

Exam - Public Transport Modelling

MSc (M-CEM)

Faculty of Engineering Technology

Module/course code: 201800070

Date: 8 April 2019

Time: 3 hours (180 minutes) (+25% = 45 minutes for students who may use extra time)

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Questions	Points
Question 1 (a:7, b:2, c:2, d:11, e:6)	28
Question 2 (a:4, b:4, c:5)	13
Question 3 (a:9, b:3)	12
Question 4 (a:8, b:3, c:3, d:5)	19
Question 5 (a:8, b:5)	13
Question 6 (a:4, b:5, c:3, d:3)	15
Total	100

The exam consists of 6 questions. The points are listed in the table above.

Good luck.

dr. ir. Konstantinos Gkiotsalitis

Question 1 [Networks and Strategic Planning] (28 points)

Consider the following network of links and nodes in an urban area:

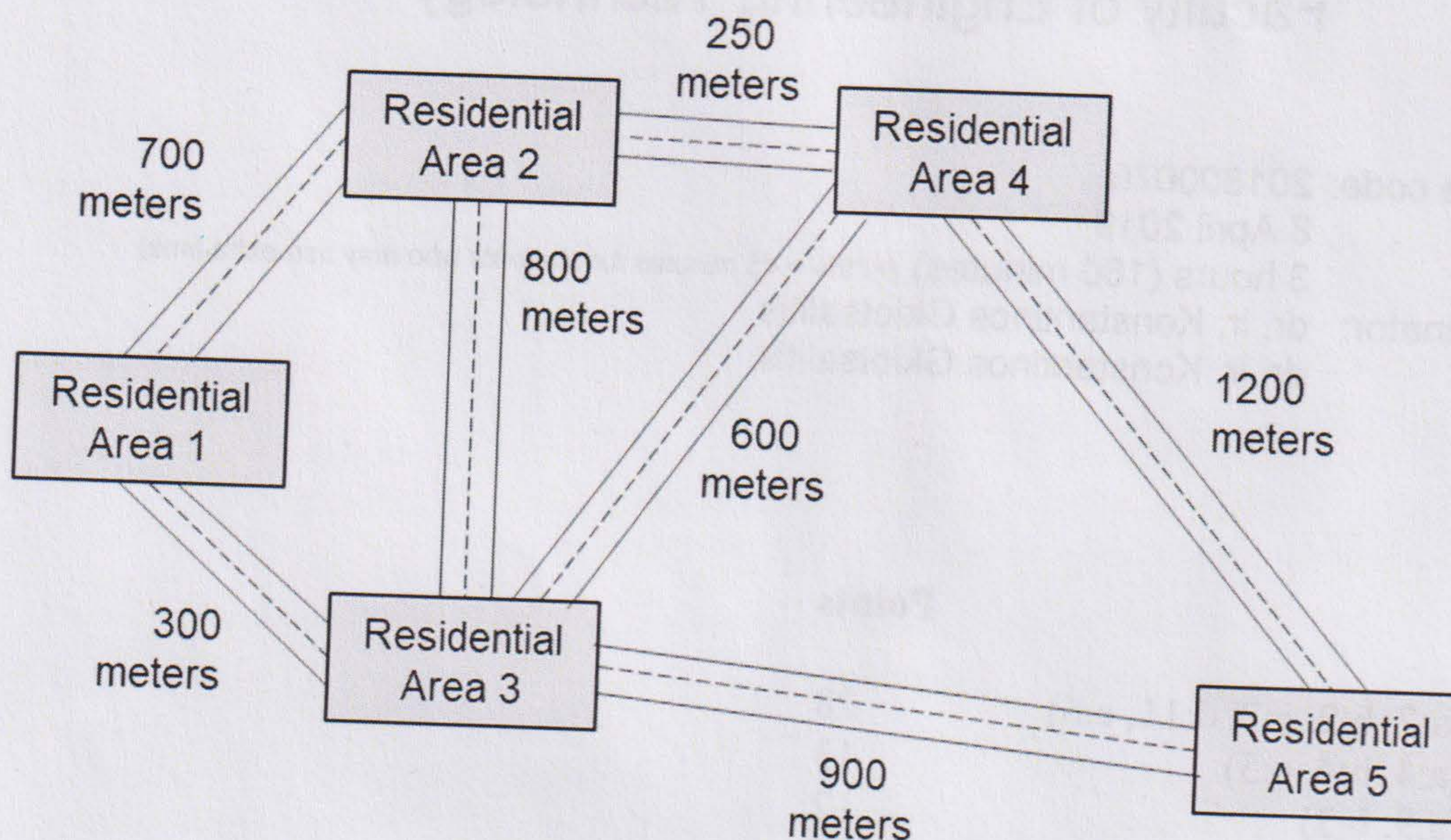


Figure 1. Network of links and nodes.

- a) Suppose that each residential area is a node of the network. What is the diameter, connectivity (gamma index), and complexity of the network? [7 points]

Suppose now that you need to select the locations of public transit stops that are allowed to be placed at any network node (residential area), except residential area 3 which has very low passenger demand.

