BEHAVIORAL URBAN INFORMATICS, LOGISTICS, & TRANSPORT LAB (BUILT@NYU)
C2SMART University Transportation Center, New York University

--- 2022 Research Brief ---

This year will be marked as a transition period for our lab: living and working under COVID-19 has stabilized; several of our PhD students graduated; a number of grants were completed and even the C2SMART Center's Tier-1 UTC status is under pending renewal. Our lab continued to produce research products this year in our area of specialization of "smart MaaS" research – data-driven, automated operations and decision support for a broad class of Mobility-as-a-Service systems, with more emphasis on deliveries in response to the rise in these research problems. On a bright note, I was included in the list of top 2% of scientists in the subfield of Logistics & Transportation career-wide for the first time in 2022.

Our lab completed one grant from C2SMART, our on-call task for NYSDOT to help them produce an RFP for a next-generation statewide mobility program, the EAGER and CAREER grants from NSF. Meanwhile, we started on two new grants from C2SMART, started a contract with Volkswagen/MOIA, started officially on two projects with NYSERDA: one with CALSTART on mobility hubs in the capital region and one with Dollaride as part of a $10M Clean Transit Access Program, and completed a task order with Bureau of Transportation Statistics as a National Expert to help define the data and analytical tools development needs.

- NYCDOT Off-Hour Deliveries (**NYCDOT**, Lead Arcadis) *(notified of award)*
- PON 4743 Clean Neighborhoods Challenge*: Clean Transit Access Program* (**NYSERDA**, lead Dollaride) *(ongoing)*
- NY Statewide Behavioral Equity Impact Decision Support Tool with Replica (**C2SMART**) (*ongoing*)
- One-to-Many Simulator Interface with Virtual Test Bed for Equitable Tech Transfer (**C2SMART**) *(ongoing)*
- Development and evaluation of an electric-charging-constrained, non-myopic, dynamic routing algorithm with synchronized transfers (**MOIA/Volkswagen**) *(ongoing)*
- Capital Region Mobility Hubs (**NYSERDA**, lead CALSTART, SP:20-1155) *(ongoing)*
- Quantifying and visualizing city truck route network efficiency using a virtual test bed (**C2SMART**, with $300K in-kind cost share from NYC DOT) (*ongoing*)
- M-EVRST (Multimodal Electric Vehicle demand ReSponsive Transport) (**FNR**, as a collaborator with PIs Dr. T.Y. Ma/LISER and Prof. F. Viti/U. Luxembourg) *(ongoing)*
- Bureau of Transportation Statistics Analytical Support Services IDIQ, Task Order #2 Federal Support for Local Decision-Making (**BTS**, Lead Weris Inc., National Expert: J.Y.J. Chow) *(completed)*
- EAGER/Collaborative Research: Enable elastic capacity for transportation infrastructure through a transmodal modular autonomous vehicle system (**NSF CMMI-2022967**, as a co-PI with lead PI Prof. X. Li from USF) *(completed)*
- Urban Transport Network Design with Privacy-Aware Agent Learning (**NSF CAREER CMMI-1652735**) *(completed)*
- NYS DOT on-call agreement Task: Statewide Mobility Serivces Program Strategic Procurement Planning (**NYSDOT SR-20-02**) *(completed)*
- Autonomous Vehicle Good Citizenry Standard (**C2SMART**, as co-PI with lead PI Sarah Kaufman at NYU Rudin Center) (*completed*)

Collaborations include folks from Siemens (Y.D. Zhong, B. Dey), Replica (Robert Regue), MOIA (Felix Zwick, Nico Kühnel), Li Jin (Shanghai Jiaotong University), Ali Diabat at NYU Abu Dhabi, Kaan Ozbay, Sarah Kaufman, and Oliver Gao (Cornell).

BUILT participated in two summer research programs once again: the Summer Undergraduate Research Program at NYU, and the ARISE program, which supports high school students interested in STEM research.

Research briefs from 2015 – 2021 can be found here.

Research Highlights

With 9 journal articles and 33 other research products, our research agenda this year is divided into two main thrust areas: (1) learning/inference with dynamic network optimization, and (2) MaaS systems evaluation. Prototypes of our algorithms can be found either online at https://github.com/BUILTNYU, or through the included link or by request. Key findings are presented.

