Nikola Marković

Employment

Job Title	**Assistant Professor**	Aug 2018 — Present
Employer	**University of Utah**	Salt Lake City, USA
	Civil and Environmental Engineering Department	

Job Title	**Senior Faculty Specialist**	Jan 2018 — Jul 2018
Employer	**University of Maryland**	College Park, USA
	Center for Advanced Transportation Technology (CATT)	

Job Title	**Faculty Assistant**	Sep 2015 — Dec 2017
Employer	**University of Maryland**	College Park, USA
	Center for Advanced Transportation Technology (CATT)	

Job Title	**Postdoctoral Research Associate**	Dec 2013 —Sep 2015
Employer	**University of Maryland**	College Park, USA
	Civil and Environmental Engineering Department	

Job Title	**Graduate Research Assistant**	Aug 2009 — Dec 2013
Employer	**University of Maryland**	College Park, USA
	Civil Engineering Department	

Education

Degree	**Ph.D. in Transportation Engineering**	Dec 2013
Thesis	**Evasive Flow Capture**	
Focus	**Facility location, stochastic optimization, logistics**	
Advisor	**Paul Schonfeld**	
University	**University of Maryland**	College Park, USA

Degree	**M.S. in Transportation Engineering**	Dec 2010
Thesis	**Scheduling Under Uncertainty for a Single-Hub Intermodal Freight System**	
Focus	**Probabilistic analysis, metaheuristics, logistics**	
Advisor	**Paul Schonfeld**	
University	**University of Maryland**	College Park, USA

Degree	**Dipl.-Ing. in Transportation Engineering**	Jun 2009
Thesis	**A Petri Net Simulation Model of the Batajnica Railway Station**	
Focus	**Simulation modeling, railway systems, regression analysis**	
University	**University of Belgrade**	Belgrade, Serbia

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375

Research Interests

Operations Research

I am interested in development and application of operations research techniques in analyses of transportation systems. In my dissertation I developed models for the optimal location of violator-intercepting facilities in large-scale transportation networks. The work on this topic was funded by the NSF (`http://www.nsf.gov/awardsearch/showAward?AWD_ID=1335416`). My other research projects in the area of operations research included freight logistics, vehicle routing and scheduling for ridesharing, and public transit.

Data Science

I am interested in applications of machine learning and visualization techniques to extracting value from big data. Currently, I am analyzing GPS trajectories of 2.5 million trips in Utah (12 GB) and using these data to estimate statewide traffic via supervised learning. My other projects related to machine learning included analysis of train delays, predicting work zone collision probabilities, and predicting vehicle fleet sizes for dial-a-ride operations.

Interface of Optimization and Data

Traditional optimization approaches do not account for the cost of acquiring input data, which can be very important in many applications of engineering and operations research, including transportation. My current research is concerned with developing methods for optimizing the amounts of data acquired for calibrating transportation optimization models. Initial work on this topic was funded by the NSF (`https://www.nsf.gov/awardsearch/showAward?AWD_ID=1745198`).

Current Projects

Focus	**Machine learning, data visualization, big data (12 GB)**
Title	**Visual Exploration of Utah Trajectory Data and their Applications in Transportation**
Period	**2018 – 2019**
Funding	**National Institute for Transportation and Communities**
PI	**Nikola Markovic**
Funding	**$40,000**

To help transportation agencies better understand the tremendous value of trajectory data, we will acquire Utah GPS trajectory data from INRIX and conduct visual analyses demonstrating applications of trajectory data in various areas of transportation, including planning, measuring mobility, public transit, and measuring performance.

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375

Teaching

Graduate Course	**Quantitative Methods in Transportation Operations**
Focus	**Operations Research, Machine Learning, Data Visualization**
Software	**GAMS, Matlab, LaTeX**
Code	**CVEEN 6530**
Offered	**Fall 2018**

I developed from scratch a graduate level course covering relevant techniques from operations research, machine learning, and data visualization. During the first 10 weeks of the course I covered 10+ distinct operations research models. All the models were solved in GAMS for the Utah state highway network and resulting solutions were visualized in Matlab. After every class students were assigned homework that included programming sets in Matlab, GAMS and LaTeX. During the remaining 6 weeks of the course I set up a hybrid module, where students took Stanford's online Machine Learning course. The class time was used to introduce data visualization techniques that are relevant to machine learning and to cover applications of machine learning algorithms in transportation.

