MINOA Research Challenge: Problem Description – Junior

M.A.I.O.R. srl, University of Pisa

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Contents

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1 Introduction

M.A.I.O.R. (Management Artificial Intelligence and Operations Research) designs and develops advanced software solutions for service planning, vehicles and crew scheduling, and company performance analysis in several transportation industries. Its solutions help bus and rail transit providers, airline companies, air traffic controllers, and seaport agencies to optimally plan their services and manage their day-to-day operations in order to significantly reduce costs and increase customer satisfaction while respecting complex technical and regulatory constraints. With 30 years of experience, M.A.I.O.R. is a global leading company with over 100 customers in Asia, Europe, and North America, among which 8 of the 10 largest Italian cities.

Planning a public transportation system is a complex process, which has traditionally been broken down in several phases, performed in sequence. Most often, the trips required to cover a service (Time Tabling—TT) with the desired frequency (headway) are decided early on, while the vehicles needed to cover these trips (Vehicle Scheduling—VS) are determined at a later stage. This potentially leads to requiring a larger number of vehicles (and, therefore, drivers) than would be possible if the two decisions were performed simultaneously.

Reducing the number of circulating vehicles not only brings clear economic benefits to the transportation company, but it also contributes to reduce CO_2 and other harmful emissions.

A further element of interest for LPT companies after the COVID-19 outbreak is the increased alert to local epidemiological situations. Restrictive measures applied by the government can cause sudden variations of flow of passengers, while social distancing dispositions can produce a variation in vehicles capability. It is therefore even more essential than ever for LPT companies to be able to plan different services according to the possible different scenarios and quickly compute contingency plans to respond to unforeseeable events.

In light of the above, we propose a challenge for the implementation of algorithms for the solution of an Integrated Timetabling and Vehicle Scheduling (ITTVS) problem with a fleet of traditional Internal Combustion Engine (ICE) vehicles. A relevant characteristic of the problem is that it requires a non-periodic planning in which both travel times and required frequencies/headways significantly vary along the time horizon.

2 Description of the problem

This section describes the ITTVS problem in detail.

The main input to the integrated TT-VS problem is a *public transportation network* (PTN). In general, a PTN is given in the form of a graph, where the nodes correspond to bus stops or depots, and the links correspond to direct bus transits. Upon the given PTN, a *planned service* is specified by means of a given set L of *lines*. A line $l \in L$ is a bi-directional path AB in the PTN between two terminals A_l and B_l (i.e., start/end stops of a line). A line l has two *directions*, called in-bound and out-bound and denoted by $D_l = \{\overrightarrow{A_lB_l}, \overrightarrow{B_lA_l}\}$, respectively. We denote by $D = \cup_{l \in L} D_l$ the set of all directions, and, similarly, by $N = \cup_{l \in L}\{A_l, B_l\}$ the set of all terminals of the involved lines. For each direction, a *main stop* is identified, represented by a clock in Figure 1. The regularity of the service is measured by means of the *headways*, i.e., the interval of time between two consecutive vehicles (performing trips of that line) passing by the main stop. Although the figure may suggest that the main stop needs be the same for the two directions of a line, this is not necessarily true (especially since the stops along the two directions could be disjoint). The choice of the main stop can vary, depending on the structure of the line; usually it is a "busy" point of the line, with high passenger demand, for which the planners are interested to monitor service frequency. It may coincide with one of the terminals if it is a relevant location of the line (e.g., a railway node). For each line, for each direction of the line, and for each of the time windows in which the time horizon is subdivided, the *maximum headway* is given; this basically defines the required level of customer service on the direction (in that time window) as it is the inverse of the *minimum frequency* with which buses show up at the main stop. The lines are independent in terms of the maximum headways, i.e., their Time Tabling (TT) requirements, but are linked by the fact of being served by a unique pool of vehicles, i.e., by the Vehicle Scheduling (VS) requirements.

