair: Imma Ribas

School Bike Sharing Program: Will It Succeed?
Gabriele D’Orso, Marco Migliore, Massimo Attanasio, Marco Enea, Gabriele Di Maria, Riccardo Lo Monaco, Domenico Caminiti, Marcello Marchese and Nunzio Bongiorno

Encouraging active and sustainable transport modes in order to limit the excessive use of cars, reduce pollutant emissions and create livable urban environments has become one of the priorities for policymakers in recent years. The introduction of innovative systems increasingly being introduced in modern cities, such as bike sharing, can certainly contribute to the spread of cycling and thus allow a radical change in the mobility habits of their citizens. This can be especially true for high-school students who are often otherwise accompanied by their parents in cars. This article aims to assess the influence that a bike sharing program for students, teachers and school staff has on modal share and on city mobility. As a case study, the city of Palermo was chosen, where the use of the car for home-school trips is prevalent. The “Go2School” project, which involves the creation of a bike sharing program for four schools, with the construction of cycle docks and cycle paths in the nearby areas, will soon become a reality. Thanks to appropriate surveys and questionnaires, a multinomial logit model was calibrated to estimate the modal share towards bike sharing for the students and evaluate the demand for this transport mode.

Leonardo Caggiani, Luigi Pio Prencipe and Michele Ottomanelli

Car-Sharing Systems (CSSs) are becoming increasingly popular in urban areas replacing car ownership, especially in high-density cities. The most attractive CSSs give users the opportunity to make one-way trips. This behaviour, however, creates an unbalanced status between stations. As an alternative and more sustainable carbon-free mode of transportation, some CSSs are employing Electric Vehicles (EVs). A recent technology applied to EVs, called Vehicle-to-Grid (V2G), has allowed to sell energy, transferring it from vehicle batteries to an electric grid. In this paper, we propose to adopt Electric Cars (ECs) with V2G for one-way station-based CSSs. In particular, we suggest ECs distributions among stations at the beginning of each day, simultaneously making the most of V2G technology and satisfying CSSs customers’ requests. These distributions represent the final configurations that should be obtained through overnight vehicle relocations. The proposed model has been applied to a real-based test case achieving promising results.

An Efficient Insertion Heuristic for on-Demand Ridesharing Services
Jarmo Haferkamp and Jan Fabian Ehmke

In recent years, several ridesharing operators have launched their services across the globe. For these services, mobility requests arrive dynamically and have to be realized with a limited number of vehicles. The problem of request acceptance and route planning can be modeled as Dynamic Dial-a-Ride Problem (DDRP). Due to the limited transportation capacity of the shared vehicles, an important objective of the new service operators is to maximize the number of accepted requests. Since not all requests can be fulfilled, it is necessary to inform passengers immediately about the acceptance or rejection of their request. One way to achieve this is via feasibility check of the DDRP, which in this case must be performed within a very short computing time. The aim of this contribution is to examine the trade-off between computing time and solution quality as well as the effects of rescheduling during the feasibility check under realistic conditions of a typical urban on-demand ridesharing service. For this purpose, a Large Multiple-Neighborhood Search is proposed as an efficient approach to solve the DDRP. The analysis of different computing time limitation’s as well as the performance evaluation of the developed heuristic is based on computational simulation.

On-Demand Shared Ride-Hailing for Commuting Purposes: Comparison of Barcelona and Hanover Case Studies
Mireia Gilibert, Imma Ribas, Christian Rosen and Alexander Siebeneich

Two case studies that offered a shared ride-hailing service to work-commuters and students as an alternative to the private car and the public transport are analyzed and compared. The first case study took place during one week in Barcelona with the participation of 55 volunteers that used the service to commute from the city center to the most western district of the city. The second case study was based on the service test of MOIA in Hanover and involved the participation of 529 users that used MOIA to commute within Hanover and also as a first and last mile service. Results prove the suitability of this new mobility service for the use case commuting as well as for leisure trips and indicate the most important design factors to attract users and gain customer loyalty.

Session T12: Public Transport Planning and Operation 2
Room: VS217. Chair: Silvio Nocera

Keys to Effective Transit Strategies for Commuting
Francesco Bruzzone, Federico Cavallaro and Silvio Nocera

Endorsing transit effectiveness has become a key concern in promoting mobilities within urban and suburban surroundings. Many aspects in the burden of commuting have attracted increasing attention from researchers, and many interesting studies on this topic have been published already. This paper aims to contribute fresh evidence by examining the materials deriving from a thorough literature research for the sake of some of the case studies included in the European project SMART-COMMUTING. The research will include a combination of quantitative and qualitative approaches,
aiming at examining which of the factors considered may be the best predictors of the efficiency of a given transit commuting policy for concrete applications on the project areas.

**A Model for the Simultaneous Selection of Bus Lines and Frequency Setting Problems in the Expansion of Public Transit Systems**

*Grace Maureira and Esteve Codina*

When expanding an existing public transport system a common practice consists of defining a set of candidate new lines and from them, choose those that will revert into a greater increase of the system’s performance while keeping at a moderate level the associated amount of economical costs. In this work, a mathematical programming model for the selection of candidate lines in extensions of the public transport system is proposed based on the linearization of the model presented by Codina et al. (2013) and its application to situations of medium congestion. The model assumes that the pool of candidate lines is an input externally determined by technical criteria and it is focused in the compatibility constraints that the final set of selected lines must verify. These constraints include the overall throughput capacity of the stops/stations of the model, the availability of space for users to wait at stations, the resulting line capacities for passenger flows at line segments and the waiting times of passengers at stops. Solution procedures are based on the subgradient and Cutting Plane’s algorithms and several small to medium size instances are successfully solved in the computational tests.

**School Commuting: the Influence of Soft and Hard Factors to Shift to Public Transport**

*Cassilda Mariza Motta Queiroz, Pedro Celeste and Filipe Moura*

School commuting is critical for modern societies considering its potential and long-lasting impacts in travel behavior of younger generations, today and in the future. Besides positive health impacts, exposing younger cohorts to more sustainable modes (e.g., walking, cycling and transit) is believed to be crucial to form future adults with more sustainable mobility decisions. Despite the vast research on school commuting, scrutinizing the foremost factors that determine the modal choice of households when children and youth commute to school is still challenging. Here, we carry out an analysis of the main factors that impact the willingness to shift to public transportation for school commuting, in the Lisbon Metropolitan Area. Also, we analyze the potential of hard and soft measures to change the households’ perception towards transit and their willingness to shift away from private car. While hard measures relate to interventions in the transport operation characteristics, soft measures act on the users’ side and aim to influence their collective and environmental consciousness. The preliminary results (from a sample of 1640 households) suggest that in order to achieve a modal shift towards public transportation, we should focus on improving transit services supply as the baseline for the whole system change.

**Distribution of passenger costs in fixed versus flexible station-based feeder services**

*David Leffler, Wilco Burghout, Oded Cats and Erik Jenelius*

This paper presents a comparative analysis of demand-responsive and fixed-schedule, fixed route operations for a simplified station-based feeder to mass transit scenario. Traffic dynamics, demand-responsive fleet coordination, and the behaviour of individual transit users are represented using a public transit simulation framework. Each operational strategy is simulated for varying levels of demand and two fleet compositions with respect to vehicle capacities and fleet size are compared. The services are evaluated based on resulting passenger waiting times, in-vehicles times and additional waiting time if one is denied boarding a fully occupied vehicle. Results indicate that dividing planned service capacity into larger fleets of smaller vehicles can provide a higher level-of-service to passengers. On an aggregate level, utilizing a fixed operational policy results in shorter and more reliable waiting times for levels of demand where there is slack in service capacity. In scenarios where planned service capacity is sometimes exceeded, the on-demand service provides a more even spatial distribution of passenger waiting times, relative to a fixed service.

