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EXTENDED ABSTRACT FOR DTA2018

COVER PAGE

**DAY-TO-DAY MULTIMODAL DYNAMIC TRAFFIC ASSIGNMENT: IMPACTS OF THE
LEARNING PROCESS IN CASE OF NON-UNIQUE SOLUTIONS**

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Keywords: Day-to-day, dynamic traffic assignment, Unicity analysis, trip-based, multimodal

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DAY-TO-DAY MULTIMODAL DYNAMIC TRAFFIC ASSIGNMENT: IMPACTS OF THE LEARNING PROCESS IN CASE OF NON-UNIQUE SOLUTIONS

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1. INTRODUCTION

Unicity of the solution is an important character of the Dynamic Traffic Assignment (DTA) problem. Beckman *et al.* (1956) indicate the importance of unicity and stability of the solution. The conditions of unicity have been properly reviewed by Iryo (2013) for flow-based DTA by considering the different approach to solving the DTA problem. Moreover, many researches have been done to prove the unicity of DTA solutions on flow-based dynamic traffic model with several assumptions and limitations on traffic network model (Mounce, 2007; Mounce and Smith, 2007; Iryo 2011; Iryo 2015; Iryo and Smith, 2017). This study adapts the conditions to trip-based DTA wherein each traveler is defined as an individual. A key characteristic for unicity is strictly monotone path travel time function with respect to the number of travelers that use the path. There is no guaranty to hold the monotonicity condition in the multimodal urban transportation network (Mounce, 2001). This study aims to investigate the end result of the evolution of a transportation system over a long-term day to day learning process. Mathematically speaking, we are going to address the impact of initial solutions in the day-to-day multimodal DTA.

The goal is first, to prove the non-unicity of the problem with theory and experiments and then analyze the impact of initialization on solving process of trip-based day-to-day DTA problems. In this work, we consider a trip-based multi-modal approach to network equilibrium. We assume that mode and path choice are carried out at the same level, therefore travel time (TT) depends on travel path and the mode(s) attributes of travelers. Travelers in the traffic network attempt to minimize their own TT. Therefore, the solution of assignment problem based on Wardrop's first principle (Wardrop, 1952) is called User Equilibrium (UE). If travelers have an indifference bound for minimization, the solution will be Bounded Rational User Equilibrium (BRUE) (Di and Liu, 2016). In order to find the equilibrium, this study considers a day-to-day optimization process wherein the assignment pattern is changed day by day in order to find UE or BRUE. Smith and Wisten (1995) show that under UE conditions there is an equilibrium state of this dynamical procedure. This work considers a large-scale network with fixed demand but flexible opening over time of several public transport facilities and attempts to find deterministic equilibria by simulation-based optimization.

The learning curve of travelers plays a big role in day-to-day DTA to guide the optimization process to find a stable equilibrium. Learning curve defines as a guide to determine the direction of changing the status of the network to find the equilibrium (Peeta and Ziliaskopoulos, 2001). It contains the predictive TT (by dynamic traffic model) and perceived TT (by simulator) based on the topology of the network and available modes for users. It helps the user to select the path for the next day by the experiments of traveling in following day (Smith *et al.* 2014). This study explores the impact of the user learning curve on the unicity of user network equilibrium when the new transportation facility is added to the network. Normally for BRUE, we will have the non-unicity of solutions in each scenario with mono-class users because of the initial conditions (BRUE setting) but for UE we will investigate the equilibrium for both cases mono and multi-class travelers in a multimodal network. For non-unicity of UE, the most likely situation is when we have heterogeneous travel behaviors, e.g. distributed values of time. Because generally multi-class network equilibrium is expressed as a nonmonotone problem (Marcotte and

Wynter, 2004). In order to analyze the impact of nonunicity, we are going to work on learning process when the facilities are introduced in the different order during the day-to-day process.