Together with the PTN, the set T of potential *trips* is specified in the input data. Each trip $i \in T$ corresponds to an uniquely identified direction $d(i)$ in a line l in the PTN, and is therefore characterized by a start and end terminal (those of $d(i)$), in the following denoted for convenience respectively by $sn(i)$ and $en(i)$, with the corresponding departure time (from $sn(i)$) and arrival time (at $en(i)$) being denoted by $st(i)$ and $et(i)$, respectively. Also, the length $l(i)$ of the trip (in km) is given. Since each trip belongs to a given direction of a line, we define $T = \{ T_d \}_{d \in D}$ as the "direction partition" of T. Note that all trips in T_d share the same length, but *not* the same duration. Indeed, the main rationale for the non-periodic setting of our ITTVS problem, as opposed to the periodic setting prevalent in the timetabling literature, is precisely that trips times on the same line at different times of the day (and even within the same time window) can be significantly different, e.g. due to congestion during rush hours. It is also important to remark that *not every trip* in T has to be operated by some vehicle, and in fact the aim of the ITTVS problem is precisely to select which of the potential trips need to be selected.

For VS purposes it is necessary to consider in the PTN, besides the terminal nodes A and B, also the single depot node O (but not any other intermediate stop of the line).

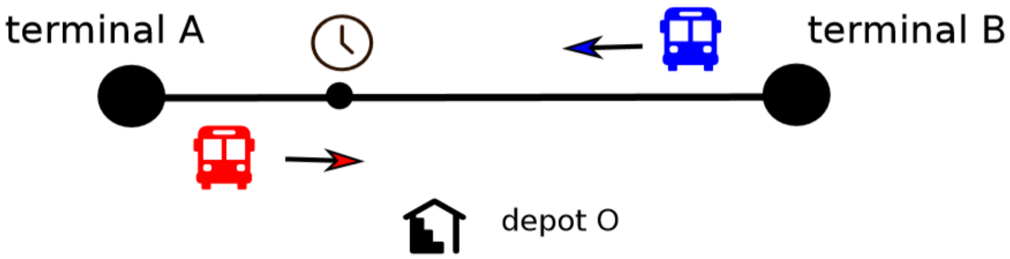


Figure 1: A line.

In the following, we will denote by $N^+ = N \cup \{ O \}$ the set of all nodes in the PTN relevant for our problem.

3 Constraints

3.1 TT Constraint

In our non-periodic planning, the *time horizon* H is given; say 5:00—27:00, i.e., each day is treated independently and with 27:00 we refer to 3:00 AM of the next day. Any time-related quantity is expressed as an integer, measuring seconds (hence, typically ≤ 97200). For each trip $i \in T$, besides the above-mentioned arrival times at the terminals, also the arrival time $a(i)$ at the main stop of $d(i)$ is known. Although we have different types of vehicle, we assume that the arrival times of all trips are independent from the type of vehicle chosen to perform them.

A *timetable* π_d for a direction $d \in D$ is a subset of its potential input trips T_d; a timetable is then just the union of $|D|$ (independent) timetables, one for each direction of each line, i.e.,

$\pi = \cup_{d \in D} \pi_d$. In order to measure the regularity of a timetable we have to consider the pairs of consecutive trips; thus, we denote by $P(\pi_d)$ the set of all consecutive pairs of trips in π_d. Given a trip i, its consecutive trip j is the one in π_d passing by the main stop at the closest point in time after $a(i)$ (if any), i.e., such that $a(j) \geq a(i)$ and $a(j) - a(i)$ is minimal. For any $(i, j) \in P(\pi_d)$, we define the (actual) *headway* of the pair as the amount of time separating their passing by the main stop, i.e., $w_{ij} = a(j) - a(i)$.

As the *desired frequency* of service typically varies along the day, H is partitioned into k *time windows* defined by $k + 1$ time instants $t_0, \ldots, t_k$, where t_0 and t_k are the initial and final time instants of H. For each time window h and each direction $d \in D$, we are given the *maximum headways* $I^h_{d,\max}$. For each trip i, we will denote by $h(i)$ the time window in which $a(i)$ is (note that the time window is $(\, t_{h(i)-1}\, ,\, t_{h(i)}\,]$, i.e., $h(i)$ is the index of the ending instant and the starting instant do not belong to the window). Given a pair $(i, j) \in P(\pi_d)$, if both trips pass by the main stop within the same time window, i.e., $h(i) = h(j) = h$, then the *maximum headway for the pair* are simply defined as $I_{ij,\max} = I^h_{d,\max}$. Only minor changes are required to account for "border effects" when $a(j)$ and $a(i)$ fall in two consecutive time windows, i.e., $h(j) = h(i) + 1$ (we assume that feasible pairs of consecutive trips can never be so far away in time as to fall in non-adjacent time windows). We take

$$I_{ij,\max} = \max \left\{ I^{h(i)}_{d,\max}\, ,\, I^{h(j)}_{d,\max} \right\} \ .$$

With the above definitions, a *feasible timetable* $\pi_d \subset T_d$ for a direction $d \in D$ is a set of trips that satisfy all the minimum and maximum headway constraints, that is, such that $w_{ij} \leq I_{ij,\max}$ for each pair $(i, j) \in P(\pi_d)$. Furthermore, the first and the last trip of π_d have to belong to given subsets T^{ini}_d and T^{fin}_d of initial and final trips, specified as an input of the problem.