Dynamic transport system learning and network optimization

The research in this thrust deal with designing algorithms for systems in an online setting, where design decisions (e.g. routing, dispatch, positioning) are interdependent with learning efforts. One application is in emergency vehicle (EMV) dispatch, where the increasing urbanization continues to degrade the response times for EMVs. We developed a **reinforcement learning system in collaboration with Siemens to provide decentralized routing to the EMVs and accompanying traffic control** to improve response times by over 40% in simulation tests of arterial grids in Manhattan and Hangzhou.

Gyugeun Yoon completed his dissertation on integrated transit network route design and optimal learning, significantly expanding on **sequential transit route design with correlated knowledge gradients**. This will prove beneficial for emerging technology providers operating fixed route transit services where data from users are limited and require careful management of exploitation and exploration as they use AI to grow their routes. Some of the preliminary work was presented as a poster at the Google Workshop on Urban Mobility Simulation and Optimization and a paper was accepted for presentation at the upcoming TRB Annual Meeting (Event 4081).

Srushti Rath also completed her dissertation, where one chapter involves designing **real options policies for selecting and timing zones to expand a service region with**. The challenge is that complex inter-related options can be evaluated but require sequence enumeration; she overcame this challenge using recurrent neural networks to train an algorithm to sample only a small subset of sequences with near optimal performance. This work will allow mobility providers with uncertain environments to use data to drive their decisions to flexibly adapt their service regions over time, which should hopefully reduce the amount of deployment failures.

Farnoosh Namdarpour and Bingqing Liu are wrapping up a project with MOIA to integrate a transfer feature to an online system. We adapted a nonmyopic cost function approximation policy to account for the opportunity costs of transfers that are committed to in real time. The policy is being tested using real data provided by the MOIA team for Hamburg. Results should be published in the next year.

MaaS evaluation

Bingqing Liu successfully extended an earlier model from Ted Pantelidis to **analyze Mobility-as-a-Service platforms**. The extension includes more efficient solution algorithms that can also model mobility-on-demand (MOD) services while ensuring that a design reaches a stable "MaaS platform equilibrium". This is important as many MaaS initiatives at the moment lack analytical tools to help them design their markets: which operators should operate where, how should they integrate with one another to provide services in a coopetitive manner, how much fleet or capacity to consider. The preliminary work was presented at INFORMS at Indianapolis and will be presented at TRB.

Evaluation of MaaS and individual mobility providers also needs to equity. However, treating equity requires more powerful behavioral models; Xiyuan Ren proposes an **agent-based mixed logit model for evaluating individual-level heterogeneity** in choice behavior (what Joffre Swait calls "individual parameter logit"). This is now being applied in collaboration with Replica (Robert Regue) to develop choice models for different population segments across New York State (NYS) using synthetic data. This work will make it possible to add tractable behavioral response to system design problems (e.g. optimizing service regions for an MOD service across NYS).

In addition to building more fitting models of heterogeneity using inverse optimization, we have been studying the impacts of aggregating zones (**"zone districting") to better make use of public data for equity analysis**. We found that many public surveys (e.g. American Community Survey) may be highly unreliable for marginalized

population segments when viewed at Census tract level. This work can help define a common zone districting system that can be used nationwide as policymakers seek unified standards for data sharing between mobility providers. This work was presented at INFORMS and will be presented at the upcoming TRB.

MaaS does not have to just deal with passengers, but also with deliveries. Along that direction, we are developing both simulation-based tools (including a synthetic truck population for inclusion in MATSim-NYC) and analytical models such as a **parcel delivery model** developed by Hai Yang for NYC. The study has been accepted for presentation at the upcoming TRB and at the 12th International Conference on City Logistics at Bordeaux, France.

Looking Ahead

We continue to develop on the virtual test bed with the enhancement of MATSim-NYC to include deliveries and for MATSim simulations to be able to interface with local simulators. We expect to have more to report on this in the next year as the extended simulation tools will also find use in two of the new projects starting (Dollaride's CTAP project for NYSERDA and Arcadis' off-hour deliveries project for NYCDOT). Related to those efforts, we expect next year to focus even more on freight deliveries and on electric mobility, as well as in equity considerations under different data availability considerations.