2. PROBLEM STATEMENT

Multi-modality permits travelers to use different transportation facilities. Urban public transportation facilities are costly to create and have impacts on traffic network equilibrium. Opening the new metro line or closing some metro stations for maintenance are some examples of changing equilibrium in the network. These events change the access of travelers to some transportation modes. In other words, the path set is changed for several origin-destination (OD) pairs. In case of maintenance process, the transportation network comes back to the initial situation. The question is, do we have the same equilibrium as before? For the second case, if we want to add three metro lines, do we have a same equilibrium with a different order for opening metro lines? Here, we want to answer this question by a numerical experiment on the large-scale network. We are looking for the impact of the opening frequency of three metro lines on unicity of UE and BRUE. We can open three metro lines at the same time and calculate the equilibrium or successively open one metro line every 100 days and look for equilibrium in the day-to-day process. In optimization point of view, it means we change the initial assignment pattern to find the equilibrium. This study is going to be mostly based on simulation but we are currently investigating also if we can derive the same pattern from analytical derivation. There are four main questions that we are going to figure out in this study:

- Is the network UE/BRUE unique when we have different scenarios for opening the metro lines (different initial point) with homogenous users?
- Do we have unicity in case of UE conditions and multi-class users?
 - we are also investigating analytical derivation to find UE.
- The practical question would be also if there is no unicity, which order has the minimum total travel time? Are we precise enough when we predict total travel time by simulator?

3. NUMERICAL EXPERIMENTS

In this work, we use Symuvia as a trip-based simulator for calculating the needed variables in the network. Symuvia has been developed by the LICIT laboratory in IFSTTAR. It is a microscopic simulator based on the Lagrangian resolution of the LWR model (Leclercq *et al.*, 2007). The day-to-day DTA is applied to the large-scale network of Lyon 6e + Villeurbanne with 1,883 Nodes, 3,383 Links, 94 Origins, 227 Destinations and 54,190 trips. Walking, buses and private cars are the initial available transportation modes in the network. There are three metro lines (A, B and C) and 25 metro stations in the network (figure 1).

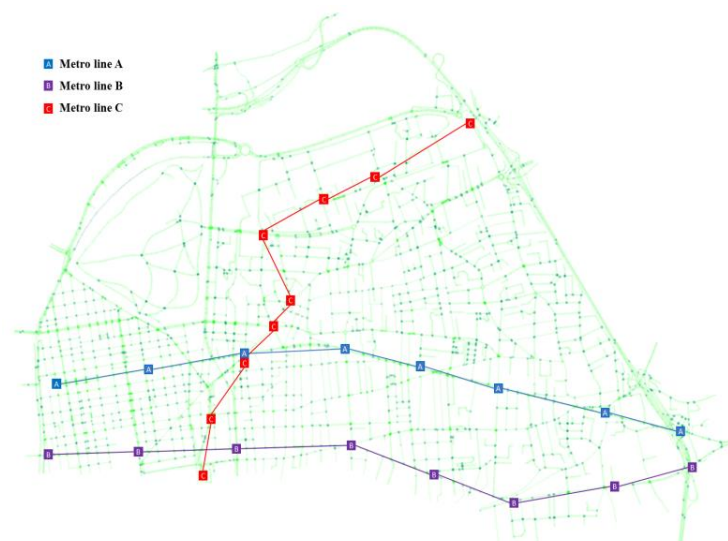


Figure 1. Lyon 6e + Villeurbanne

Each metro station has a parking. Parkings are the connector between the metro grid and traffic network. Therefore, the traveler can start their trip with the private car then use the parking to take the train. All mode changes during the trip have a walking time for connection and possibly a waiting time for the next bus or metro to arrive to the station. There are 7 scenarios to activate the metro lines: open 3 metro lines in the same time and 6 scenarios to open metro lines with the different order (figure 2). For each scenario, we run the day-to-day DTA for 300 days to represent the peak one and half an hour of the network. The experiments are designed for 3 phases. Each phase executes the simulation for 100 days to find the equilibrium (table 1). In the primary results, we allow all travelers to choose between a private car and public transportation and we converged to different UE solutions for 7 scenarios with homogenous travelers. Table 2 shows the number of travelers who use the metro lines in the UE solution for each scenario. Moreover, the total travel time is different for each scenario at the optimal solutions. The results show not only we have non-unicity but also, we can save around 150 hours on total travel time by opening the metro lines in specific order (ACB). We are going to run the same experiments for BRUE with mono-class and UE with multi-class users in order to analyze the unicity of solutions by evaluating assignment patterns, links flow and paths flow.