3.2 VS Constraint

Besides performing trips in T, vehicles can move in the PTN without passengers on board, which is called a *deadhead trip*. In particular, a vehicle leaving a depot to reach the start-terminal of a trip is said to be performing a pull-out trip; similarly, it performs a pull-in trip when it returns to the depot from the end-terminal of a trip.

For each node $n \in N^+$ and for each time window h we are given a *minimum and maximum stopping time*, denoted by $\delta^h_{n,\min}$ and $\delta^h_{n,\max}$, respectively; however, we assume that there is no maximum stopping time at the depot, i.e., $\delta^h_{O,\max} = \infty$ for all h. The period during which a vehicle is stationary at a node is defined as a *break*. We distinguish between stopping-time and breaking-time: the former is the duration of a break, while the latter is the portion of stopping-time considered in the VS objective function (see item 2 in Section 4 for details). If a break falls in two or more consecutive time windows, its minimum and maximum stopping time are these of the first time window (arrival at the node). Note that we do not consider stopping times for any intermediate node of a line.

For each terminal $n \in N$ and for each time window h, we are also given the *travel time* for a pull-in and pull-out trip, denoted by t^h_{n+} and t^h_{n-}, respectively, as well of the corresponding lengths l_{n+} and l_{n-}. Note that, as for trips, the lengths do not depend on the time of the day; travel times do, but, unlike for trips, the time is supposed to be constant at least inside the same time window. The travel time of a deadhead is that of the time window that contains the instant (indicated as "terminal-time") in which the vehicle is at the terminal n, i.e., the initial instant in the case of pull-in and the final instant in the case of pull-out. We add that if the terminal-time of deadhead is before the beginning of the first time window or is after the end of the last time window, the travel time of that deadhead is respectively the travel time of the first or last time window.

Two trips $i, j \in T$ (not necessarily belonging to the same line) are said to be *compatible* if they can be performed consecutively by the same vehicle. This immediately implies $st(j) \geq et(i)$, i.e., trip j has to start after that trip i has finished. We distinguish two types of compatibility:

- *in-line compatibility* means that:
  1. $en(i) = sn(j)$, i.e., the trip starts at the same terminal in which it ends;
  2. $\delta^{h(i)}_{en(i),\min} \leq st(j) - et(i) \leq \delta^{h(i)}_{en(i),\max}$, i.e., the stopping time at the terminal between the end of trip i and the start of trip j is feasible;
- *out-line compatibility* means that:
  1. $en(i) \neq sn(j)$;
  2. $st(j) - et(i) \geq t^{h(i)}_{en(i)+} + \delta^{h(i)}_{O^+,\min} + t^{h(j)}_{sn(j)-}$;

  in other words, there must be enough time between the end of trip i and the start of trip j to perform a pull-in trip from $en(i)$, wait the minimum amount of time at the depot, and then perform a pull-out trip towards $sn(j)$. Note that it is not allowed to stop (with stopping time >0) at terminals between a trip and a pull in/out trip. Note that pull-in and pull-out (deadhead) trips are not included in T, as they are not (passenger) service trips (i.e., no passengers on board).

In our problem, if $en(i) \neq sn(j)$, the vehicle cannot move directly from one terminal to the other, but it must necessarily perform an out-line compatibility. In other words, we only allow deadhead trips that start or end at the depot (i.e., pull-in/pull-out trips).

3.2.1 Feasible vehicle schedule

A *feasible vehicle block* is the workplan for a vehicle for a whole day, composed of an initial pull-out trip, a sequence of (compatible) trips in T, possibly separated by breaks or pull-in/out trips, and a final pull-in trip to return to the depot, with all the activities satisfying the corresponding constraints. A *feasible vehicle schedule* Ω is a subset of the input potential trips T that can be partitioned in feasible vehicle blocks. Each of the vehicle blocks in the vehicle schedule must be annotated with the type of the vehicle performing it The number of vehicle available for each type of vehicle is unbounded.