**Session T13: Sensors and Automatic Data Collection Methods**

Room: VS219. Chair: Jie Li
Traffic Modelling Using Plate Scanning Data: Models and Challenges
Fernando Álvarez-Bazo, Santos Sánchez-Cambronero, Ana Rivas, Inmaculada Gallego and José María Menéndez

The analysis of the functionality of road network and the quantification of travel times along the paths that vehicles follow is fundamental in the traffic engineering field. To analyze and estimate the flows that take to place in a network, some methodologies and tools have been used in the last decades. This paper revises the advantages of the use of data from plate scanning for the modelization and estimation of network traffic flows, considering also the definition of Origin-Destination matrix and traffic assignment into the network, as well as the quantification of travel times. The existing models and methods provide tools to determine the number of links which are valid to locate a device that collect data through the Automatic Vehicle Identification. This devices location can even lead a full observability of traffic flows, and a good estimation of travel times, since this techniques provide us more information than other known technique. For a correct application of this methodology in the real world, some challenges have to be faced as for example: it is necessary develop a device that combine efficiency and low-cost

Traffic Police Operation Based on Sensors and Data Analytics
Mali Sher

Traffic Police enforcement is one of the main operations (along with engineering and education) to reduce road accidents by changing driver behavior. The traffic police is also responsible for handling events on the road, investigating road accidents, and prosecution. All these operations are based on three stages: (1) collecting data – from sensors embedded in the road, pictures and videos, cellphones, in-vehicle-data records, crowd sourcing and professional; (2) analyzing the data using a business information (BI) system and geographic information system (GIS); (3) Developing specific models for resource operations. The results of these operations are a reduction in the traffic offences and road accidents by severity in 2017-2018.

Urban Travel Time Data Cleaning and Analysis for Automatic Number Plate Recognition Data
Jie Li, Henk Van Zuylen, Yuansheng Deng and Yun Zhou

Data recorded by Automated Number Plate Recognition (ANPR) cameras can be used to determine several important traffic characteristics, such as real time travel time, travel time statistics, travel time reliability and OD matrices. In this paper ANPR data collected in Chinese city Changsha have been validated. Travel time extracted from ANPR data includes some outliers which are often caused by drivers who have an intermediate stop between two observation points or deviate from the straight route. Exceptional travel time reduces the validity of the estimation of the travel time and reliability. Firstly, the Rapid-Moving Window method is introduced to identify outliers. Afterwards, another method based on wavelet analysis is put forward to identify and remove the outliers in the travel time series. The wavelet analysis method is compared with the Rapid-Moving Window method and shows to be more accurate in outlier identification. The method for eliminating outliers in travel time can be implemented in real time to enhance the data quality for traffic network monitoring and management. After removal of outliers, the resulting travel times are used for the analysis of the relation between average travel time and the standard deviation and skewness.

A Comparison of Deep Learning Methods for Urban Traffic Forecasting Using Floating Car Data
Juan José Vázquez Giménez, Jamie Arjona Martínez, Mari Paz Linares Herreros and Josep Casanovas García

Cities today must address the challenge of sustainable mobility, and traffic state forecasting plays a key role in mitigating traffic congestion in urban areas. For example, predicting path travel time is a crucial issue in navigation and route planning applications. Furthermore, the pervasive penetration of information and communication technologies makes floating car data an important source of
real time data for intelligent transportation system applications. This paper deals with the problem of forecasting urban traffic when floating car data is available. A comparison of four deep learning methods is presented to demonstrate the capabilities of the neural network approaches (recurrent and/or convolutional) in solving the traffic forecasting problem in an urban context. Different tests are proposed in order to not only evaluate the developed deep learning models, but also to analyze how the penetration rates of floating cars affect forecasting accuracy. The presented experiments were designed according to a microscopic traffic simulation approach in order to emulate floating car data fleets, which provide vehicle position and speed, and to validate the obtained results. Finally, some conclusions and further research are presented.

Session T21: Big Data and Machine Learning 2
Room: VS208. Chair: Maria Paz Linares

Improving Parking Availability Information Using Deep Learning Techniques
Jamie Arjona, Maria Paz Linares, Josep Casanovas-Garcia and Juan José Vázquez Giménez

Urban traffic currently affects the quality of life in cities and metropolitan areas as the problem becomes ever more aggravated by parking issues: congestion increases due to individuals looking for slots to park their vehicles. An Internet of Things approach allows drivers to know the state of the parking system in real time through wireless networks of sensor devices. This work focuses on studying the data generated by parking systems in order to develop predictive models that generate forecasted information. This can be useful in improving the management of parking areas. This research begins by looking at the state of the art in predictive methods based on machine learning for time series. This paper then introduces the recurrent neural network methods that were used in this research, namely Long Short-Term Memory and Gated Recurrent Unit, as well as the models developed according to real scenarios in different cities. In order to improve the quality of the models, exogenous variables like hourly weather and calendar effects are taken into account, and the baseline models are compared to the models that used this information. Finally, the preliminary encouraging results are described, followed by suggestions for corresponding future work.

The Method of Random Trajectory Perturbation in Surrogate Safety Indicators
Vittorio Astarita and Vincenzo Pasquale Giofrè

Traffic conflicts based surrogate safety indicators have been applied extensively on real trajectories and in simulation. Such indicators can be useful to assess the safety of a given scenario without the need to use real crash data (which in many cases may be unavailable). Unfortunately, all traffic conflict indicators that are commonly used have a structural limitation: they are not able to consider potential conflicts with roadside obstacles or barriers and conflicts between vehicles which are travelling on non-conflicting trajectories. This limitation is a serious limitation since crash data analysis shows that at least 40% of fatal crashes are originated by single vehicle accidents against a fixed object or by vehicles travelling in opposite directions. The method of perturbation of trajectories presented in this paper allows researchers to implement new conflict indicators that can overcome the above indicated limitations.

Learning a Precipitation Indicator from Traffic Speed Variation Patterns
Yu Feng, Claus Brenner and Monika Sester

Previous research has shown that people tend to drive slower under rain or snow conditions. Precipitation information was utilized to analyze its impact on traffic or to improve the traffic speed prediction. Conversely, traffic speed variation patterns of multiple roads may also provide indirect indication on weather conditions. In this paper, we analyzed an eight-month traffic speed dataset of New York City. With a seasonal trend decomposition model, residuals between the observations and the model were used as features to represent the level of anomaly as compared to the normal traffic situation. Based on the timestamps of weather records on sunny days and rainy/snowy days, such features were extracted from traffic data and assigned to the corresponding labels. A binary classifier was trained on six-month training data and achieved an accuracy of 91.74% when tested on the remaining two-month test data. We proved that there is a significant correlation between the precipitation events and
traffic speed variation patterns, which can be used to learn a binary indicator. This indicator can be used to identify the anomalies of traffic infrastructures caused by precipitation events, which could improve the emergency response of cities where massive real-time traffic speed observations are available.

**Energy Consumption of Electric Vehicles: Models’ Estimation Using Big Data (FCD)**  
Antonello Croce, Giuseppe Musolino, Corrado Rindone and Antonino Vitetta

The paper presents a framework to estimate energy consumption of Electric Vehicles (EVs) by combining: (a) models derived from traffic flow theory and from mechanics of locomotion and (b) Floating Cara Data (FCD) from available Information and Communications Technology (ICT) devices. Existing energy consumption models may be classified into aggregate vs. disaggregate, according to the level of aggregation of variables related to driver, vehicle, and infrastructure. The proposed models have a hybrid nature: the aggregate component allows to estimating the values of vehicular speed and acceleration on a road link; the disaggregate one allows to estimating the discrete variability of EVs’ energy consumption inside a spatial-temporal domain. The energy consumption models are estimated using traffic data extracted from FCD. The proposed framework is structured into four steps: FCD processing, estimation of vehicular speeds and accelerations, estimation of resistance/energy consumption. The framework is applied in a pilot study area, composed by the backward (sub-)urban area of the port of “Porto delle Grazie” of Roccella Jonica (South of Italy). The preliminary results show that the methodology allows relative inexpensive and accurate calculation of EVs’ energy consumption and that it can be integrated into Intelligent Transportation System (ITS) applications.

**Session T22: Transportation Planning and Traffic Engineering**  
Room: VS217. Chair: Bernhard Friedrich

**The Greater Jakarta Area Commuters Travelling Pattern**  
Tri Tjahjono, Andyka Kusuma and Ahmad Septiawan

The Jakarta greater area has high proportion of commuters who commutes daily from the municipalities i.e. Bogor, Depok, Tangerang and Bekasi (JABODETABEK). Jakarta introduces the first Light Rail Transit (LRT), it serves the eastern part of Jakarta and Dukuh Atas (Jakarta-CBD). In fact, most of the commuter prefers either uses the private vehicles (i.e. car, and motorcycle) rather than public transport. Motorcycle has higher accident risk compared to the traveling modes. A travel diary survey in this study captures the commuting pattern (prospective LRT passenger) which assists the stakeholder in optimising the network. This study identifies that the availability of a good and reliable schedule, and pedestrian facility encourage the commuter shifting to involve in active transport. 42% of the respondents accept to walk up 300m rather than uses a moto-taxi for their first and last-mile, if they have well-designed pedestrian network and facility. Public transport integration is a need for the commuter (17%), where they can transfer from one mode to the others. Pricing policy may attract the commuters, 69% of the respondents prefers zoning system rather than flat tariff system. Tariff differentiation (concession, off-peak ticket) may shift the commuter travelling pattern which assists public transport optimization and efficiency.