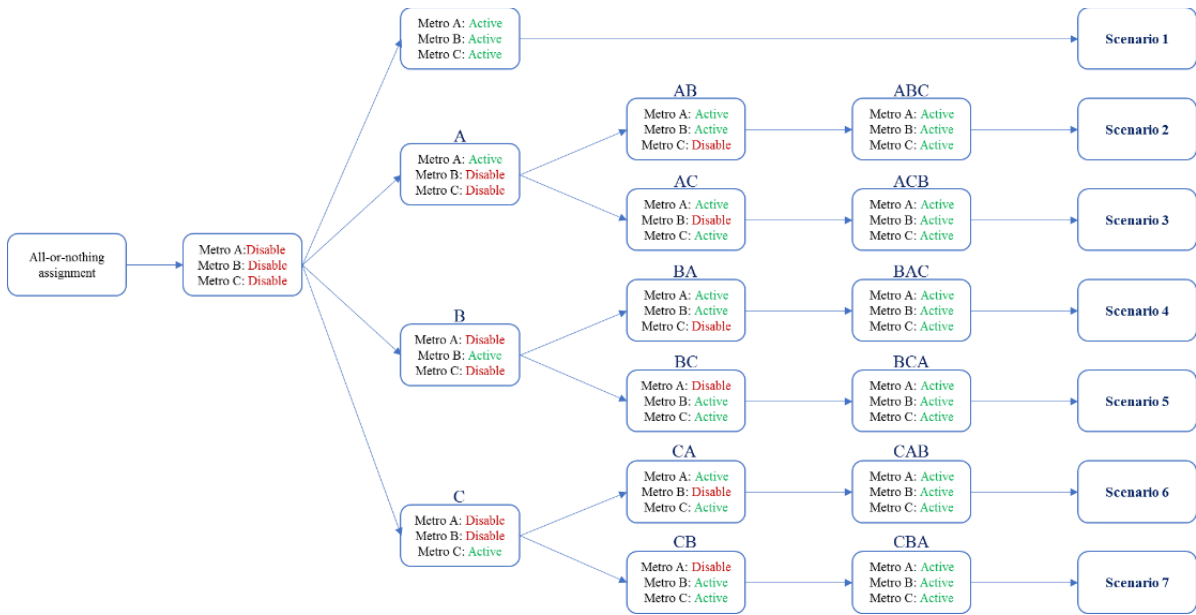


Figure 2. Chart of experiments

Table 1. Experiments description

	# active metro	Sequence	Scenario	Initial assignment pattern is obtained by (Description)	Optimal assignment path code
Phase 1 (day 0)	0	-	-	All-or-nothing assignment	P1.1
	3	A&B&C	1st Scenario	P1.1 (All metro lines are available for the users)	P1.2
	1	A	-	P1.1 (Just metro A is available)	P1.3
	1	B	-	P1.1 (Just metro B is available)	P1.4
	1	C	-	P1.1 (Just metro C is available)	P1.5
Phase 2 (day 100)	2	AB	-	Phase 1 simulation code P1.3	P2.1
	2	AC	-	Phase 1 simulation code P1.3	P2.2
	2	BA	-	Phase 1 simulation code P1.4	P2.3
	2	BC	-	Phase 1 simulation code P1.4	P2.4
	2	CA	-	Phase 1 simulation code P1.5	P2.5
	2	CB	-	Phase 1 simulation code P1.5	P2.6
Phase 3 (day 200)	3	ABC	2nd Scenario	Phase 2 simulation code P2.1	P3.1
	3	ACB	3rd Scenario	Phase 2 simulation code P2.2	P3.2
	3	BAC	4th Scenario	Phase 2 simulation code P2.3	P3.3
	3	BCA	5th Scenario	Phase 2 simulation code P2.4	P3.4
	3	CAB	6th Scenario	Phase 2 simulation code P2.5	P3.5
	3	CBA	7th Scenario	Phase 2 simulation code P2.6	P3.6

Table 2. Primary results

Scenario	Sequence	Number of users used Metro line			Total travel time (hour)
		A	B	C	
1	A&B&C	480	138	9	6723.64
2	ABC	844	282	6	6821.81
3	ACB	590	132	15	6574.00
4	BAC	560	210	84	6969.03
5	BCA	391	225	27	6761.89
6	CAB	697	168	15	6729.28
7	CBA	633	360	9	6798.39

4. ACKNOWLEDGEMENT

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