Report Title: Optimizing mobility on demand with dynamic pickup station and drop of with time window

This is a tentative title

Written by: **Ayman MAHMOUD** Supervisors:
Prof. Jakob Puchinger
Prof. Asmaa Ghaffari

A report presented for the
validation of first year in Master

Master Ingénierie des systèmes complexes
Laboratoire Génie Industrielle
CentraleSupélec - Université Paris Saclay
Gif Sur-Yvette - Paris - France
Date: March 27, 2020

Contents

1 Introduction **1**

2 Motivation **2**

3 Literature **2**

4 Methodology **3**
- 4.1 Scientific Journals 3
- 4.2 Books 4
- 4.3 Online Tools 4
- 4.4 Online Material 4

5 Taxonomy **5**

6 Problem Definition **5**
- 6.1 Introduction & Overview 5
- 6.2 Problem setting: 6
- 6.3 Problem Visualisation 7
- 6.4 First step 7
- 6.5 CPLEX 7

7 Conclusion **8**

1 Introduction

Increasing mobility demands raise the pressure on existing transport networks. As the most used mode of transport, private cars have a particularly strong environmental impact and produce congestion.

Ride sharing as in mobility on demand, where a driver and several riders form a carpool, can help to address these issues by increasing the number of persons per car. Therefore, recent years have seen a strong interest in carpooling. However, there exists no effective method of integrating carpooling into transport trip planners as of now, mainly due to the fuzzy and flexible nature (e.g., no fixed stops, possibility of making detours) of carpooling.

This hinders the acceptance of carpooling by the general public. This paper proposes a new method to merge public transport and carpooling networks for multimodal route planning.

It is based on the concept of drive-time areas and points of action. The goal is to provide users with trips from an origin to a destination using different combinations of modes.

Mobility research is broad and can include many topics, when we talk about mobility optimization it involves the integration of information, transportation, inventory, warehousing, material handling, and packaging, and certainly security

Ayman & Jakob

2 Motivation

Aware of the challenges of pursuing my studies in an intense way, I consider this option as a chance for me specializing in a field based on a multidisciplinary scientific approach essential to my future projects and my desire to create real expertise at the level of region of the world I come from a region strongly impacted by the transport problems, which is only a fuel that drives me to find innovative solutions.

I want to contribute to the optimization of mobility systems around the world, to contribute to the future of mobility and ultimately to reduce overall journey times for passengers.

When it comes to this subject, my readings had risen a question that needs an answer, the conflict between mobility on demand and public transit systems.

To look into this conflict I decided to read about existing problems from both sides (Public Transport and Mobility on Demand)

In the last few years, there has been a resurgence of interest in demand-responsive shared-ride systems for the general public. (see Ho et al. 2017)[**?**] This has been fueled in part by concerns for the environment; each commuter using a separate car leaves a large carbon footprint and also causes congestion in central business districts. Thus, the notion of a sharing economy that advocates a shift from car ownership to “mobility as a service”is gaining popularity.

3 Literature

In (Celsi et al. 2017)[1] The proposed solution allows to optimally solve the related routing problem, by relying on a constrained shortest path algorithm, for users travelling within multiple transportation networks, thus enabling multi-modality, and exploits the users’ availability to be aggregated into carpools.

In (Huang et al. 2019)[2] the paper proposes a new method to merge public transport and carpooling networks for multimodal route planning, considering the fuzziness and flexibility brought by carpooling. It is based on the concept of drive-time areas and points of action

(Stiglic et al. 2016)[4]

Investigated the possibility of realizing a seamless integration of ride-sharing and public transit as it may offer fast, reliable, and affordable transfer to and from transit stations in suburban areas thereby enhancing mobility of residents. They investigate the potential benefits of such a system, as well as the ride-matching technology required to support it, by means of an extensive computational study.

The study shows that the integration of a ride-sharing system and a public transit system can significantly enhance mobility and increase the use of public transport which is an expected result.