**Introducing New Criteria to Support Cycling Navigation and Infrastructure Planning in Flat and Hilly Cities**  
Ricardo Cruz, Jorge Marto Bandeira, Mónica Rodrigues, Mariana Vilaça, José Maria Fernandes and Margarida C. Coelho

The main objective of this work is to quantify the energy consumption, travel-time, difficulty of each route and also safety levels for cyclists over different routes. Cyclists ride a conventional bicycle equipped with a GNSS to quantify energy required based on Bicycle Specific Power Methodology. Cyclists also wore equipment to record the heart rate called Vital Jacket and a video camera to record road conflicts between cyclists and cars. The aforementioned methodology was applied to three different routes chosen in the Portuguese cities of Aveiro (flat terrain) and Porto (hilly). For the flat city, the average energy expenditure was 44,5 Wh/km while for the hilly area the energy expenditure was 96,05 Wh/km. For each origin-destination pair by choosing an appropriate route it is possible to save about 28% energy in Aveiro and 35% in Porto. Regarding comfort, the average number of
Managing Connected Automated Vehicles in Mixed Traffic Considering Communication Reliability: a Platooning Strategy
Shengyue Yao, Rahi Avinash Shet and Bernhard Friedrich

Managing automated vehicles in mixed traffic scenario necessitates special attention when introducing them into the market. In this research, we propose a strategy that operates connected and automated vehicles (CAV) to drive in a platoon which is led by a human driver. Following the strategy, detailed approaches are designed with the objective of increasing the time duration for which the vehicles drive automatically without increasing the total travel time. Reliable communication is essential for the application of these management approaches. In the examined scenario, all CAVs are assumed to be V2X enabled. CAVs will start communicating with each other and the roadside unit (RSU) when they enter the AV zone. The RSU will require CAVs to follow a certain platooning approach and CAVs cooperate with each other to form platoons. Micro-simulation is used for evaluating these approaches, as well as verifies it for communication reliability.

Strategic Road Network Formulation: Developing an Alternative Methodology Towards Sustainable Mobility.
Stefanos Tsigdinos and Thanos Vlastos

The hierarchy of urban transport networks constitutes the cornerstone of the traffic organization of a city. Until now, the conventional hierarchy approach has given exclusive priority to car movement, resulting in dysfunctional urban systems with unattractive public spaces and environmental issues. The need for a new hierarchy formulation that promotes sustainable means of transport is now more imperative than ever. The aim of this paper is to create a methodological framework for formulating the strategic road network of a city. This method classifies the primary roads into 6 categories based on their topology, their trip length, their urban characteristics, the existence of trunk bus lines or metropolitan cycling routes as well as their current classification. The study area of the research is the city of Athens in Greece. The implementation of the proposed method can benefit Athens in many ways, such as promotion of sustainable means of transport, enhancement of urban vitality, environmental protection, unification of the urban fabric, accessibility improvement etc. The methodological framework described, constitutes a street-oriented planning tool that gives priority to public transportation, walking and cycling. It can be applied to other study areas as well, acting as a roadmap for strategic road network formulation.

Session T23: Decision Support Analysis and Operations Research 1
Room: VS219. Chair: Hanna Sawicka

Computational Benchmarking of Exact Methods for the Bilevel Discrete Network Design Problem
David Rey

The discrete network design problem (DNDP) is a well-studied bilevel optimization problem in transportation. The goal of the DNDP is to identify the optimal set of candidate links (or projects) to be added to the network while accounting for users’ reaction as governed by a traffic equilibrium. Several approaches have been proposed to solve the DNDP exactly using single-level, mixed-integer programming reformulations, linear approximations of link delay functions, relaxations and decompositions. To date, the largest DNDP instances solved to optimality remain of small scale and existing algorithms are no match to solve realistic problem instances involving large numbers of candidate projects. In this work, we examine the literature on exact methodologies for the DNDP and attempt to categorize the main approaches employed. We introduce a new set of benchmarking instances for the DNDP and implement three solution methods to compare computational performance and outline potential directions for improvement. For reproducibility purposes and to promote further research on this
challenging bilevel optimization problem, all implementation codes and instance data are provided in a publicly available repository.

**The Methodology of Solving Stochastic Multiple Criteria Ranking Problems Applied in Transportation**

*Hanna Sawicka*

The aim of this paper is to present the methodology of solving complex multiple criteria problems with the presence of stochastic information. The author proposes a universal approach of ranking variants applied to solve decision problem in transportation. Since the nature of transportation process is stochastic, the evaluation criteria are expressed by nondeterministic values. Moreover, the preferential information is usually contradictory, with some level of uncertainty. As a result, the proposed methodology is composed of two phases, including the selection of the most suitable multiple criteria decision aiding (MCDA) method and its application using stochastic information. The first phase includes: suitability of MCDA method to both decision problem and decision maker’s preferences expressed during the modeling process, within the aggregation procedure and final results. The second phase is composed of four steps, such as: transformation of stochastic information into deterministic values, computation of relations between variants resulting in many deterministic rankings, calculation of stochastic relations between variants, and construction of final ranking. The proposed methodology is verified on the exemplary decision problem in transportation. The application of the procedure increases the credibility of the final decision, giving an opportunity to use deterministic MCDA method in the stochastic transportation process.

**Development of a Station-Level Demand Prediction and Visualization Tool to Support Bike-Sharing Systems’ Operators**

*Neofytos Boufidis, Andreas Nikiforiadis, Katerina Chrysostomou and Georgia Aifadopoulou*

Bike-sharing systems operate in a number of cities around the world, aiming to promote sustainable urban mobility. Successful management of these systems is to a large extent linked to the optimal distribution of bicycles, which implies the accurate prediction of demand for rentals and returns at each station within the day. For this purpose, a tool for predicting bike demand for rentals and returns and visualizing the results has been developed and is presented in the present paper. Different predictive models, based on machine learning regression algorithms are trained and evaluated. The tool is tested using data from the bike-sharing system that operates in the city of Thessaloniki, Greece for which the results indicate that the tested system’s utilization is highly correlated to the location and spatial characteristics of a station, as well as the season of the year and time of day. The proposed machine learning algorithms use custom engineered features to learn those correlations and achieve the highest possible performance.

**A Procedure to Support the Distribution of Drinking Water for Victims of Drought: the Case of the Brazilian Semi-Arid Region**

*Yesus Vieira, Renata Bandeira, Luiz Lopes, Orivalde Júnior and Marcelio Júnior*

Although there has been an increase in the number of researches involving humanitarian logistics, few studies address slow disasters, such as drought. Although this phenomenon is one of the worst types of disaster in terms of casualties, water distribution to those affected by the drought still lack academic development, and few studies guide local public managers regarding the efficient use of available resources, guaranteeing a high service level to the population. This paper presents a procedure for the implementation of transport and routing of water delivery. By this procedure, we can evaluate the strategy of complementary use of the water supply of drilled artesian wells. It also provides a contextualized routing tool for the practices and policies of motorized water distribution, commonly found in scenarios of water shortages. The algorithms have been implemented considering the capacitated vehicle routing problem with time windows (CVRPTW), providing a friendly-user tool that helps choosing water sources to be activated and in the definition of the routes between these and the points supply. Results have been validated in the Brazilian Semi-arid region, showing improvement in the current logistical performance of drought coping, in advantageous scales of operation in terms of costs and efficiency.
Session T24: Impact Assessments
Room: VS218. Chair: Gabriella Mazzulla

Multiple Criteria Evaluation of Trams based on Customers’ Specifications (Expectations) in Selected Countries
Damian Kurek and Jacek Żak

The paper presents a Multiple Criteria Analysis (MCA) of trams, based on customers’ specifications and open bid regulations in different countries, such as: Czech Republic, France, Germany, Hungary, Poland and Turkey. We propose a universal assessment procedure for trams to be used in urban, public transportation system, based on the principles of Multiple Criteria Decision Making/Aiding (MCDM/A). The analysis of trams is formulated as a multiple criteria ranking problem. The proposed paradigm includes: the definition of the group decision maker – DM and stakeholders, selection of variants (trams), formulation of the consistent family of criteria, recognition and modeling of the DM and stakeholders’ interests/ preferences, performance of the computational experiments, generation of the ranking of trams. We perform a series of computational experiments with an application of selected multiple criteria ranking methods (Electre III/IV, AHP, ANP, Promethee). The generated rankings result in a comprehensive analysis of the quality of trams in different countries and the suitability of selected MCDM/A methods for the evaluation of trams.