Undergrad Course	**Probability and Statistics**
Software	**Matlab**, **R**
Code	**CVEEN 2310**
Offered	**Spring 2019**

In Spring 2019 I taught a sophomore class in Probability in Statistics. In my teaching I leveraged an online course from MIT OpenCourseWare, Introduction to Probability, and the corresponding textbook. Students were asked to watch a 40 min video lecture before every class, while the in-class time was used to summarize key theoretical concepts and solve problems. For labs we leveraged Stanford's online Machine Learning course to cover linear and logistic regression in Matlab, and Duke's online Statistics with R specialization to cover data visualization and hypothesis testing.

Journal Articles

1. Kim, M., **Marković, N.**, & Kim, E. (2019). A vertical railroad alignment design with construction and operating costs. *Journal of Transportation Engineering, Part A: Systems.*

2. Sekuła, P., **Marković, N.**, Vander Laan, Z., & Sadabadi, K. F. (2018). Estimating historical hourly traffic volumes via machine learning and vehicle probe data: A Maryland case study. *Transportation Research Part C: Emerging Technologies.* Vol. 97, 147-158

3. **Marković, N.**, Sekuła, P., Vander Laan, Z., Andrienko, G., & Andrienko, N. (2018). Applications of Trajectory Data from the Perspective of a Road Transportation Agency: Literature Review and Maryland Case Study. *IEEE Transactions on Intelligent Transportation Systems*, Vol. 99, 1-12.

4. **Marković, N.**, Ryzhov, I.O. & Schonfeld, P. (2017). Evasive flow capture: A multi-period stochastic facility location problem with independent demand. *European Journal of Operational Research*, Vol. 257 (2), 687-703.

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375

5. **Marković, N.**, Kim, E.K. & Schonfeld, P. (2016). Statistical and machine learning approach for planning dial-a-ride systems. *Transportation Research Part A: Policy and Practice*, Vol. 89, 41-55.

6. **Marković, N.**, Ryzhov, I.O. & Schonfeld, P. (2015). Evasive flow capture: Optimal location of weigh-in-motion systems, tollbooths, and safety checkpoints. *Networks*, Vol. 65, 22-42. Glover-Klingman Prize for the best paper published in Networks in 2015.

7. **Marković, N.**, Nair, R., Schonfeld, P., Miller-Hooks, E., & Mohebbi, M. (2015). Optimizing dial-a-ride services in Maryland: Benefits of computerized routing and scheduling. *Transportation Research Part C: Emerging Technologies*, Vol. 55, 156-165.

8. **Marković, N.**, Milinković, S., Tikhonov, K.S., & Schonfeld, P. (2015). Analyzing passenger train arrival delays with support vector regression. *Transportation Research Part C: Emerging Technologies*, Vol. 56, 251-262.

9. **Marković, N.**, Drobnjak, Ž., & Schonfeld, P. (2014). Dispatching trucks for drayage operations. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 70, 99-111.

10. **Marković, N.**, Milinković, S., Schonfeld, P., & Drobnjak, Ž. (2013). Planning dial-a-ride services: Statistical and metamodeling approach. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2352, Num. 1, 120-127.

11. **Marković, N.** & Schonfeld, P. (2011). Scheduling under uncertainty for a single-hub intermodal freight system. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2238, Num. 1, 24-31.

12. **Marković, N.**, Kim, M., & Kim, E. (2019). A simple threshold policy for dispatching vehicles in demand-responsive transit systems. *Promet – Traffic & Transportation.*

13. **Marković, N.** & Schonfeld, P. (2013). Scheduling for a single-terminal intermodal system recovery with Poisson arrivals. *Strojniški Vestnik – Journal of Mechanical Engineering*, Vol. 59, Num. 9, 564-572.

Journal Articles Under Review

14. Chen, Y., **Marković, N.**, Ryzhov, I.O. & Schonfeld, P. (2019). Data-driven robust resource allocation with isotonic cost functions. *Transportation Science.* Submitted.

15. Sina, D., **Marković, N.**, Heaslip, K., Reddy, C. (2019). A deep learning approach for vehicle classification using large-scale GPS data. *Transportation Research Part C: Emerging Technologies.* In revisions.

Refereed Conference Proceedings

1. Sekuła, P., **Marković, N.**, Vander Laan, Z., & Sadabadi, K. F. (2018). Application of vehicle probe data in estimating traffic volumes: A Maryland case study. Transportation Research Board 97$^{\text{th}}$ Annual Meeting.

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375

2. **Marković, N.**, Nair, R., Schonfeld, P., Miller-Hooks, E., & Mohebbi, M. (2014). Optimizing dial-a-ride services in Maryland. Transportation Research Board 93rd Annual Meeting.

