CASA dissertation plan submission form

Please use your UCL information (e.g. email)

Email address *

hussein.mahfouz.19@ucl.ac.uk

First Name *

Hussein

Last Name *

Mahfouz

Student Number *

19122800

Select your programme *

MSc Smart Cities and Urban Analytics

Potential supervisor. Note, academics have different capacity for supervision. *

Thomas Oléron Evans

Have you contacted this supervisor *

- (●) Yes
- ( ) No

Do you have a 2nd choice supervisor *

Maarten Vanhoof

Are you planning to collaborate with a partner or apply for an advertised project (listed below) *

- ( ) Yes
- (●) No
- ( ) I've found my own partner

What project are you applying for *

I'm not, i've got my own project

If you have your own partner, who are they

If you have picked a partner or listed project what makes you suitable for their project (100-200 words)

Have you read the mark scheme on Moodle *

- [x] Yes

Have you read the dissertation handbook on Moodle before completing the rest of this form *

- (•) Yes

What is the proposed title of your project (insert industry title if selected industry project) *

Comparing Different Methods for Solving the Transit Route Network Design Problem

What is the proposed research question - see handbook *

How can public bus networks be optimized while accounting for user and operator needs?

What are your proposed objectives - see handbook *

1. Review the existing literature on solving the Transit Route Network Design Problem (TRNDP) and identify the different objective functions, constraints and approximation algorithms used to solve it
2. Understand how to reduce the road network to a weighted graph (two graphs with weights being travel demand and travel time)
3. Get familiar with the different approximation algorithms and compare them. Do this by solving the TRNDP on a case study city with available public transport data (GTFS feed and fleet capacity). The solutions are compared using different criteria to see how they differ in:
   a. the value of the objective function (e.g. overall travel time)
   b. network criticality measures
   c. accessibility (job reach) *
4. Compare the solutions to the existing transit network (GTFS feed) in the chosen city and see by how much optimization improves the network
5. Compare [a] route and frequency optimization to [b] optimization of frequency only to see whether a complete redesign of a network has considerable benefits compared to altering the frequencies on the existing bus routes.

Provide 400-500 words of background for the research *

As more people continue to move into cities, the task of providing public transport networks that accommodate the needs of these people is becoming more urgent (Walker 2012). Congestion is one of the biggest issues faced by cities, and the phenomenon of 'induced demand' has shown that building more road space to cater for private vehicles has not been successful in alleviating congestion (Dunkerley and Laird 2018). Issues of equity and sustainability are other driving forces behind public transport investment.

Investment in public transport is only as good as the ridership it attracts, which is itself correlated with the convenience of the network for users (Walker 2012). Traditionally, local knowledge and guidelines set by experienced planners have been used to design public transport networks, but this falls short of creating efficient networks (Soares et al. 2019). The same inefficiencies exist for vehicle allocation, where "dispatchers responsible for traffic operations tend to use their own experience and intuition when allocating the available means of transport to the available lines" (Borowska-Stefanska and Wisniewski 2017).

Creating an efficient transport network is difficult mainly due to the combinatorial nature of the problem (ibid). The different stages include route design, frequency setting, timetable design, fleet assignment, and crew assignment, with each stage influencing the following one (Martínez, Mauttone, and Urquhart 2014). Throughout the design process different user and operator objectives must be accounted for. User incentives to take public transport include cost, competitive travel times (compared to private vehicles), service coverage and comfort. Operators must balance these with their own cost budget when designing a network.

The design of an efficient public transport network that can compete with private vehicles is referred to in the literature as the Transit Route Network Design Problem (TRNDP) (Kepaptsoglou and Karlaftis 2009). TRNDP is an optimization problem with constraints including but not limited to fleet capacity, length of routes and allowable frequencies (ibid). The TRNDP has been modelled using different objective functions and constraints. Past formulations include:

- minimizing the total travel time on the network (Schéele 1980; Yu, Yang, and Yao 2010)
- minimizing both crowding and passenger waiting times (Han and Wilson 1982)

It has also been modelled as single objective, multi-objective and bilevel optimization problems, with varying levels of complexity using different algorithms.