Assessing the Distribution of Impacts of More Ambitious CO2 Standards on Car Manufacturers Across Household Income Groups
Pelopidas Siskos, Konstantinos Fragkiadakis and Stergios Statharas

The European Commission proposed emission reduction targets on car manufacturers by 2030, to reduce CO2 emissions. The present analysis aims to assess whether the implementation of policy bears positive or negative impacts across different household income classes. The analysis is based on a quantitative post-processing analysis of PRIMES-REMOVE and GEM-E3 scenarios. The scenarios used in this paper are the ones that supported the quantitative analysis of the EC proposal. The paper draws policy information by observing at each case, if the fuel savings of the vehicles marketed under the more ambitious targets on cars are enough to outweigh the higher purchasing prices. At the end of the exercise, a sensitivity analysis is conducted by changing the vehicles’ depreciation rate, the assumed economic lifetime and the household discount rates, to examine the degree of change and impact of those parameters on the answer to the policy question. The analysis shows that households that purchase more efficient vehicles in the second-hand car market benefit to a greater extent from the annual fuel savings by paying a fraction of the additional cost of the first owner. The sensitivity analysis shows that such conclusion is supported for a range of assumptions.

Learnheuristics for Solving the Sustainable Team Orienteering Problem
Lorena Silvana Reyes-Rubiano, Javier Faulin, Angel A. Juan, Javier Panadero and Chris Bayliss

It is well-known that the transport sector activity causes different detrimental effects on the environment and the social welfare of our society. These negative impacts are usually presented as negative externalities which increase the logistic costs. In this paper, we solve a Sustainable Team orienteering problem (STOP) in which those negative impacts are mitigated by minimizing the travel times. It consists of maximizing the collected profit by a driving range, visiting each client at most once. Thus, if a customer is visited and the maximum driving range is completed, no profit is collected. In this work, the travel time varies according to the routing plan and the system state. A learnheuristic-based approach is proposed to maximize the collected profit and minimize the negative impacts of transport, under dynamic conditions. A series of computational experiments contribute to illustrate the advantages of the proposed method.

Estimation of Changes in Costumer’S Mobility Behaviour by the Use of Parcel Lockers
Karl Hofer, Stefan Flucher, Martin Fellendorf, Michael Schadler and Norbert Hafner

The last-mile is the most inefficient and most expensive part of a supply chain and comprises up
to 55% of total delivery costs. A system of parcel lockers operated by a non-competing company, usable by any logistic service provider can contribute to make goods distribution and the last-mile more sustainable. The research project “SoWAS” investigates the development of such a system and will evaluate generated changes in costumer’s mobility behaviour by an online panel in a living lab area. This paper presents the approach of the online panel and its first application on two focus groups. Besides findings of approach testing, the collected data give interesting and precise insights into costumer’s mobility behaviour in connection with received and dispatched/returned parcels – a field with very poor available data. Based on the collected data we will estimate changes in mobility behaviour and reduction potential concerning vehicle kilometers, emissions and pick-up trips due to the introduction of a parcel locker system.

Session T31: Innovative Solutions 1
Room: VS208. Chair: Margarida Coelho

Propensity Assessment to Car Sharing Services Using Mixed Survey Data
Tiziana Campisi, Vincenza Torrisi, Matteo Ignaccolo, Giuseppe Inturri and Giovanni Tesoriere

The sustainable development of urban areas, characterized by the expansion of university sites, can benefit from car sharing services, expanding the potential of public transport, especially when the population is almost represented by off-side students and commuters. Based on this premise, the main focus of this work is on the investigation of a set of attributes able to interpret and measure the propensity of students to join car sharing services. The paper provides a discussion about the potential implementation of a car sharing service, including a presentation of the state-of-art practices and particularly referring to the case of the Enna (Italy), where students constitute a significant percentage of residents. The propensity was assessed by a survey based on the Likert Scale and a chi-squared test of independence was calculated to check the difference between the expected and observed frequencies for the considered attributes and for several of their combinations. Students have been involved via a wide consultation survey and the analysis was conducted by using mixed Internet/paper survey data. Results are useful to understand their heterogeneous preferences and to pave the way for a well-thought-out design of a new shared transport service

A New Dynamic Repositioning Approach for Bike Sharing Systems
Enrique Jiménez Merono and Francesc Soriguera Martí

Repositioning is the main set of operations on station-based bike-sharing systems. It is necessary to avoid shortages of bikes on certain stations and parking slots on others. Therefore, its cost optimization is key to determine system success or failure. Scientific literature has dealt many times with this problem, mostly modelling it as a routing problem and providing solution algorithms. Those models are considered “static” or “dynamic” if the repositioning takes place when system is closed or still open. This paper addresses those problems by redefining dynamic repositioning as an alarm-based set of operations which complements the routing-based solution and improves the overall performance.

Empirical Analysis on Long-Distance Peer-to-Peer Ridesharing Service in Japan
Yuki Yamashita, Wataru Nakanishi and Yasuo Asakura

In accordance with the spread of ridesharing services, users’ data, how, when, where and for what purpose they use the service, are gradually collected in the world. However, there are few studies that deal with empirical situations in Japan. In addition, ridesharing services in Japan are not yet popular compared with that in Western countries thus far. Therefore, in this study, we aim to show the present situation of ridesharing behavior in Japan. We conduct the empirical analysis by using actual long-distance peer-to-peer ridesharing data in Japan. Firstly, we classify ridesharing drives into three classes by OD pairs. Next, we formulate the binomial probit model that explains matching success for each drive class. Estimated model shows that departure time and day, days to departure from registration date, page views and driver’s past experiences are important factors for successful match make.

Added Value of a Customized Transit App for Metropolitan Bus Trips
Carlos Romero, Andrés Monzón, Andrea Alonso and Raky Julio
In the last years, bus passengers require reliable and real-time information but the real-time information systems developed still do not fully satisfy their needs. Within the framework of the project HARMONY, a mobile transit app has been developed in Madrid Region to improve the information that metropolitan bus passengers receive from operators, and enabling an option for passengers to send incidences to operators in real-time. A SWOT matrix has been built and a two-stage consultation to passengers has been carried out. This allows to know the current transit app market and to detect gaps in the users’ needs, leading to the features to be implemented. None of the existing apps allow a bi-directional communication between operators and passengers. Survey results reveal that apps like Google Maps do not compete with specific transit apps that include official, real-time information because of the type of data offered.

**Session T32: Vehicle Routing and Route Planning**

Room: VS217. Chair: Yuval Hadas

**Creation of Individualized Sets of Multimodal Travel Itineraries**

*Thomas Horstmannshoff* and Jan Fabian Ehmk

Digitalization enables travelers to access an ever-increasing number of mobility services. Creating door-to-door multimodal travel itineraries from individual mobility services is challenging, since the impact of individual travelers’ preferences on complex multimodal travel itineraries is not transparent. To support travelers in their individual choice of relevant itineraries, travel websites create variants of multimodal travel itineraries using multimodal shortest path approaches. Then, they let travelers specify their individual preferences further to reduce or extend the set of travel itineraries. However, due to the complexity of the underlying search space, it is challenging to individualize the created set of travel itineraries systematically. In this paper, we use solution sampling to create request-specific meta-information about the complex solution space of multimodal travel itineraries. We identify intervals of and relationships between travel parameters such as travel time, price, number of transfers and mode choice by applying multimodal shortest path approaches with solution sampling. The derived request-specific meta-information is used to individualize a traveler’s set of multimodal travel itineraries. We examine solution sampling in a laboratory setting with data on scheduled and non-scheduled transportation services from German transit networks.

**A Savings-Based Heuristic for Solving the Omnichannel Vehicle Routing Problem with Pick-up and Delivery**

*Leandro Do C. Martins*, Christopher Bayliss, Angel A. Juan, Javier Panadero and Mage Marmol

In recent times, new models of commerce have incorporated new decisions and constraints which have led to new variants of classical problems in supply chain management. Modern advances in Information and Communication Technologies have increased the number of marketing channels that are available to consumers. This paper focusses on the new “omnichannel” delivery concept for the retailing industry which addresses the replenishment of a set of retail stores and on the direct shipment of the products to customers (last-mile delivery) within an integrated VRP formulation. The VRP in omnichannel distribution systems consists of a group of retail stores that must be served from a distribution center and a set of online consumers that must be served by the same fleet of cargo vehicles from these retail stores. Since the VRP in omnichannel distribution systems is an NP-Hard problem, we propose a savings-based heuristic for solving large-size instances the VRP in omnichannel retailing. Results show that the proposed heuristic is able to find feasible and competitive solutions in a very short computational time.