2- Synthèse de l'état de l'art:

Construction de la bibliothèque.

Information objective: Qui travaille sur le sujet: labos, chercheurs, entreprises, autres ? Some leading laboratories already have a remarkable output

Quelle est la maturité du sujet? nombre d'articles, répartition géographique ou par acteurs principaux, ancienneté du sujet,...

Contexte de votre sujet, arguments scientifiques ou données autres (presse, média autres, enquêtes,..)

* Restituez l'état de l'art sur votre sujet à partir de vos lectures: une synthèse (pas de résumé d'articles séparés).

4 Methodology

1- Méthodologie :

Comment avez-vous cherché l'information?

The literature review can be divided into two categories, the first one is a general discovery to search for the current research trends in the intelligent transport community and research boards. The second category is more precise and technical to look into the mathematical and scientific problem definitions and identify the problems where there is need and requires research force.

Thanks to the free access that is granted by the school network I was able to reach the targeted articles without difficulties. My method of looking for information consisted on three main sources: The key contributions are the following: 1. a comprehensive survey of the journal papers published since 2007, 2. an overview of application areas of DARPs, 3. a detailed taxonomy of the problem variants, and discussion on subtleties of the classification, 4. a systematic review of exact and meta-heuristic solution methodologies, 5. full references to benchmark instances, with valid hyperlinks and computational comparisons, 6. identification of potential research gaps, and 7. discussion of emerging technologies and their impacts on future research directions.

Scientific journals

Books

Online Material

4.1 Scientific Journals

My main sources of research were the journals, more specifically Transportation Research Journal, this journal that is published regularly is divided into 6 parts, ranging from policy and practice, emerging technologies to Transport and Environment, the parts that significantly contributed to my literature review are Parts B & C.

Part B publishes papers on all methodological aspects of the subject, particularly those that require mathematical analysis while part C addresses development, applications, and implications, in the field of transportation, of emerging technologies from such fields as operations research. In Transportation Research Part B I found the article that was recommended by my supervisor "A survey of models and algorithms for optimizing shared mobility"(Mourad et al. 2019)[3]

4.2 Books

Books are the main reference if you want to understand correctly a scientific topic, in this survey I stumbled upon many references such as:

4.3 Online Tools

The literature review process wouldn't have been possible without the very powerful online tools such as ScienceDirect that helped me widden my research by suggesting 6 related articles to the paper I am currently investigating. Google Scholar is a freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines this tool helped me to find many articles, know where it has been cited and published this tool also shows me the researcher profiles and who they have collaborated with, their most cited work and their research topics of interest, in conclusion it is the Facebook of researchers, finally researchGate that helped me

4.4 Online Material

Thanks to the open source material online, we can easily find the tools that can help advance in the topic.

I was advised by the program director to start a class online on the queuing theory, "Queuing Theory: from Markov Chains to Multi-Server Systems "Queuing theory aims at modelling waiting or blocking phenomena. To be more precise, in queuing theory, those phenomena are characterized by mathematical models. This makes it possible to compute average system performance such as an average delay or a blocking probability. Reciprocally it is possible to dimension system resources in order to reach a given performance level.

This online class gave me a better understanding of the queuing modelling and applications in mobility problems, this basic understanding helped me working on my first project to simulate the traffic on a road with three lane and tolling stations and then study the possibility of creating a traffic jam based on the rate of generation of vehicles.

In addition to this, the program I am into fits perfectly the technical knowledge I need to advance in my research, just in this first semester I was able to recognize and deal with many optimization and operational research problems. What's even better is that most of the work we do in the class most of the times is on a subject related to mobility as an example in the modelling class the project was on traffic modelling using a hydromatic analogy and the law of conservation of flow.

Attending the class of optimization for transportation. The project

What I noticed a month into readings is that is is very easy to get lost into the articles, you can start searching for a specific topic but 30 minutes into the search you find yourself on

quels mots clés, bases de données, documents, enquêtes?