3. **Marković, N.**, Milinković, S., Schonfeld, P., & Drobnjak, Ž. (2013). Planning dial-a-ride services: statistical and metamodeling approach. Transportation Research Board 92nd Annual Meeting.

4. Bešinović, N., **Marković, N.**, & Schonfeld, P. (2013). Optimal allocation of truck inspection stations based on k-shortest paths. Transportation Research Board 92nd Annual Meeting.

5. Perovanović, J., Jaiswal, J., **Marković, N.**, & Hoffman, E. (2013). Nuclear envelope laminopathies: evidence for developmentally inappropriate chromatin-nuclear envelope interactions. Epigenetics & Chromatin, 6(Suppl 1), P65.

6. **Marković, N.**, Drobnjak, Ž., & Schonfeld, P. (2012). Nonstationary Markov chain framework for optimizing dedicated check-In. Transportation Research Board 91st Annual Meeting.

7. **Marković, N.**, Bešinović, N., & Schonfeld, P. (2012). Simulation-based optimization of recovery for multi-terminal freight transportation system. Transportation Research Board 91st Annual Meeting.

8. Bešinović, N., **Marković, N.**, & Schonfeld, P. (2012). Location of truck inspection stations based on stochastic flows. Transportation Research Board 91st Annual Meeting.

9. **Marković, N.** & Schonfeld, P. (2011). Scheduling under uncertainty for a single-hub intermodal freight system. Transportation Research Board 90th Annual Meeting.

Previous Projects

Focus	**Operations research, big data (250 GB)**
Title	**Optimization with Data Acquisition in Transportation Engineering**
Period	**2017 – 2018**
Funding	**National Science Foundation**

This EArly-concept Grant for Exploratory Research (EAGER) project will acquire fundamental knowledge in determining the amount of data that should be purchased for statistically estimating the coefficients of optimization models. This will be done by examining the tradeoffs between the cost of data used for calibrating optimization models and the quality of solutions obtained with those models. These questions are tackled using a new robust optimization framework that was developed for resource allocation problems with isotonic cost functions. (Journal article #14)

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375

Focus	**Machine learning, big data (250 GB), visualization**
Title	**Analysis of 20 million GPS trajectories in Maryland**
Period	**2016 – 2018**
Funding	**Maryland State Highway Administration, I-95 Corridor Coalition**

We visually explore 20 million GPS traces in Maryland and show novel applications of this type of data in transportation. The analysis employed an array of data visualization and machine learning techniques, and the visual analytics developed in this paper will be made available for public use via Regional Integrated Transportation Information System (RITIS), an automated data sharing, dissemination, and archiving system developed and maintained by the CATT Lab at the University of Maryland. (Journal article #4)

We also use the GPS traces to estimate traffic volumes throughout the state of Maryland. We apply machine learning regression to learn the relation between the GPS traces and the actual volumes that are available at the locations where we have automatic traffic recorder (ATR) stations. This relation is further used to estimate volumes at locations where ATR stations are unavailable. The resulting statewide volume map will be used in RITIS for computation of various performance measures in accordance with the requirements of the MAP-21 bill. (Journal article #3)

Lastly, we recognize that a challenge with trajectory data is lack of information about the type of vehicles that performed the recorded trips, which clearly limits any analysis. To overcome this limitation of trajectory data, we develop a deep convolutional neural network for vehicle classification to identify the vehicles' class from their trajectories. From a practical perspective, this approach allows us to label raw GPS trajectories with vehicle classes, thereby enriching the data and enabling more comprehensive transportation studies. (Journal article #15)

Focus	**Facility Location**
Title	**Evasive Flow Capturing Problem: Optimal Allocation of Weigh-in-Motion Stations, Tollbooths, and Security Checkpoints**
Period	**2013 – 2016**
Funding	**National Science Foundation**

We addressed the problem of locating facilities with the goal of intercepting stochastic traffic flows that exhibit non-cooperative behavior. Such behavior arises when locating weigh-in-motion systems, vehicle inspection stations, tollbooths, or other fixed flow-capturing facilities used for law enforcement. The main objective was to find and exploit the structural properties of the problem to make it tractable. For example, we showed that: (1) some random parameters can be replaced with their means; (2) some integer variables can be linearly relaxed; (3) the scenario-based variables and constraints can be formulated recursively. This significantly reduced complexity of the problem (without altering it), and enabled us to solve our stochastic

facility location problem on real-world road networks of Nevada and Vermont. (Journal article #7)