**Planning Tourists Evacuation Routes with Minimal Navigation Errors**

*Oren Nahum*, Guy Wachtel and Yuval Hadas

Tourism is one of the largest growing industries worldwide, and so are the increased safety concerns. This is due to increasingly frequent and severe natural hazards as well as terrorism, where large crowds of tourists can be targeted. Furthermore, tourists are often less informed and are therefore
more vulnerable to being trapped in chaotic situations. In such situations, normally we are interested in fast evacuation routes. However, tourists, especially during emergency situations, are prone to orientation and navigation errors. Such errors can be avoided by providing electronic guidance at various intersections along the evacuation path (controlled intersections). This study formulates the above-mentioned situation as the shortest path problem with stochastic routing. The stochastic routing is the probabilistic selection of an outgoing arc at each node. As it is practically difficult to equip every intersection with guidance devices, a multi-objective model is developed. The model simultaneously minimizes the number of controlled intersections and minimizes the gap between the actual evacuation route and the optimal evacuation route. The problem is formulated as a stochastic multi-objective problem. A Pareto-front of solutions is obtained using a genetic algorithm and a simulation.

Routing Drones in Smart Cities: a Biased-Randomized Heuristic for Solving the Team Orienteering Problem in Real Time
Angel Alejandro Juan, Alfons Freixes, Javier Panadero, Alejandro Estrada-Moreno and Carles Serrat

The concepts of unmanned aerial vehicles and self-driving vehicles are gaining relevance inside the smart city environment. This type of vehicles might use ultrareliable telecommunication systems, Internet-based technologies, and navigation satellite services to decide about the routes they must follow to efficiently accomplish their mission and reach their destinations in due time. When working in teams of vehicles, there is a need to coordinate their routing operations. When some unexpected events occur in the city (e.g., after a traffic accident, a natural disaster, or a terrorist attack), coordination among vehicles might need to be done in real-time. Accordingly, this paper analyzes how the use of extremely fast, yet effective, biased-randomized heuristic allows for ‘agile’ optimization of routing plans for drones and other autonomous vehicles.

Session T33: Rail Transport Systems
Room: VS219. Chair: Nicoletta Ricciardi

A Model That Assesses Proposals for Infrastructure Improvement and Capacity Expansion on a Mixed Railway Network
Francisca Rosell and Esteve Codina

In this paper, a mathematical programming-based model is presented for evaluating the impact that proposals for infrastructure improvement and capacity expansion can have on a mixed railway network, mainly oriented to increase freight transportation. In this model, the authors have considered extensions of elements of an existent mixed railway network, jointly with actions on the network with relative smaller cost, such as the inclusion of new sidings or new gauges in several rail segments, expansion of classification terminals or stations, and also capacity enhancements by adding new blocking/control systems at specific locations. These aspects are usually not taken into account in models for regional planning. Our approach, rather than a model of railway capacity expansion can be considered a mixture of capacity-expansion with network design. The model is tested on a small regional network of the Mediterranean Corridor, and the computational results show its applicability to larger networks.

Estimating Time of Arrival of Trains at Level Crossings for the Provision of Multimodal Cooperative Services
Neofytos Boufidis, Josep-Maria Salanova Gruu, Panagiotis Tzenos and Georgia Aifadopoulou

While cooperative services have been almost fully deployed in the road sector and are already being implemented in various cities in Europe as a pre-requisite for the introduction of autonomous vehicles, few attempts have been made in the same direction for the rail sector. This study proposes a system that aims to improve safety and minimize risk in the meeting point between road and rail, known as level crossings, by monitoring the location of floating road vehicles via a mobile device application. A neural network predictive model for estimating time of arrival of trains is also utilized. The safety system has been implemented and tested under real life conditions in the city of Thessaloniki, Greece.

Train Punctuality Analysis in a Rolling Stock Perspective
Nils O.E. Olsson

This paper studies how time delays spread through the railway system. We evaluate timetable and rolling stock interaction in relation to medium size delays. In particular, we study the connection between arrival and departure delays for trains that are operated by the same rolling stock individual. We studied one year of data for trains circulating in the Oslo area. Research questions in this study are:  
• What is the connection between arrival and departure delays for rolling stock individuals?  
• How can delays be tracked through the time table and the rolling stock circulation plan? Punctuality analysis was performed to investigate if there is a connection between arrival and departure delays. A correlation analysis of the arrival delays and the corresponding departures was done in order to find the possible connection. There was a connection between the size of arrival delays and the size of the corresponding departure delays. We found a threshold at around 20 minutes. An arrival delay over 20 minutes is expected to cause departure delays. Arrival delays of less than 20 minutes are to a larger extent absorbed by the production plan.

Block Planning for Intermodal Rail: Methodology and Case Study
Gianluca Morganti, Teodor Gabriel Craainic, Emma Freijinger and Nicoletta Ricciardi

Blocking constitutes an important rail freight operation, by which cars with potentially different origins and destinations are grouped to be then moved and handled as a single unit, yielding important economies of scale. We address the block tactical planning problem for intermodal railroads, which has been little studied so far. We propose a new service network design model that explicitly considers the specificity of intermodal rail and which may be solved using commercial software for realistic sizes. We illustrate the performance and interest of the proposed method through an extensive case study of a major North American railroad

Session T34: Survey Applications and Statistical Methods
Room: VS218. Chair: Ricardo Garcia

Using GPS Tracking Data to Validate Route Choice in OD Trips Within Dense Urban Networks
Lídia Montero and Xavier Ros-Roca

Nowadays, there are several companies providing processed or raw global positioning system (GPS) measurements from fleets of commercial vehicles, internet applications or automobile companies. The aim of this paper is to deepen the understanding on the GPS data applicability for transportation modelling purposes by providing systematic and quantified insights into collected data representativeness in describing individuals' route choice. Unfortunately, real data often contain noise, uncertainty, errors, redundancies or even irrelevant information. Useless models will be obtained when built over incorrect or incomplete data. This is why pre-processing is one of the most critical steps of data analysis in any of its forms. However, pre-processing has not been properly systematized yet, this paper focuses on pre-processing steps required in GPS tracking data together with a proposal to systematize it. Furthermore, the aggregation level is at waypoint location for low latency GPS positions in the trajectory in their trip. Travel time reliability in OD paths is addressed among other OD path characteristics. Route choice in dense urban networks face multiple possibilities and data from new technologies offers the opportunity to understand route choice behavior.

Factors Influencing Accident Severity: an Analysis by Road Accident Type
Laura Eboli, Carmen Forciniti and Gabriella Mazzulla

Nowadays, road safety is an issue particularly relevant because of the increasing occurrence of road accidents. For this reason, it is very important to analyse accident severity and the factors influencing it. This paper aims to investigate on the characteristics that can influence the severity of an accident, grouped in different categories, related to road, external environment, and driver. The proposed analysis has the specific objective to discover the possible differences between the various types of accident (e.g. clash, collision, pedestrian investments) in terms of factors influencing the severity expressed through information such as the number of dead or injured persons. The method proposed to this
aim is represented by mathematical models able to determine the weight of each factor involved in the analysis on accident severity. The preliminary results suggest that there are interesting differences between the types of accident.

Road Pricing in Indonesia: How Will Public Respond?
Yos Sunitiyoso, Shimaditya Nuraeni, Tutik Inayati, Fikri Hadiansyah, Ilham Fadhil Nurdayat and Noorhan Firdaus Pambudi

Road pricing basic rationale argues that congested occur as the result of increasing number traveller which used private transportation mode, instead of public transport. Road pricing could influence road users’ choice for transportation method. An electronic road pricing (ERP) is planned to be implemented in 2019 in Jakarta, the capital of Indonesia, while the public acceptance of the policy is not yet be discussed. This study aims to describe public acceptance of road pricing with the influence of the differences in socio-demographic condition (Model 1), traffic management strategies perception (Model 2), and road pricing revenue allocation perception (Model 3). The data is collected from 356 respondents in Jakarta. This study uses logistic regression (logit) model to facilitate discrete nature of the data especially public acceptance as a dependent variable that is categorized as an accept/not accept answer. Preliminary results show that Model 1 is not significant; while Model 2 shows that perception on road pricing is significant; and finally Model 3 is significant especially if road pricing revenue is allocated to develop public transport, to increase road connectivity, and to protect the environment.