Comment avez-vous sélectionné vos articles? a quoi arrivez-vous aujourd'hui à repérer qu'un article est pertinent pour votre problématique?

5 Taxonomy

To introduce and clarify basic terminology is called setting. Besides indicating where a transportation request needs to be picked up and where it should be transported to, a shared trip must also indicate when this process can take place. This is usually done by associating a time window with each transportation request, whether for a passenger or freight. In ride-sharing systems, this time window is usually given by each passenger indicating the earliest departure time from his origin and the latest arrival time at his destination. In intermodal itineraries, the goal of the passenger is to use on demand mobility service (e.g. van-pooling service) to get to the main transportation method (e.g. a train)

6 Problem Definition

6.1 Introduction & Overview

Before defining the problem (writing the problem statement) I will present here a brief description in few lines of the actual optimization problems that exist in the literature, for works please refer to the literature review. Travelling Salesman Problem, minimum cost flow problem, vehicle routing problem, Dial a ride problem.

The Dial-a-Ride Problem (DARP) consists of designing vehicle routes and schedules for n users who specify pickup and delivery requests between origins and destinations. The aim is to plan a set of m minimum cost vehicle routes capable of accommodating as many users as possible, under a set of constraints. Several local authorities are setting up dial-a-ride services or are overhauling existing systems in response to increasing demand such as BVG BerlKönig [Add ref here], to better describe the problem as illustrated in (fig. 1) the dial a ride problem often receives the pick up and drop-off time windows as inputs from the users, most of the trip planners such as Citymapper [], for mobility on demand the pick up location is usually the nearest point to the customer, in the problem we're going to introduce dynamic pick up locations taking into consideration the drop-off time windows and fair walking distance between customers. In this problem the drop-off time window is defined by the timetable of the destination and not by the user, which makes the whole experience more reliable and seamless.

6.2 Problem setting:

We can start by finding an exact optimization method using linear programming we can define the problem as the following: In this part we will describe the problem only at peak hours when the mobility on demand is only serving a many-to-one (Many pick up stations to one drop-off station), in the case of normal operating hours, the service runs a basic mobility on demand service where its mathematical model can be found in the following paper. (Laporte et al. 2007) [add ref here] We have n number of users, m number of vehicles in the fleet and s is the number of stations the customers can be dropped-off at (These stations must have clear and predefined timetables such as train stations and school) $P = \{1, ..., n\}$ is the set of pick up requests and $l = \{1, ..., n\}$ are the respective locations. $D = \{1, ..., s\}$ is the set of drop-off stations, $B = \{1, ..., b\}$ is the set of vehicles available, in this basic problem the capacity of the fleet is unlimited and the travel cost will no be considered in the optimization problem.

A request is a couple (i, j), where $i \in P \& j \in D$ the travel time of this couple will be denoted t_{ij}.

As we can see this is an optimization problem that requires a lot of pre-processing, simply because the pick up will be realised by a cluster of demands sharing the same geographical area, there will be a designed algorithm that calculates the location of the best virtual pick-up station, for this algorithm we will introduce a distance limit denoted by l_i which is the maximum distance the customer is willing to make to reach the pick up station, because when transporting passengers, reducing user inconvenience must be balanced against minimizing operating costs.

The algorithm will then introduce m the number of pick up stations defined $m \leqslant n$, $M = \{1, ..., m\}$ is a set of pick up stations, (k, j) is a couple of a pick up station M_k and a drop-off station D_j, this couple will be represented by a vertex $v_i \in V$ to each vertex associated the pick up time at the station. Let R_k the pick up time from the station and R_j the drop off **predefined**, $R_k + t_{ij} \leqslant R_j$.