Borowska-Stefanska, Marta, and Szymon Wisniewski. 2017. "Vehicle Routing Problem as Urban Public Transport Optimization Tool." Computer Assisted Methods in Engineering and Science 23 (4): 213–29.
Dunkerley, Fay, and James Laird. 2018. "Latest Evidence on Induced Travel Demand: An Evidence Review." Department for Transport.
Han, Anthony, and Nigel Wilson. 1982. "The Allocation of Buses in Heavily Utilized Networks with Overlapping Routes." Transportation Research Part B: Methodological, 221–32.
Kepaptsoglou, Konstantinos, and Matthew Karlaftis. 2009. "Transit Route Network Design Problem: Review." Journal of Transportation Engineering 135 (8).
Martínez, Héctor, Antonio Mauttone, and María Urquhart. 2014. "Frequency Optimization in Public Transportation Systems: Formulation and Metaheuristic Approach." European Journal of Operational Research 236 (1): 27–36.
Schéele, Siv. 1980. "A Supply Model for Public Transit Services." Transportation Research Part B: Methodological 14: 133–46.
Soares, Philipp Heyken, Christine Mumford, Kwabena Amponsah, and Yong Mao. 2019. "An Adaptive Scaled Network for Public Transport Route Optimisation." Public Transport 11: 379–412.

Van Nes, Rob, Rudi Hamerslag, and Immers Ben. 1988. “Design of Public Transport Networks.” Transportation Research Record, no. 1202: 74–83,.
Walker, Jarett. 2012. Human Transit.
Yu, Bin, Zhongzhen Yang, and Jinbao Yao. 2010. “Genetic Algorithm for Bus Frequency Optimization.” Journal of Transportation Engineering 136 (6).

Provide a 300-500 word methodological outline *

1) Framing the Problem

The research will focus on one or both of [a] route design and [b] frequency setting stages of the network design.

The problem is a multi-objective function that takes into account both user and operator costs: The objectives could be:
- minimizing the total travel time for users (proxy for user cost)
- minimizing the total mileage on the network (proxy for operator cost)

Potential constraints used in optimization problem:
- Maximum and minimum route length
- Maximum and minimum bus frequencies (according to standard practice. Frequencies could also be limited to a range of integer values)
- Load of buses. Derived from assigning ONS flow data to bus routes
- Fleet capacity (number of available buses)
- Roads suitable for buses (filter out road types from Open Street Maps)

2) Modelling the Network as a Weighted Graph

The methodology is taken from Soares et al. (2019). The street network is modelled as a graph with the nodes being the junctions and the links being the road segments

Two adjacency matrices are then created:
- Travel time matrix. This could be based on:
  a. OSM road speed data
  b. Fixed speeds for buses (simplification)
  c. Travel time data from Quant project (if available)
- Travel demand matrix
  a. Assign census OD flow data to the nodes on the graph.
  b. Get population weighted centroids of zones and assign each centroid to a node based on the catchment area of each node on the graph. This step allows OD flow data to be converted to trips between nodes depending on which node each zone is assigned to.

Assigning Commuter Demand and Generating Routes

The research will utilize the census commuter flow data to measure public transit demand. The data could be used as is for the optimization problem or a calibrated spatial interaction model of the flow data could be used.

Then following Kiliç and Gök (2014) and Soares et al. (2019):

- The shortest path between each OD pair is calculated and the demand between that OD pair is assigned to the links that make up the shortest path. This is done for all OD pairs so that the weight of each link is equal to the total demand on all shortest paths utilizing that link.
- An adjacency distance matrix is created, where the distance between neighboring nodes is inversely proportional to the demand on the links connecting the nodes. This means that nodes with high demand will be used more in the route generating process
- Generation of candidate routes and iteration to reach optimal routes (I still don't understand how

this is done)

Kılıç, Fatih, and Mustafa Gök. 2014. “A Demand Based Route Generation Algorithm for Public Transit Network Design.” Computers & Operations Research 51: 21–29.