Latent Factors on the Assessment of Service Quality in an Italian Peripheral Airport
Jaime Allen, Maria Grazia Bellizzi, Laura Eboli, Carmen Forciniti and Gabriella Mazzulla

Compared to the other public transport systems, air transport has received limited attention on the assessment of service quality. This paper aims to explore the factors employed to assess the airport service quality, taking as case study the International Airport of Lamezia Terme, a peripheral airport placed in the south of Italy. Specifically, through a Principal Component Analysis (PCA) latent factors influencing service quality were identified and the dimensionality of the phenomenon was reduced. After that, a Structural Equation Modelling (SEM) approach was performed in order to define the relationships among the latent variables, and between the observed variables and the latent ones. For these purposes, we analyzed a database derived from Customer Satisfaction Surveys (CSS) conducted during 2015-2016 in the Lamezia Terme airport. The results confirm that overall airport service quality is significantly related to latent factors such as the accessibility to the services, the control operations in the terminal, and the comfort offered to the passengers.

Friday 20th September, 2019

Session F11: Big Data and Machine Learning 3
Room: VS208. Chair: Joel Ribeiro

Process Discovery on Geolocation Data
Joel Ribeiro, Tânia Fontes, Carlos Soares and José Luís Borges

Fleet tracking technology collects real-time information about geolocation of vehicles as well as driving-related data. This information is typically used for location monitoring as well as for analysis of routes, vehicles and drivers. From an operational point of view, the geolocation simply identifies the state of a vehicle in terms of positioning and navigation. From a management point of view, the geolocation may be used to infer the state of a vehicle in terms of process (e.g., driving, refueling, maintenance, or lunch break). Meaningful information may be extracted from these inferred states using process mining. An innovative methodology for inferring process states from geolocation data is proposed in this paper. Also, it is presented the potential of applying process mining techniques on geolocation data for process discovery.

Floating Car Data Mining: Identifying Vehicle Types on the Basis of Daily Usage Patterns
Danyang Sun, Fabien Leurent and Xiaoyan Xie
This paper presents a novel approach for exploring vehicle daily mobility patterns using Floating Car Data in the Paris region. The objective is to reveal vehicle types and analyze usage patterns on different roadway sub-classes. Firstly, mobility representative features are recovered to recognize vehicle activity context, which includes modeling single trip pattern in terms of time windows, traveling distances, and speed; and building vehicle mobility profile of trip combinations. Based on that, a two-step clustering algorithm is developed to explore the constitution of trip patterns and cluster vehicle types. Characterization analysis is conducted to find out outstanding features of clustered groups, thus helping to categorize the vehicles behavioral types. As a result, 4 major vehicle types were identified over the Paris region with the 2 comparative leading groups as those mainly composed by morning-activity trips and long-distance trips. Then, statistical association assessment by Configural Frequency Analysis is employed to examine the usage intensity on different roadway classes of identified types. The association analysis reveals that the identified types have statistically significant differences in the usage of different roadway classes. Furthermore, this approach can be expected to provide more representative results with more generalized sampling by the development of connected vehicles.

Characterizing System Optimum by Trajectory Data Analysis
Ruiwei Chen and Ludovic Leclercq

This work investigates network-related trajectory features to unravel trips that the most contribute to the system under-performance. When such trips are identified, features analysis also permits to identify the best alternatives in terms of routes to make the system to its optimum. First, descriptive analysis is carried out on trajectories obtained from reference dynamic traffic assignment (DTA) simulations in a real-world network, based on User-Equilibrium (UE) and System-Optimum (SO). This analysis helps us (i) to target the trajectories to be changed, and (ii) to identify their main features (path marginal costs, network-related features such as betweenness centrality and traffic light parameters, etc.). Then, we give targeted users predefined paths and re-run DTA simulation under UE condition, in order to evaluate the efficiency of targeting methods. Results show that changing routes of 10% users whose trajectories are (i) with high betweenness centrality or (ii) with small mean MFD capacity, can already bring more than 6% of total travel time (TTT) reduction with respect to TTT in UE-simulation, while the TTT reduction from UE to SO simulation is about 14%.

Citation Network Analysis of Vulnerability Studies in the Fields of Transportation and Complex Networks
Kashin Sugishita and Yasuo Asakura

In recent years, studies on network vulnerability have grown rapidly in the fields of transportation and complex networks. Even though these two fields seem to be closely related, it is not clear how these two fields have evolved over time and how the two fields have influenced each other. In this study, in order to add clarity comprehensively and objectively, we analyze a citation network where nodes represent publications and directed links represent citation relations. We collect publication records from the Web of Science and construct a citation network with 1,181 nodes and 4,601 links. Then we analyze the giant weakly connected component with 705 nodes and 4,584 links. By performing the community detection algorithm, we identify seven communities representing different research domains: 1) transport vulnerability, 2) metro and shipping, 3) resilience, 4) topological vulnerability, 5) cascading failure, 6) interdependent networks, and 7) scattered community. Then we identify the major research development in each research domain with main path analysis. Finally we reveal the citation patterns among different research domains.

Session F12: Control and Management of Transportation Systems 2
Room: VS217. Chair: Toru Seo

Reactive Dynamic Traffic Assignment: Impact of Information
Megan Khoshyaran and Jean-Patrick Lebacque

The object of the paper is to study issues related to reactive dynamic assignment in the context
of communication, and specifically to analyze some impacts of information on reactive DTA (dynamic traffic assignment). New means of communication and new services will make instantaneous information on the network traffic state available to drivers / vehicles. Instantaneous and long range interaction between all drivers /vehicles will become feasible, with possible negative effects on the network traffic dynamics. In order to analyze such effects, the paper proposes the following: i) a dynamic multimodal macroscopic traffic flow model, for analysis an also prediction, based on the GSOM (generic second order model) approach; ii) a methodology for travel times estimation, compatible with the GSOM model; iii) a simple test setting for analyzing the impact of information on DTA; iv) and a simple control strategy based on a dynamical systems approach, designed to foster user optimality. Preliminary results show that instantaneous travel time constitutes an information liable to induce unfavorable impacts and that predictive travel times or the simple control strategies yield better traffic dynamics.

Dynamic Resilience of Public Transport Network: A Case Study for Fleet-Failure in Bus Transport Operation of New Delhi
S. M. Hassan Mahdavi M., Neila Bhouri and Gerard Scemama

The paper presents a methodology to measure the dynamic resiliency of a public transport network and its application to New Delhi bus network. Variability in service supply that arises from normal day-to-day service fluctuations leads to negative passenger experiences and therefore satisfaction. The paper explores the utilization of dynamic data to develop a systematic approach analysing disruption impacts with respect to service-wide capacity changes due to fleet failures. In order to measure the dynamic resilience, an index is formulated that covers the magnitude of changes in the network performances in terms of robustness, reliability, and residual capacity; measures that describe the network complexity in a physical and a service operational specifications. In this regard, the relationship between system components is characterized by network topology, passenger flow, and service performance dynamics. Our proposed approach is able to capture the dynamics of the resilient system and to quantify the extent to which operational strategies are capable of delivering efficient systems. We illustrate our model by an application to the New Delhi bus transport system and demonstrate how system resiliency for different fleet-failure states can be quantified.

Quantifying Road Traffic Emissions Embedded in a Multi-Objective Traffic Assignment Model
Eloisa Macedo, Ricardo Tomás, Paulo Fernandes, Margarida Coelho and Jorge Bandeira

In a road network, drivers typically seek to minimize their own travel time, often affecting system-wide performance. For an efficient traffic assignment (TA), besides concerns with travel times, traffic managers should not neglect system-wide level of pollutant emissions. Measuring road traffic emissions can be costly and models based on vehicle-specific parameters with many input variables have been suggested in the literature. This paper proposes a simple way to quantifying carbon dioxide (CO2) and nitrogen oxides (NOX) emissions with only average speed as input variable and presents a multi-objective TA approach that seeks to minimize system-wide travel time, distance travelled (associated with fuel consumption) and global and local pollutant emissions. A real-world case study on an intercity corridor with many alternative routes between two zones is presented. Experiments considering TA based on travel time, and on time, distance travelled and pollutant emissions are reported. Results highlight that system optimal distribution based on the suggested multi-objective TA based on three components yields savings in terms of distance travelled (2.6%) and emissions (1.3% for CO2 and 1.1% for NOX), but penalizes travel time 3% translated in an increase of 20sec per vehicle, when compared to the solution only focused on minimizing travel time.