3.3 Linking constraint

The constraint linking the TT and VS part of the problem is simply that each trip in the TT must be performed by exactly one vehicle. In other words, the set of trips in the feasible timetable and in the feasible vehicle schedule must coincide.

4 Objective function

The objective of our integrated problem is to provide a solution that minimize the service provider cost. Since one of the main costs for the service provider is usually the number of vehicles used weighted with the type of vehicle used, the primary VS objective is the minimization of the number of vehicle blocks. Secondary metrics for the service provider cost consist in

the time spent by the vehicles waiting at the terminals in excess to the minimum waiting time and recharge time (for drivers will typically have to man them even when stationary, thus increasing labour cost), the time spent by the vehicles performing pull-in and pull-out trips (for the same reason as above, plus the fact that vehicles typically consume some fuel), and the driving time to consider CO_2 emissions from vehicles in service.
With B denoting the set of vehicle blocks, for each $b \in B$ the following quantities are defined:

1. a fixed cost c_v for using the vehicle (depending on the type $v \in V$), irrespectively on how much time it is used and how many times it re-enters and leaves the deposit during the block;
2. a break cost, proportional to the break time t_b^{break} spent at the nodes of the block (which does not include the minimum stopping-times) by a coefficient c^{break};
3. pull-in/pull-out costs, proportional to sum of the pull-in and pull-out times t_b^{pi} and t_b^{po} by a coefficient c_v^{pio} (also depending on the type of vehicle);
4. a cost for CO_2 emissions produced, proportional to the total driving time $d(b)$ by a coefficient c_v^{CO2} depending on the type of the vehicle.

All in all, the objective function is obtained as

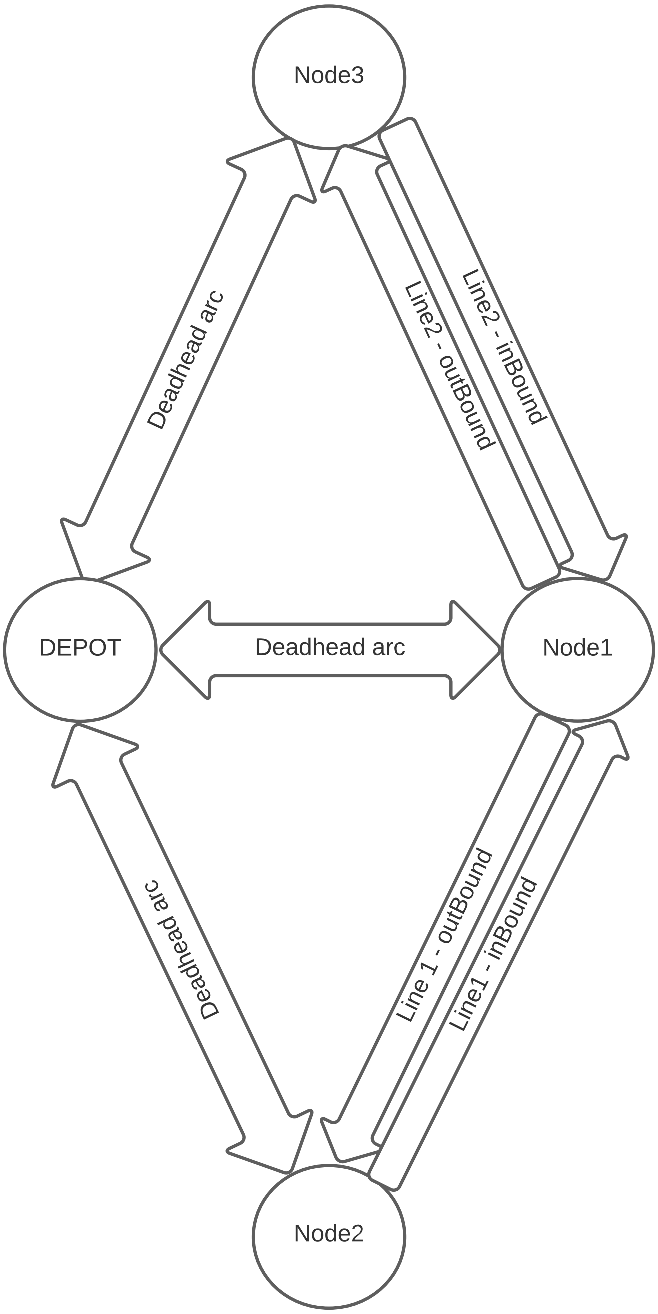
$$c = \sum_{b \in B} \left(c_v + c^{break} t_b^{break} + c_v^{pio} (t_b^{pi} + t_b^{po}) + c_v^{CO2} d(b) \right) \ .$$