Soares, Philipp Heyken, Christine Mumford, Kwabena Amponsah, and Yong Mao. 2019. “An Adaptive Scaled Network for Public Transport Route Optimisation.” Public Transport 11: 379–412.

List the sources of data you are considering using *

- Road Network Data from Open Street Maps
- ONS commuter flow data ONS - https://www.nomisweb.co.uk/census/2011/wu03uk
- GTFS feed with bus network of chosen city
- Road traffic data

Are you planning on conducting any field work *

- ○ Yes
- ◉ No
- ○ Maybe

If yes or maybe, outline which UCL forms you will need to submit. Consult: https://www.ucl.ac.uk/safety-services/a-z/off-site-working

Do you think you will need UCL ethics committee approval at this stage. Follow the link within the dissertation handbook. More information on ethics will be provided in a later lecture. *

- ○ Yes
- ◉ No
- ○ Not sure yet, might do
- ○ Not sure yet, but don't think so

What ethical considerations will consider within your research, even if you don't need formal approval (100-200 words) *

- Plagiarism
- Acknowledging the assumptions made in the research and the resulting limitations
- Not disclosing any private data
- Citing data sources and attributing ideas

Are you aware of the penalties for poor academic practice or academic misconduct. Consult the UCL academic manual, Chapter 6, section 9. *

- ◉ Yes

Have you joined the slack dissertation channel *

- ◉ Yes

Do you have access to the CASA0004/0010/0012 Moodle page *

- (●) Yes
- ( ) No

Are you aware of the submission deadlines of 5pm 24th August for the digital version on Moodle and 5pm 1st September for the hard copies in the CASA office *

- (●) Yes

Bullet point (or list) an action plan for March for this project *

- Go over the literature to get familiar with the methodologies required
- Find relevant online material on optimization and go though it
- Narrow scope of work by identifying study area
- Explore option of carrying out the research on a city with no commuter flow data
- Find/Ask for datasets

Do you have anything else to add

Ideally I would do this project on a city like Cairo. I will look at the possibility of using a radiation model to predict commuter flow. If this adds too much work or if there are too many assumptions then I will discard this and work on a UK city

If you are applying for an industry project you might not be successful, what is your plan B title. If you have proposed your own project or secured your own partner (that is not from the CASA list) you do not need to complete any plan B questions

What is your plan B research question

What would be your plan B objectives

What data would you use for the plan B project

Give a brief description of the project (100 words)

Do you think you will need UCL ethics committee approval at this stage for the plan B idea. Follow the link within the dissertation handbook. More information on ethics will be provided in a later lecture.

- ◯ Yes
- ◯ No
- ◯ Not sure yet, might do
- ◯ Not sure yet, probably not

Are you planning on conducting any field work for the plan B project

- Yes
- No
- Maybe

If yes or maybe, outline which UCL forms you will need to submit. Consult: https://www.ucl.ac.uk/safety-services/a-z/off-site-working

What ethical considerations will consider within your plan B research, even if you don't need formal approval (50 words)

ROUND 2: What project are you applying for

Choose

ROUND 2: If you have picked a partner or listed project what makes you suitable for their project (100-200 words)

ROUND 2: What is the proposed title of your project (insert industry title if selected industry project)

ROUND 2: What is the proposed research question - see handbook

ROUND 2: What are your proposed objectives - see handbook

ROUND 2: Provide 400-500 words of background for the research

ROUND 2: Provide a 300-500 word methodological outline

ROUND 2: List the sources of data you are considering using

ROUND 2: Are you planning on conducting any field work

- ◯ Yes
- ◯ No

ROUND 2: If yes or maybe, outline which UCL forms you will need to submit. Consult: https://www.ucl.ac.uk/safety-services/a-z/off-site-working

ROUND 2: Do you think you will need UCL ethics committee approval at this stage. Follow the link within the dissertation handbook. More information on ethics will be provided in a later lecture. *

- ◯ Yes
- ◯ No
- ◯ Not sure yet, might do
- ◯ Not sure yet, but don't think so

ROUND 2: What ethical considerations will consider within your research, even if you don't need formal approval (100-200 words)