I will also be taking a short break from NYU next semester, taking my sabbatical and using that time to visit and collaborate with researchers at TU Delft while exploring software licensing for our research products.

Sincerely,

Joseph Chow, Ph.D., P.E.
Institute Associate Professor, Department of Civil & Urban Engineering
Deputy Director, C2SMART University Transportation Center
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New York University Tandon School of Engineering

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BUILT Lab members active in 2022

PhD student researchers
Gyugeun Yoon, Qi Liu, Jesse Fu, Bingqing Chloe Liu, Srushti Rath, Haggai Davis, III, Farnoosh Namdarpour, Hai Yang, Xiyuan Ren

MS student researchers
Patrick Scalise, Hector Landes

Undergraduate student researchers
Ethan Wong, Zhixi Sean Lin, Ngoc Hoang

New Research Products in 2022

Journal publications:

1) Su, H., Zhong, Y.D., **Chow, J.Y.J.**, Dey, B., Jin, L., 2023. EMVLight: a multi-agent reinforcement learning framework for an emergency vehicle decentralized routing and traffic signal control system. *Transportation Research Part C*, 146, 103955.
2) **Ren, X.**, **Chow, J.Y.J.**, 2022. A random-utility-consistent machine learning method to estimate agents' joint activity scheduling behavior from ubiquitous data. *Transportation Research Part B* 166, 396-418.

3) Abou Kasm, O., Diabat, A., **Chow, J. Y. J.**, 2022. Simultaneous operation of next-generation and traditional quay cranes at container terminals. *EJOR*, in press, doi: 10.1016/j.ejor.2022.10.035.
4) **Rath, S.**, **Chow, J.Y.J.**, 2022. Single-allocation choice-constrained air taxi skyport location problem for airport access. *Journal of Air Transport Management*, 105, 102294.
5) **Liu, Q.**, **Chow, J. Y. J.**, 2022. Efficient and stable data-sharing in a public transit oligopoly as a coopetitive game, *Transportation Research Part B* 163, 64-87.
6) **Scalise, P.**, **Chow, J. Y. J.**, 2022. Paratransit shared-ride capacity design with infectious disease contact exposure. *Transportation Research Record*, 2676(10), 104-118.
7) **Yoon, G.**, **Chow, J. Y. J.**, **Rath, S.**, 2022. A simulation sandbox to compare fixed-route, flexible-route transit, and on-demand microtransit system designs. *KSCE Journal of Civil Engineering*, SI: Future Urban Mobility with MaaS, 26, 3043-3062.
8) **Rath, S.**, **Chow, J. Y. J.**, 2022. Worldwide city transport typology prediction with sentence-BERT based supervised learning via Wikipedia. *Transportation Research Part C* 139(3), 103661.
9) **Liu, Q.**, **Chow, J. Y. J.**, 2022. A schedule-based dynamic transit passenger flow estimator using stop count data. *Transportmetrica B*, in press, doi: 10.1080/21680566.2022.2060370.

Conference proceedings:

10) **Rath, S.**, **Chow, J.Y.J.**, 2023. A recurrent neural network-reinforced real options policy for sequential service region design and timing. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
11) **Liu, Q.**, **Chow, J.Y.J.**, 2023. A generalized network level disruption resource allocation model for urban public transport systems. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
12) **Ren, X.**, **Chow, J.Y.J.**, 2023. A random-utility-consistent machine learning method to estimate agents' joint activity scheduling choice from a ubiquitous data set. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
13) **Yang, H.**, **Landes, H.**, **Chow, J.Y.J.**, 2023. A large-scale analytical residential parcel delivery model with cargo bike substitution in New York City. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
14) Wang, D., Tayarani, M., **He, B. Y.**, Gao, J., Gao, H.O., Ozbay, K., **Chow, J.Y.J.**, 2023. Transportation electrification for climate action goals in the post-pandemic: an agent-based modeling approach. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
15) **Liu, B.**, **Namdarpour, F.**, **Chow, J.Y.J.**, 2023. A zone districting problem with sample data margin of error constraints for equity analysis. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
16) **Yoon, G.**, **Chow, J.Y.J.**, 2023. An optimal learning system with correlated beliefs for sequential transit network design. Proc. 102nd Annual Meeting of the TRB, Washington, DC.
17) **Liu, B.**, **Chow, J.Y.J.**, 2023. A mobility-as-a-service platform design game for fixed-route transit and mobility-on-demand services with stability guarantee. Proc. 102nd Annual Meeting of the TRB, Washington, DC.