5 Solution

The solution must specify the subset $T_S \subset T$ of the potential trips which represents both a feasible timetable and a feasible vehicle schedule. T_S must be explicitly partitioned into a set of feasible vehicle blocks, each annotated with the type of vehicle performing it, in such a way as to satisfy the fleet capacity constraints. A minimum-cost solution is sought for.

6 Example

In this section, we provide a graphic representation of a test case. The PTN in this case is made up of two lines and four nodes (one of which is the depot). For each line we provide the data related to the headways and an admissible solution (not necessarily optimal). The solution shows the details of the timetabling and of the activities of each vehicle block in the solution.



Nodes				
Name	node1	node2	node3	depot
break Capacity	2	1	1	1000

LineName		line1	line1	line2	line2
Direction		inbound	outBound	inbound	outBound
Time window 1	Headway	1080	1080	1080	1080
Time window 2	Headway	1820	1820	1820	1820
Time window 3	Headway	1080	1080	1080	1080

Hedway report	
Line	Line1
Direction	InBound
Start node	Node2
End node	Node1
Main stop	Node2
Time	Achieved headway
29580	780
30360	780
31140	780
31920	780
32700	780
33480	780
34200	720
34980	780
35700	720
36780	1080
38100	1320
39420	1320
40740	1320
42060	1320
43320	1260
44100	780
44880	780
45660	780
46440	780
47220	780
48000	780
48780	780
49560	780
50340	780

Hedway report	
Line	Line1
Direction	OutBound
Start node	Node1
End node	Node2
Main stop	Node2
Time	Achieved headway
29220	840
30060	840
30840	780
31620	780
32400	780
33180	780
33960	780
34740	780
35820	1080
37140	1320
38460	1320
39780	1320
41100	1320
42420	1320
43260	840
44040	780
44820	780
45600	780
46380	780
47160	780
47940	780
48720	780
49500	780

Hedway report	
Line	Line2
Direction	InBound
Start node	Node3
End node	Node1
Main stop	Node3
Time	Achieved headway
29100	840
29880	780
30660	780
31440	780
32220	780
33000	780
33780	780
34560	780
35520	960
36720	1200
37920	1200
39120	1200
40320	1200
41580	1260
42720	1140
43560	840
44400	840
45240	840
46080	840
46920	840
47760	840
48600	840
49440	840

Hedway report	
Line	Line2
Direction	OutBound
Start node	Node1
End node	Node3
Main stop	Node3
Time	Achieved headway
29940	840
30720	780
31500	780
32280	780
33060	780
33840	780
34620	780
35400	780
36420	1020
37620	1200
38820	1200
40020	1200
41220	1200
42480	1260
43560	1080
44400	840
45240	840
46080	840
46920	840
47760	840
48600	840
49440	840
50280	840

Vehicle block report				
Vehicle block			0	
Vehicle type			ICE	
Type of activity	Start node	Start time	End node	End time
pull-out:	Depot	28260	Node2	28800
trip:	Node2	28800	Node1	29760
break:	Node1	29760	Node1	29880
trip:	Node1	29880	Node3	30600
break:	Node3	30600	Node3	30720
trip:	Node3	30720	Node1	31500
break:	Node1	31500	Node1	31620
trip:	Node1	31620	Node2	32340
break:	Node2	32340	Node2	32700
trip:	Node2	32700	Node1	33660
break:	Node1	33660	Node1	33780
trip:	Node1	33780	Node3	34500
break:	Node3	34500	Node3	34620
trip:	Node3	34620	Node1	35400
break:	Node1	35400	Node1	35520
trip:	Node1	35520	Node3	36240
break:	Node3	36240	Node3	36420
trip:	Node3	36420	Node1	37200
break:	Node1	37200	Node1	37920
trip:	Node1	37920	Node3	38640
break:	Node3	38640	Node3	38820
trip:	Node3	38820	Node1	39600
break:	Node1	39600	Node1	40320
trip:	Node1	40320	Node3	41040
break:	Node3	41040	Node3	41220
trip:	Node3	41220	Node1	42000
break	Node1	42000	Node1	42420
trip:	Node1	42420	Node2	43140
break:	Node2	43140	Node2	43320
trip:	Node2	43320	Node1	44280
break:	Node1	44280	Node1	44400
trip:	Node1	44400	Node3	45120
break:	Node3	45120	Node3	45240
trip:	Node3	45240	Node1	46020
break:	Node1	46020	Node1	46380
trip:	Node1	46380	Node2	47100
break:	Node2	47100	Node2	47220
trip:	Node2	47220	Node1	48180
break:	Node1	48180	Node1	48600
trip:	Node1	48600	Node3	49320
break:	Node3	49320	Node3	49440
trip:	Node3	49440	Node1	50220
pull-in:	Node1	50220	Depot	50820