The requirements are that no passenger is farther away from a stop than a pre-selected, critical distance, $L_{critical}$, and the number of stops is as small as possible. The demand is assumed to be generated at the nodes (residential areas).

- b) For which critical distance is the problem infeasible? [2 points]
 c) How many decision variables has your problem? [2 points]
 d) Formulate the problem as a mathematical model (program) that can be solved to optimality. [Tip: Use sets, parameters, decision variables, constraints and an objective function] [11 points]
 e) Determine whether your objective function is convex with a suitable test. [6 points]

Name: _____

St. nr: _____

Question 2 [Frequency Settings] (13 points)

The average observed hourly passenger load of a tram line is presented in the table below. The capacity of each vehicle is $c = 90$ passengers and the desired load factor at each time period j is $\gamma_j = 5/9$.

Stop no	Distance (km) to next stop	Average observed load (passengers), by hour			
		6:00-7:00	7:00-8:00	8:00-9:00	9:00-10:00
1	2	70	140	290	280
2	2	90	500	360	320
3	2.5	290	470	470	190
4	3	180	380	340	210
5	2.5	60	270	320	290

Table 2. Average observed load (passengers) by hour, after departing from each stop

- Compute the optimal frequency and headway at each hourly time period using the Maximum Load Point method. [4 points]
- Compute the empty space-km at the time period 08:00-09:00 when we implement the frequency of the Maximum Load Point method. [4 points]
- Compute the optimal frequency and headway at each hourly time period using the Load Profile method. [5 points]

Question 3 [Timetabling and Vehicle Scheduling] (12 points)

Assuming uniform passenger arrival rates and the *preliminary* departure times provided at table 3:

- derive the departure times of trips using the Even Load method. Note that the capacity of each vehicle is $c = 90$ passengers, the load factor γ_j is $5/9$ from 6:00-7:00 and $6/9$ from 7:00-8:00, and the desired load at the maximum load point is $c \cdot \gamma_j$. [9 points]
- determine the required number of vehicles to operate the service derived by sub-question (d) if all trips operate a circular service with a round-trip travel time of 30 minutes [Tip: use the graphical method] [3 points]

Time period	Departure time	Average load (passengers) at the maximum load point
6:00-7:00	6:00*	-
	6:15	28
	6:50	75
7:00-8:00	7:15	90
	7:30	37
	7:50	50
* the first trip is pre-determined		

Table 3. Average load (passengers) at the maximum load point

Question 4 [Rescheduling] (19 points)

Consider the circular bus line with a currently running bus trip, noted as trip 0, in the following figure.