Research reports:

18) AVs in NYC: a Policy Framework, PI: S. Kaufman, Co-PI: J.Y.J. Chow; Sponsor: C2SMART.
19) COVID-19's Effect on Transportation: Developing a Public COVID-19 Data Dashboard, PI: K. Ozbay, Co-PIs: J.Y.J. Chow, J. Gao; Sponsor: C2SMART.

Dissertations and Theses completed:

20) **Yoon, G.**, 2022. Route design with optimal learning. PhD dissertation, New York University.
21) **Liu, Q.**, 2022. Data use and sharing in public transit systems. PhD dissertation, New York University.
22) **Rath, S.**, 2022. Data-driven decision support tools for large-scale strategic deployment of emerging mobility services. PhD dissertation, New York University.

Working papers:

23) **Rath, S.**, **Chow, J.Y.J.**, 2023. A deep real options policy for sequential service region design and timing. arXiv preprint.
24) **Fu, Z.**, **Chow, J.Y.J.,** 2022. Dial-a-ride problem with modular platooning and en-route transfers. arXiv preprint arXiv:2212.00289.

Invited Talks:

25) "A stable matching analysis framework for Mobility-as-a-Service platforms as two-sided markets", University at Buffalo, Oct 21, 2022.
26) "A stable matching analysis framework for Mobility-as-a-Service platforms as two-sided markets", University of Connecticut, Oct 14, 2022.
27) "Behavioral Modeling Advances in MaaS Systems", University of Tokyo, June 1, 2022.
28) "Towards day-to-day assignment games for mobility ecosystems", Dagstuhl Seminar: Dynamic Traffic Models in Transportation Science, May 9, 2022.
29) "Shared, electric, modular automated mobility in smart cities", Chulalongkorn University, Apr 28, 2022.
30) "Tackling operational inefficiencies toward sustainable Mobility-as-a-Service", Texas A&M, Mar 3, 2022.

Conference Presentations:

31) "The dial-a-ride problem with modular platooning", CASPT, Tel Aviv, Nov 8, 2022.
32) "Optimal zone sizing for equitable data sharing of mobility providers", INFORMS, Indianapolis, Oct 17, 2022.
33) "Stable mobility-as-a-service market design with fixed-route transit and mobility-on-demand services", Indianapolis, INFORMS, Oct 18, 2022.
34) "Microtransit deployment portfolio management using simulation-based data upscaling", TRANSED 2022, Sept 13, 2022.
35) "Sequential transit route design by link expansion using knowledge gradient with correlated beliefs", TRISTAN XI, Mauritius, June 19-25, 2022.
36) "A subsidy-stabilized assignment game for Mobility-as-a-Service markets with both fixed route and on-demand operators", TRISTAN XI, Mauritius, June 19-25, 2022.
37) "A random-utility-consistent machine learning method to estimate agents' joint activity scheduling choice from a ubiquitous data set", TRISTAN XI, Mauritius, June 19-25, 2022.

Prototypes and data:

38) Mobility data dashboard, https://trid.trb.org/view/2052131
39) Data for AMXL model (Paper #2), https://github.com/xr2006/AMXL
40) Sample data for transit data sharing game (Paper #5), GitHub - BUILTNYU/transit-data-game
41) Dataset produced by sBERT algorithm for city typologies around the world (Paper #8), Worldwide city transport typology prediction with sentence-BERT based supervised learning via Wikipedia | Zenodo
42) Code and data for passenger flow estimator using stop data (Paper #9), transit-flow-estimation/schedule-based at master · BUILTNYU/transit-flow-estimation · GitHub