Trial-and-Error Congestion Pricing for Morning Commute Problem with Day-to-Day Dynamics
Toru Seo

A trial-and-error congestion pricing scheme finds the optimal toll based only on observable information (e.g., travel time) without information on travelers’ personal preferences that are often unobservable in practice (e.g., value of time, scheduling preference). This paper proposes a trial-and-error pricing
scheme for the morning commute problem, also known as the departure time choice problem and Vickrey’s bottleneck model, with day-to-day dynamics. We mathematically prove that the proposed scheme is guaranteed to find the social optimal congestion toll under somewhat restrictive assumptions. Then, we numerically confirm that the proposed scheme converges to the social optimal toll fairly quickly.

**Session F13: Decision Support Analysis and Operations Research 2**
Room: VS219. Chair: Teodor Gabriel Crainic

**A Multi-Objective Programming Model for Timetables on Corridors Integrating Macroscopic and Microscopic Approaches**
Ángel G. Marín and Esteve Codina

It is proposed an integrated framework for timetable design which combines the requirements of service planners, which usually adopt a purely macroscopic point of view of the demand requirements and the conflicts that these timetables may arise at stations. These aspects may not be considered by the service planners since a microscopic analysis of the stations structure is necessary considering possible conflicts at platforms. The proposed integrated model guarantees feasible timetables balancing performance indexes for the passenger and operator interests while guaranteeing feasibility. The differences between optimal timetables for the service planners and those who are operational at stations are kept within specified bounds. The resulting problem has been modeled as a multi-objective Mixed Integer Linear Programming problem. The model can be solved to optimality in reasonable computing time as shown in the tests using the Madrid-Zaragoza-Barcelona high speed railway network. For this case a Pareto frontier analysis is performed showing that the problem is well-posed. Also, based on the previous model a heuristic procedure is developed in order to obtain timetables which avoid as much as possible concentrations of arrivals/departures to/at stations, thus allowing for a better recoverability and robustness of the timetable in case of unexpected disruptions.

**Scenario-based optimisation of a two-tier distribution network with a simplified route construction**
Piotr Sawicki

The paper deals with a problem of distribution network design with regularity of deliveries. A combinatorial model of two-tier distribution network is proposed, where the objective is a cost-oriented function, taking into account all transport and handling operations, excluding an inventory costs. The model is universal, and it constitutes a skeleton of decision making on network design. However, scenario-based extension of the optimisation model allows to reflect specific business factors as: depot’s relocations, regularity limits, time limits of deliveries, and vehicle’s capacity. Each scenario is a combination of those factors. A constructed model has been experimentally applied to optimise the distribution network of drugstore companies, which is one of the key player on the Polish market. The current configuration of its network is composed of 1 central warehouse, 15 transshipment depots and 256 drugstores. There are considered five scenarios of distribution network configuration. Each of them have been optimised and those results have ranged from nearly 6% increase to more than 30% reduction of objective function, referred to current state. A scenario adopted upon managerial decision has guaranteed over 12% reduction, and validation of the result and a proposed procedure has been proved in practice.

**Planning Hyperconnected, Urban Logistics Systems**
Teodor Gabriel Crainic, Michel Gendreau and Lilia Jemai

We examine an innovative system for organizing deliveries in a collaborative fashion for an n-tier hyperconnected city logistics system. We focus on the tactical planning of services within the first tier of the system, i.e., from external zones generally located on the outskirts of the city (logistics platforms, urban/city distribution/consolidation centers, etc.) to satellites from which goods are distributed to final customers, and introduce a new optimization model for that purpose. The key distinctive feature of this model is that we consider a coalition of carriers and logistic operators who share their resources (fleets of vehicles and warehousing capacity) and information flows to provide
more effective services, thus lowering costs and environmental impact. Preliminary computational results confirm the attractiveness of the envisioned system.

Including the Voice of Transport Users in Participatory MCA: Urban Transport Projects Appraisal
Aleksandra Szczur, Paweł Zmuda-Trzebiatowski, Szymon Fierek and Maciej Bieńczak

The article presents the method of participatory multi-criteria analysis, which allows to include unorganized groups of stakeholders in the evaluation process. Special attention has been paid to transport users, who in urban conditions, can use many different means of transport. The procedures of selecting user groups, the aggregation of preference models within groups as well as the aggregation of group preferences were presented. The method was applied to identify stakeholder preferences with respect to the redevelopment options of Rondo Rataje in Poznań.

Session F21: Autonomous Systems Applications
Room: VS208. Chair: Anysia Mayerhofer

Stochastic LWR Model with Heterogeneous Vehicles: Theory and Application for Autonomous Vehicles
Irene Martínez and Wen-Long Jin

The introduction of autonomous vehicles will increase the vehicle heterogeneity in our roads. It is claimed that these vehicles will be able to achieve lower spacings for the same speed than human drivers. Therefore, a good understanding of the influence of heterogeneous driver behavior on traffic flow macroscopic characteristics is crucial. This paper presents a stochastic LWR model by introducing heterogeneous, i.e., vehicle dependent, jam densities. The model is solved in Lagrangian coordinates and the probabilistic nature of the model allows for investigating the impact of driver heterogeneity on macroscopic relations of traffic flow, both analytically and through simulations. The results show that macroscopic characteristics of the model are consistent with the deterministic version with an equivalent jam density, that is the harmonic mean of the distribution.

Macroscopic Modeling of Freeway Platooning Under Mixed Traffic Conditions
Marcel Sala and Francesc Soriguera

Autonomous vehicles (AV) will be present in freeways, and they will have to share current infrastructure with human driven vehicles. This mixed traffic scenario needs to be planed, as some research points that a mismanagement of AV could lead to a capacity decrease. This can be solved with AV platoons, which are strings of vehicles traveling at very short headways. Some research exist to that end, but all of them is done using microsimulation tools, which are very powerful but have the shortcoming of strongly rely on an uncertain calibration. The more robust macroscopic tools, have no models yet suitable for platoons. The research presented in this paper wants to fill the gap, by providing a generalized macroscopic model based on the LWR theory for platoons. This is achieved by considering a freeway with two types of lanes (platoon and general purpose) and two types of vehicles (AV and non AV) and establishing some rules of behavior. Among the rules, platoon formation has to be set, two options are presented: cooperative and opportunistic. Results show that given the appropriate conditions, great capacity increments can be achieved, multiplying by factors of more than two the current observed freeway capacities.

Identifying Conflict Points for the Examination of Automated Vehicles in the Presence of Vulnerable Road-Users
Anysia Mayerhofer, Inbal Haas, Felix Gabriel and Bernhard Friedrich

The future use of automated vehicles involves a great deal of uncertainty regarding various aspects, including the interaction with vulnerable road users. This interaction has been studied only to a limited extent so far. As a first step in examining this interaction, there is a need in detecting relevant conflict points involving both types of users (automated vehicles and vulnerable users). These conflict points should reflect both safety issues; concerning vulnerable road users and operational issues
involving automated vehicles. We present a methodology for identifying such conflict points, in order to simplify the selection of adequate instances to be used in studies involving automated vehicles. The presented methodology is based on two pillars: the statistical analysis of conflict points for the identification of safety problems based on accident statistics, and the analysis of operational aspects concerning the use of automated vehicles. The proposed methodology, will be demonstrated on the city of Braunschweig.

Shared Autonomous Vehicle Services and User’S Taste Variation: a Survey and Model Applications
Ouail Al Maghraoui, Reza Vosooghi, Abood Mourad, Joseph Kamel, Jakob Puchinger, Flore Vallet and Bernard Yannou

This study provides insights into traveler-related attributes affecting the choice of future autonomous vehicles (AVs) and explores the importance of integrating those attributes into agent-based simulations and service optimization assessments. For this purpose, an online survey was carried out to collect data on travelers of the greater Paris region and their behavior regarding autonomous vehicles. In addition, this paper identifies AV taste variation among individuals as well as the criteria behind their willingness-to-use a shared autonomous vehicle service depending on their current mode of transport. The paper shows how traveler-related attributes are relevant to studying a shared autonomous mobility system and how they can enhance the accuracy of agent-based models and the traveler preference dimension in optimization models.