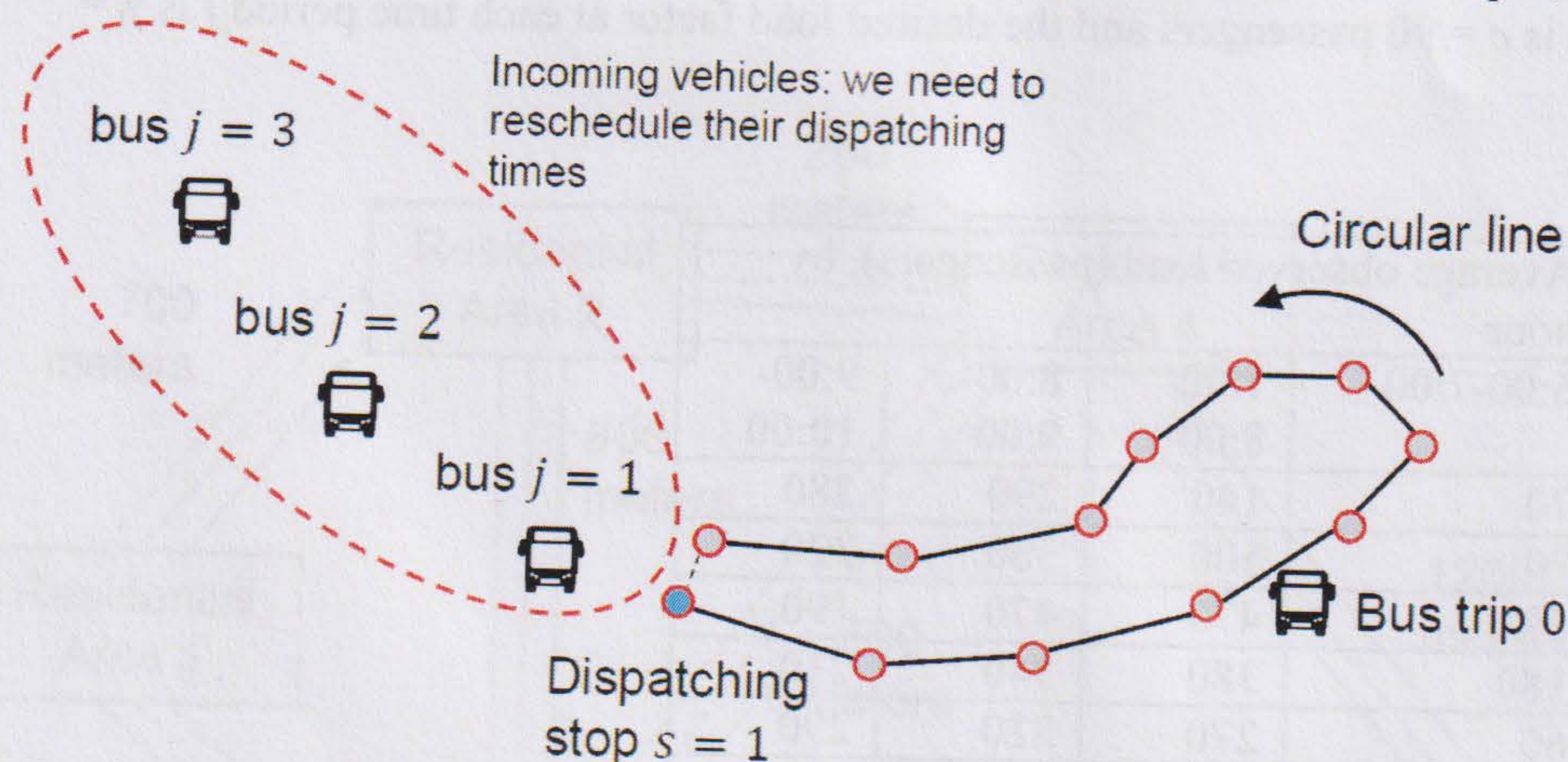


Figure 2. Snapshot of the current condition of the bus operations in the circular line.

You are asked to devise a mathematical program to reschedule the dispatching times of the incoming vehicles $j=1,2,3,\dots$ in the above figure. For this, you can shift the originally planned dispatching time, δ_j , of any trip, j , by a time interval x_j . Your objective is to minimize the deviation of the actual headways from their ideal (target) values, H_{js} , at all stops (except the first stop and the last one).

Note that the rescheduled *dispatching* times of incoming adjacent trips should satisfy the headway guidelines from the transit agency (noted as $H_{\min}$, $H_{\max}$) and each trip j has an earliest possible dispatching time d_j . You can use the following notation and expand based on it.

Sets / Parameters

j : bus trip index, where $j \in J$ and $J = \{1,2,\dots\}$ is the ordered set of incoming bus trips

s : bus stop index, where $s \in \{1,2,\dots,|S|\}$

$H_{\min}$, $H_{\max}$: Minimum and maximum *dispatching* headways of the incoming adjacent trips (agency's requirements)

δ_j : *originally planned* dispatching time of each trip j

H_{js} : ideal (target) headway between trips j and $j-1$ at stop s . Note that we seek to minimize the deviation of the actual headway from the ideal (target) headway at all stops, except the first stop and the last one.

d_j : earliest possible dispatching time of each trip j

t_{js} : interstation travel time of trip j from stop s to stop $s+1$

k_{js} : expected dwell time of trip j at stop $s \in \{2,3,\dots,|S|\}$

$\bar{a}_{0s}$: observed arrival times of trip 0 at stops $s \in \{2,3,\dots,|S|\}$

Table 4. Basic Notation

- Model the decision variables and the variables of your problem [8 points]
- Model your objective function [3 points]
- Model your constraints [3 points]
- Using the replies of (a)-(b)-(c), formulate a mathematical program that can be solved to optimality [5 points]

Name: _____
St. nr: _____

Question 5 [Holding] (13 points)

A train serves a sequence of stations. At a particular station, it has a *scheduled* departure time d . During its actual operations, the earliest possible departure time of the train from that station after finishing its boardings/alightings is $\tilde{d}$.

The train operator is allowed to hold the train at that station for x seconds beyond its earliest possible departure time, $\tilde{d}$.

The train is held with the intention to *minimize* the *squared time difference* of its actual departure time, $\tilde{d} + x$, from its scheduled departure time, d . At the same time, the train cannot be held at the station by more than t seconds due to the inconvenience caused to on-board passengers.

- Devise a minimization problem that can compute the optimal holding time x at that station. [8 points]
- Suppose that the constraint of holding the train by less than t seconds is ignored. Considering the *Necessary Condition of Unconstrained Optimization*, what is the solution of your mathematical program with respect to the $d, \tilde{d}$ values? [5 points]

Question 6 [MaaS and Feeder modes] (15 points)

As an external advisor you are asked to advise the Province (X) on MaaS. In their role as PT-authority they are starting with plans for a tender for granting a new PT concession. This concession consists mostly of rural areas, with one bigger city (Y) of 350.000 people. Their aim is that more people should use Public Transport because of the increase in congestion and they also want people to use an alternative, more healthier way of making trips. The Province is unsure how to integrate MaaS in this tender.

- Name and explain five levels of integration for MaaS [4 points].
- Describe three different scenarios in how the role of the Province should be regarding MaaS and the new concession. Give good arguments for each of the scenario's in pros and cons [5 points].
- Advise which scenario is recommended in your view, regarding the new concession. Name good reasons [3 points].
- There is also an initiative from a private company to introduce Electric Scooters in Y. This company wants to talk with the Province about this introduction. Advise the Province on how to deal with this company and the steps to be taken, regarding your recommended scenario. Bear in mind that these scooters from this company are recently allowed on public roads [3 points].