This problem can be represented using a three index formulation. The three index variable x_{kj}^b is a binary variable that is equal to 1 only if the couple (i, j) is going to be served by vehicle k.

$$\begin{aligned} \text{Minimize} \quad & \sum_{b \in B} \sum_{k \in V} \sum_{j \in V} x_{kj}^b \\ \text{subject to} \quad & \sum_{b \in B} \sum_{j \in V} x_{kj}^b \qquad\qquad (k = 1, ..., m) \\ \text{add rest} \quad & \text{of constraints here} \end{aligned}$$

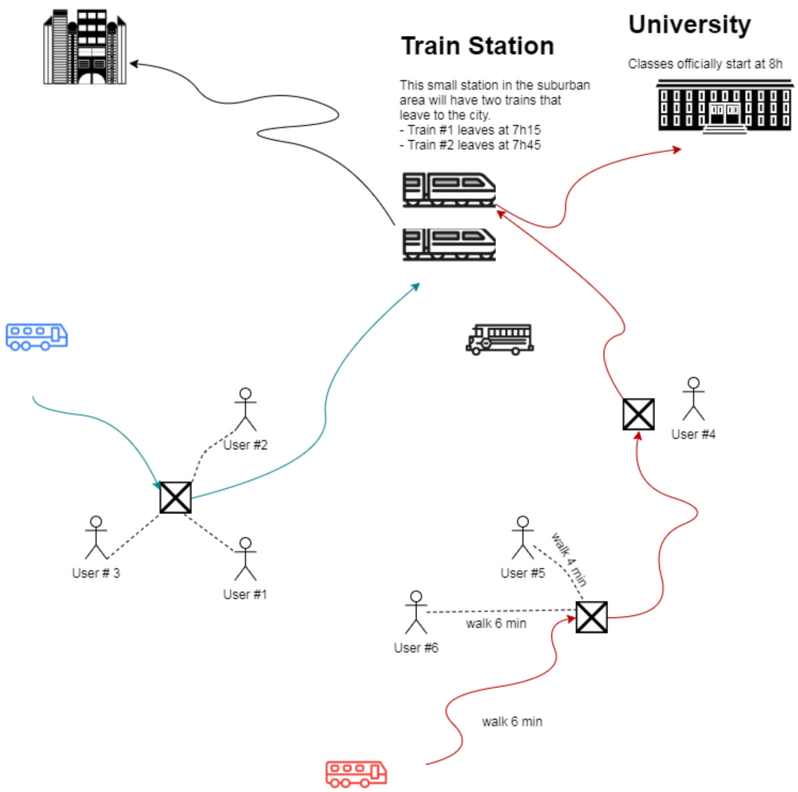

Figure 1: Diagram

6.3 Problem Visualisation

6.4 First step

The first step in the problem definition statement is to be able to present the work in a mathematical formulation.

6.5 CPLEX

CPLEX will be used to find a solution for a basic problem formulation with 1 vehicle, 3 customers and one arrival station.

Different solution approaches have been proposed for the DARP and its variants. Some solution approaches can apply to more than one problem type. For example, heuristics or metaheuristics can be applied to solve both static-deterministic DARPs and dynamic-deterministic DARPs

7 Conclusion

write what you conclude from the readings

References

[1] L. R. Celsi, A. Di Giorgio, R. Gambuti, A. Tortorelli, and F. Delli Priscoli. On the many-to-many carpooling problem in the context of multi-modal trip planning. In *2017 25th Mediterranean Conference on Control and Automation (MED)*, pages 303–309, July 2017.

[2] H. Huang, D. Bucher, J. Kissling, R. Weibel, and M. Raubal. Multimodal route planning with public transport and carpooling. *IEEE Transactions on Intelligent Transportation Systems*, 20(9):3513–3525, Sep. 2019.

[3] Abood Mourad, Jakob Puchinger, and Chengbin Chu. A survey of models and algorithms for optimizing shared mobility. *Transportation Research Part B: Methodological*, 123:323 – 346, 2019.

[4] Mitja Stiglic, Niels Agatz, Martin Savelsbergh, and Mirko Gradisar. Enhancing urban mobility: Integrating ride-sharing and public transit. *Computers Operations Research*, 90:12 – 21, 2018.