We also considered the problem of locating flow-capturing facilities over multiple time points during the planning horizon. The problem can be formulated as a multi-stage stochastic program (SP); however, under certain independence assumptions, it can be reformulated as a large two-stage SP, enabling us to solve much larger instances. We additionally propose an algorithm based on Lagrangian relaxation that separates the reformulated SP into a variant of a deterministic knapsack problem and a sum of time-decoupled single-period SPs that can be solved independently. (Journal article #5)

Focus	**Vehicle Routing and Scheduling**
Title	**Algorithms for Managing Ridesharing Services**
Period	**2011 – 2012**
Funding	**Maryland Industrial Partnerships Program and IT Curves**

We developed a software solution to manage operations of a company providing transportation services for elderly and disabled. I extended existing insertion heuristics to account for several practical requirements of the potential user of the software. My implementations of the static and dynamic vehicle routing heuristics were included into the final product and deployed by companies in three states: Maryland, Virginia, and Arizona. The comparison of heuristic-based routes with those manually designed by the dispatchers showed operational savings of about 18%. (Journal article #8)

Focus	**Logistics**
Title	**Urban Goods Deliveries**
Period	**2012 – 2013**
Funding	**U.S. Department of Transportation**

We observed a truck-rail intermodal system and developed a novel model to optimize truck dispatching decisions for drayage operations. We accounted for several sources of uncertainty (i.e., random trip durations and connection times) and developed a model to minimize expected costs given various operational constraints. The challenging part was to derive several mathematical expectations which were included in the objective function and constraints. A simple preprocessing procedure was employed to efficiently optimize a problem including hundreds of multi-dimensional integrals in the objective function and constraints. (Journal article #10)

Focus	**Logistics**
Title	**Transfer Coordination in Intermodal Freight Systems**
Period	**2009 – 2011**
Funding	**U.S. Department of Transportation**

We looked at the problem of coordinating transfers in a single-hub intermodal system. The objective was to scheduling departures on the outbound routes, given the information about the stochastic arrival times of connecting vehicles on the inbound routes. We derived

several expectations and built them into the objective function and constraints. The resulting nonlinear nonconvex model was solved with metaheuristics. (Journal articles #12 and #13)

FOCUS **Machine Learning Applications**
TITLE **Predicting Dial-a-Ride System Capacity**

We sought to establish a functional relation between the required system capacity and various characteristics of the service area and operators constraints (e.g., demand density and its temporal distribution, size of the area, time windows, maximum route duration). We accounted for new influencing factors and showed that the generalized linear model outperformed linear regression, artificial neural network, and support vector regression. The generalized linear model was consequently implemented into an online system to provide free decision support to practitioners. (Journal articles #11 and #6)

FOCUS **Machine Learning Applications**
TITLE **Predicting Passenger Train Arrival Delays**

We propose models that establish a functional relation between train delays and various characteristics of a railway system. Such models can be used to evaluate effects of different infrastructural projects on train delays, and thereby help managers design an investment plan to reduce delays in the most economical way. We identify new influencing factors. We present the first application of the support vector regression to the problem of predicting train delays, and show it outperforms the neural network, which was applied successfully to similar problems in the literature. (Journal article #9)

SOFTWARE

Optimizing Dial-a-Ride Services

I worked for 7 months on the development of commercial software for routing and scheduling vehicles in dial-a-ride operations (i.e., transportation of elderly and disabled passengers). My role was to adapt an efficient insertion heuristic from the literature to meet the requirements of several dial-a-ride operators. My implementations of static and dynamic dial-a-ride heuristics were deployed by companies in Maryland, Virginia and Arizona. The company marketing the software is IT Curves (`www.itcurves.net`). (Journal article #8.)

Dial-a-Ride System Design

I developed statistical and machine learning tools to predict the required fleet size of a dial-a-ride system, given the information about the service area and operator's constraints. The tools included linear regression, generalized linear model, artificial neural networks, and support vector regression. The generalized linear model was built into an online system (`www.planning-dial-a-ride-services.com`) which can provide practitioners with the free decision-support in designing capacities of dial-a-ride systems. (Journal article #11 and #6.)

Professional Activities

Institute for Operations Research and the Management Sciences (INFORMS) member
Transportation Research Board (TRB) member

Skills

Computer Languages	MATLAB, GAMS, LaTeX
Languages	Serbian, English, German (≈ ZMP), Spanish (DELE Intermedio), French (basic)
Ski Instructor Licenses	Landeslehrer 1, Carinthia, Austria, 2005 Kinderlehrer, Carinthia, Austria, 2004

Nikola Marković · 2135 Meldrum Civil Engineering · University of Utah · USA ✉ nikola.markovic@utah.edu ☎ (202) 650-7375