Session F22: Decision Support Analysis and Operations Research 3
Room: VS217. Chair: Jacek Zak

Genetic-Based Algorithm of the Public Transport Lines Synchronization in a Transfer Node
Vitalii Naumov

The proposed model of the bus lines synchronization in a transfer node is based on simulation of demand for changing the public transport lines with a genetic algorithm as a tool to obtain some rational solution. The described approach considers stochastic nature of demand for public transport and provides some rational solution of the synchronization problem. The total waiting time of passengers at the given transfer node is used as an objective function in the synchronization problem. Synchronization is implemented due to time shifts at the transport lines timetables for the transfer node; these time shifts are represented as chromosomes of a genetic algorithm. In order to evaluate the objective function, simulations of public transport lines servicing the passengers in a transfer node were provided. The developed mathematical model is implemented in Python within the frame of a class library for modeling of public transport processes. A case of the Wiślicka transfer node in a public transport system of Kraków city is applied in order to illustrate the developed synchronization procedure.

Design and Multiple Criteria Evaluation of Efficient and Sustainable Transportation/Logistic Corridors. the Case Study of Freight Movement to Iraq.
Jacek Zak and Ali Alazzawi

The paper refers to the development of transportation/ logistics solutions in developing and politically and militarly sensitive regions. It is focused on providing a rational paradigm of decision making that would allow the decision makers (DMs) to produce a desirable, efficient, and sustainable freight transportation/ logistics solutions. We focus on the design and evaluation of a freight logistic system delivering goods (electrical cables) to Iraq. The intuitively designed transportation/ logistics solutions are assessed with the application of the Multiple Criteria Decision Making/ Aiding (MCDM/A) methodology. Our approach is based on thorough analysis of the decision situation (internal and external conditions; decision makers, stakeholders; specific local constraints; existing expectations and preferences). We take into account the trade- offs and constraints (economic, political, social) to reach a compromise and most desireable solution. We carry out a series of computational experiments with the application of selected MCDM/A ranking methods, e.g. ELECTRE III/IV and AHP. We develop
a universal decision model and adapt it to specific local circumstances and characteristic features of
the applied decision tools, i.e. ELECTRE III/IV and AHP methods.

Planning the Use of Helicopters in Distribution of Supplies in Response Operations
of Natural Disasters
Iran Xavier, Renata Bandeira, Adriano Bandeira, Vânia Campos and Leandro Silva

In the immediate aftermath of a natural disaster, physical infrastructure, such as roads and bridges,
are often destroyed and transport capacity is extremely limited or non-existent. As a result, access to
affected areas becomes very difficult or even remote. In this scenario, helicopters are the most appro-
priate vehicles to reach the victims. However, the planning of air transport operations in the context
of a disaster response has a high degree of complexity, so that operational research has significant
application and potential contribution to the area. In this context, this paper proposes a procedure
that aims to optimize the use of helicopters in response operations to small and medium-scale natural
disasters. The proposed procedure seeks to minimize the total time of operation and the mobiliza-
tion of air resources during last mile deliveries in relief operations. This procedure was applied on a
real post-disaster scenario, taking as basis the characteristics of the response operation to the floods,
occurred in 2011, in the mountain region of the state of Rio de Janeiro, Brazil. Results indicate the
developed methodology as a viable tool to aid in the decision-making process regarding the use of
helicopters for last mile deliveries in the humanitarian supply chain.

Multiple Criteria Evaluation of P&R Lots Location
Szymon Fierek, Maciej Bienczak and Paweł Żmuda-Trzebiatowski

The article presents a comparison of methods of evaluation of establishing the rankings of variants on
the example of the location of P&R lots (car parks) in Bydgoszcz (a medium-sized city in Poland).
The methods to be compared were based on the procedure defined by municipal authorities in the
public procurement (a simple evaluation based on a weighted average) on the one hand, and at the
same time, on the well-known methodology of multi-criteria decision making. The assessment was car-
rried out for 15 predefined locations, and both methods used the same set of criteria and sub-criteria.
In order to determine the value of the criteria, among others, the travel model of the Bydgoszcz ag-
glomeration built in the VISUM tool was used. As a result, it was possible to simulate the creation
of P&R lots in selected locations. The preferences of the decision-maker (the municipal authorities)
were expressed in a direct interview with their representatives. As a result of all the calculation work,
two final rankings were obtained for each method, which allowed to draw final conclusions.

Session F23: Innovative Solutions 2
Room: VS219. Chair: Francesc Soriguera

Effects of Coordinated Formation of Vehicle Platooning in a Fleet of Shared Automated
Vehicles: an Agent-Based Model
Senlei Wang, Goncalo Correia and Hai Xiang Lin

This paper aims to explore the performance of autonomous mobility-on-demand systems (AMoD)
with the coordinated formation of vehicle platooning. In this study, an agent-based model (ABM) is
developed to explicitly simulate the operations of both vehicle platooning formation and interactions
between shared automated vehicles (SAVs) and real-time demand requests. The objective is to capture
the stochastic behavior of SAVs as trip makers, and then assess the performance of the AMoD system
with the mechanism of coordinated formation of platoons. We conclude that the impact of vehicle
dispatching strategies in the AMoD system with vehicle platooning formation predominately affects
the average waiting time and system capacity to transport travellers as a whole; however, vehicle
platooning, to some extent, could lengthen the in-vehicle travel time of participating vehicles. The
hold-on time (imposed delay) of leading vehicles in order to form a platoon could affect the average
delay of vehicles part of those platoons. The developed ABM provides the first insight into the impact
of the pervasive formation of vehicle platooning on the performance of the AMoD system.

Spatiotemporal Variation of Taxi Demand
Pedro Rodrigues, Ana Martins, Sofia Kalakou and Filipe Moura

The growth of urban areas has made taxi service become increasingly more popular due to its ubiquity and flexibility when compared with, more rigid, public transportation modes. However, in big cities taxi service is still unbalanced, resulting in inefficiencies such as long waiting times and excessive vacant trips. This paper presents an exploratory taxi fleet service analysis and compares two forecast models aimed at predicting the spatiotemporal variation of short-term taxi demand. For this paper, we used a large sample with more than 1 million trips between 2014 and 2017, representing roughly 10% of Lisbon’s fleet. We analyzed the spatiotemporal variation between pick-up and drop-off locations and how they are affected by weather conditions, irregular events and points of interest. More, based on historic data, we built two models to predict the demand, ARIMA and Artificial Neural Network (ANN), and evaluated and compared the performance of both models. This study not only allows the direct comparison of a linear statistical model with a machine learning one but also leads to a better comprehension of complex interactions surrounding different urban data sources using the taxi service as a probe to better understand urban mobility and its needs.

Jorge M. Bandeira, Mario Andrade, Paulo Fernandes, Mónica Rodrigues, Eloísa Macedo and Margarida C. Coelho

Under a likely transitional stage of co-existence of connected and automated vehicles (CAVs) and conventional vehicles (CV), this study explores the potential effects of CAVs to reduce greenhouse gases (GHG) and pollutant emissions in different road types based on improved operational parameters. Therefore, CAVs were assumed to behave like eco-driving agents to influence the environmental performance of overall traffic. A microscopic traffic and emission model platform was applied to simulate a European Medium-sized city during the morning peak period. Four roadways sections (one motorway, one rural and two urban) were selected to evaluate in detail the impact of CAVs in different roads types and over different CAVs penetration rates. Depending on the type of road, the impact may be beneficial in terms of carbon dioxide (CO2) and nitrogen oxides (NOX) reduction (up to 20%), but may also be negative in more congested roads.

Assessing the Emission Impacts of Autonomous Vehicles in Metropolitan Freeways
Paulo Fernandes, Jorge M. Bandeira, Margarida Coelho, Eloísa Macedo and Ricardo Tomas

While recent studies demonstrate the societal and economic benefits of driverless vehicles, little is known about the emission impacts of autonomous vehicles (AVs) in the context of mixed traffic. This paper explores the environmental impacts of AVs along an urban freeway corridor in a metropolitan area using Vehicle Specific Power (VSP) and EMEP/EEA emission methodologies paired with VIS-SIM traffic model. Three different AV penetration rates were implemented for through traffic along a freeway corridor in the city of Porto (Portugal) by considering long-term market predictions (10%, 20% and 30%). Afterwards, these scenarios were compared to current situation in terms of carbon dioxide, carbon monoxide, nitrogen oxides and hydrocarbon emissions, and travel time and stop-and-go situations. The emissions and traffic performance of each scenario were evaluated on three levels: a) overall study domain; b) corridor; c) impact of AVs on conventional vehicles (CV). AVs yielded small savings in emissions in the overall study domain for automation levels below 30% (differences in traffic performance and emissions were not statistically significant). Corridor-level analysis showed decreases of 5% in emissions can be expected with AVs technology, but penalizes travel time up to 13% for both AV and CV, when compared to the existing situation.