Vehicle block report				
Vehicle block		1		
Vehicle type		ICE		
Type of activity	Start node	Start time	End node	End time
pull-out	Depot	27780	Node1	28380
trip:	Node1	28380	Node2	29100
break:	Node2	29100	Node2	29580
trip:	Node2	29580	Node1	30540
break:	Node1	30540	Node1	30660
trip:	Node1	30660	Node3	31380
break:	Node3	31380	Node3	31500
trip:	Node3	31500	Node1	32280
break:	Node1	32280	Node1	32400
trip:	Node1	32400	Node2	33120
break:	Node2	33120	Node2	33480
trip:	Node2	33480	Node1	34440
break:	Node1	34440	Node1	34560
trip:	Node1	34560	Node3	35280
break:	Node3	35280	Node3	35400
trip:	Node3	35400	Node1	36180
break:	Node1	36180	Node1	37140
trip:	Node1	37140	Node2	37860
break:	Node2	37860	Node2	38100
trip:	Node2	38100	Node1	39060
break:	Node1	39060	Node1	39780
trip:	Node1	39780	Node2	40500
break:	Node2	40500	Node2	40740
trip:	Node2	40740	Node1	41700
break:	Node1	41700	Node1	42720
trip:	Node1	42720	Node3	43440
break:	Node3	43440	Node3	43560
trip:	Node3	43560	Node1	44340
break:	Node1	44340	Node1	44820
trip:	Node1	44820	Node2	45540
break:	Node2	45540	Node2	45660
trip:	Node2	45660	Node1	46620
break:	Node1	46620	Node1	46920
trip:	Node1	46920	Node3	47640
break:	Node3	47640	Node3	47760
trip:	Node3	47760	Node1	48540
break:	Node1	48540	Node1	48720
trip:	Node1	48720	Node2	49440
break:	Node2	49440	Node2	49560
trip:	Node2	49560	Node1	50520
Pull-in	Node1	50250	Depot	51120

Vehicle block report				
Vehicle block			2	
Vehicle type			ICE	
Type of activity	Start node	Start Time	End node	End time
Pull-out:	Depot	28260	Node1	29220
trip:	Node1	29220	Node2	29940
break:	Node2	29940	Node2	30360
trip:	Node2	30360	Node1	31320
break:	Node1	31320	Node1	31440
trip:	Node1	31440	Node3	32160
break:	Node3	32160	Node3	32280
trip:	Node3	32280	Node1	33060
break:	Node1	33060	Node1	33180
trip:	Node1	33180	Node2	33900
break:	Node2	33900	Node2	34200
trip:	Node2	34200	Node1	35160
break:	Node1	35160	Node1	35820
trip:	Node1	35820	Node2	36540
break:	Node2	36540	Node2	36780
trip:	Node2	36780	Node1	37740
break:	Node1	37740	Node1	38460
trip:	Node1	38460	Node2	39180
break:	Node2	39180	Node2	39420
trip:	Node2	39420	Node1	40380
break:	Node1	40380	Node1	41100
trip:	Node1	41100	Node2	41820
break:	Node2	41820	Node2	42060
trip:	Node2	42060	Node1	43020
break:	Node1	43020	Node1	43560
trip:	Node1	43560	Node3	44280
break:	Node3	44280	Node3	44400
trip:	Node3	44400	Node1	45180
break:	Node1	45180	Node1	45600
trip:	Node1	45600	Node2	46320
break:	Node2	46320	Node2	46440
trip:	Node2	46440	Node1	47400
break:	Node1	47400	Node1	47760
trip:	Node1	47760	Node3	48480
break:	Node3	48480	Node3	48600
trip:	Node3	48600	Node1	49380
break:	Node1	49380	Node1	49500
trip:	Node1	49500	Node2	50220
break:	Node2	50220	Node2	50340
trip:	Node2	50340	Node1	51300
Pull-in	Node1	51300	Depot	51900

Vehicle block report				
Vehicle block		3		
Vehicle type		ICE		
Type of activity	Start node	Start time	End node	End time
Pull-out	Depot	27660	Node1	28260
trip:	Node1	28260	Node3	28980
break:	Node3	28980	Node3	29100
trip:	Node3	29100	Node1	29880
break:	Node1	29880	Node1	30060
trip:	Node1	30060	Node2	30780
break:	Node2	30780	Node2	31140
trip:	Node2	31140	Node1	32100
break:	Node1	32100	Node1	32220
trip:	Node1	32220	Node3	32940
break:	Node3	32940	Node3	33060
trip:	Node3	33060	Node1	33840
break:	Node1	33840	Node1	33960
trip:	Node1	33960	Node2	34680
break:	Node2	34680	Node2	34980
trip:	Node2	34980	Node1	35940
break:	Node1	35940	Node1	36720
trip:	Node1	36720	Node3	37440
break:	Node3	37440	Node3	37620
trip:	Node3	37620	Node1	38400
break:	Node1	38400	Node1	39120
trip:	Node1	39120	Node3	39840
break:	Node3	39840	Node3	40020
trip:	Node3	40020	Node1	40800
break:	Node1	40800	Node1	41580
trip:	Node1	41580	Node3	42300
break:	Node3	42300	Node3	42480
trip:	Node3	42480	Node1	43260
break:	Node1	43260	Node1	44040
trip:	Node1	44040	Node2	44760
break:	Node2	44760	Node2	44880
trip:	Node2	44880	Node1	45840
break:	Node1	45840	Node1	46080
trip:	Node1	46080	Node3	46800
break:	Node3	46800	Node3	46920
trip:	Node3	46920	Node1	47700
break:	Node1	47700	Node1	47940
trip:	Node1	47940	Node2	48660
break:	Node2	48660	Node2	48780
trip:	Node2	48780	Node1	49740
Pull-in	Node1	49740	Depot	50340

Vehicle block report				
Vehicle block			4	
Vehicle type			ICE	
Type of activity	Start node	Start time	End node	End time
Pull-out:	Depot	28500	Node1	29100
trip:	Node1	29100	Node3	29820
break:	Node3	29820	Node3	29940
trip:	Node3	29940	Node1	30720
break:	Node1	30720	Node1	30840
trip:	Node1	30840	Node2	31560
break:	Node2	31560	Node2	31920
trip:	Node2	31920	Node1	32880
break:	Node1	32880	Node1	33000
trip:	Node1	33000	Node3	33720
break:	Node3	33720	Node3	33840
trip:	Node3	33840	Node1	34620
break:	Node1	34620	Node1	34740
trip:	Node1	34740	Node2	35460
break:	Node2	35460	Node2	35700
trip:	Node2	35700	Node1	36600
Pull-in	Node2	36600	Depot	37200
break:	Depot	37200	Depot	42260
Pull-out:	Depot	42260	Node2	43260
trip:	Node1	43260	Node2	43980
break:	Node2	43980	Node2	44100
trip:	Node2	44100	Node1	45060
break:	Node1	45060	Node1	45240
trip:	Node1	45240	Node3	45960
break:	Node3	45960	Node3	46080
trip:	Node3	46080	Node1	46860
break:	Node1	46860	Node1	47160
trip:	Node1	47160	Node2	47880
break:	Node2	47880	Node2	48000
trip:	Node2	48000	Node1	48960
break:	Node1	48960	Node1	49440
trip:	Node1	49440	Node3	50160
break:	Node3	50160	Node3	50280
trip:	Node3	50280	Node1	51060
Pull-in	Node1	51060	Depot	51660

7 Glossary

Headway: in transit speak headway is the amount of time between transit vehicle arrival at a stop. A route that has a vehicle once an hour have a 60 minute headway.
Line: a line is a grouping of routes that is generally known to the public by a similar name or number
Route: a route is a link sequence, defined by an ordered sequence of (two or more) points on route. A *route* may pass through the same route point more than once, as in the case of a loop.