

by Double-Click

TURNI

Optimized automatic generation of the crew
duty schedules for the staff of a public transport
company

“We sell efficiency”

Crew scheduling optimization · since 1996

Objectives and benefits

- Automatic and optimized construction of the service duties for the crews and vehicles used by a public transport company (urban, regional or mixed), by bus or rail.
 - Quality of the generated duties (average 2–8% reduction in costs).
 - Shorter time to build an entire schedule (from 30 minutes to a few hours on a PC).
 - Uniformity and feasibility of the duties (fewer internal disputes).
 - Ability to integrate urban, regional and rail services (optimal synergies).

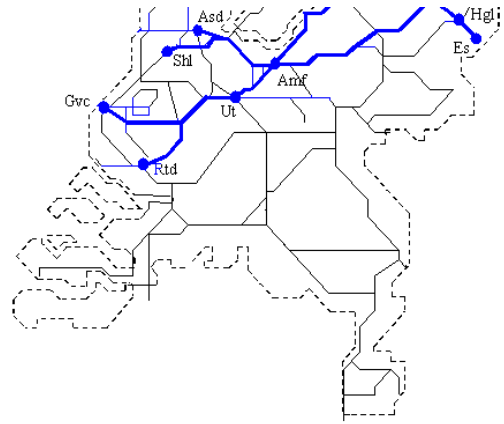


“What-if” analysis

- Fast generation of complete solutions to simulate alternative scenarios:
 - assessment of Service Level Agreements in service tenders;
 - new duty types to propose during union negotiations;
 - coverage of new trips when bidding for a procurement tender;
 - cost assessment in response to regulatory changes.
- Ability to steer the software to optimize:
 - the total number of duties used to cover all trips;
 - the average service time, and therefore overtime;
 - the spread-over (“nastro”) time;
 - the empty (dead-head) kilometres travelled by the vehicles.

Definitions

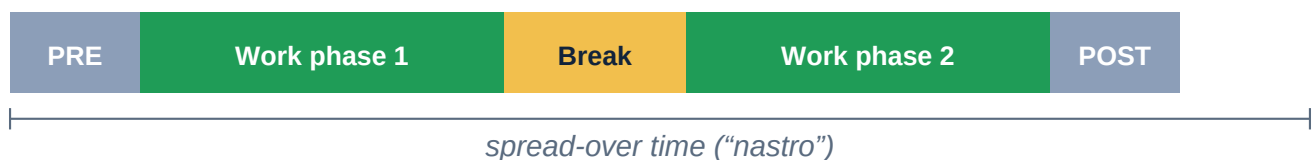
- Relief point: a location where a driver change can take place (terminus, depot, etc.).
- Trip: an indivisible unit of work between two consecutive relief points, based on the timetable.
- Duty: a sequence of trips that must be performed by the same driver, in compliance with the contractual rules.



Basic feasibility rules for duties

- Every duty must start and end at the same relief point (depot).
- Every trip must start from the arrival relief point of the previous trip, at compatible times.

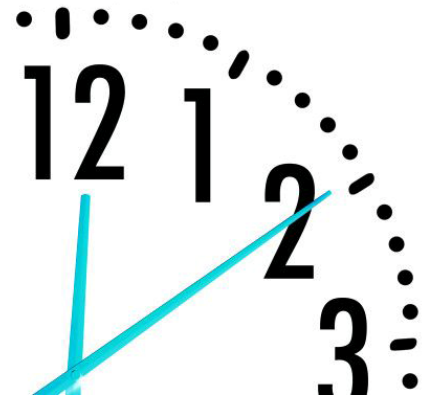
Structure of a duty



- Contractual rules on possible breaks, service duration, total driving time, etc.
- “Local” rules derived from company-level supplementary agreements.

Feasibility rules for the solution

- Maximum and average number of duties in each depot.
- Maximum percentage of long, heavy or arduous duties, ...
- Overall average of the working time paid to the drivers.
- ...



- | SOLUZIONE C: OPTIMIZATION TURN IN PRVPR SOL | | | | | | | | | | | | | | | | | | | | |
|---|--------------------------------------|-------|-------|-------|----------------|-------|----------|-------|-------------------------------------|-------|----------|-------|-----------------------|-------|-------------|-------|--------|-------|----------|--|
| | 02.00 | 03.00 | 04.00 | 05.00 | 06.00 | 07.00 | 08.00 | 09.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 | |
| 4-16 | Effic= 62% Nastro= 9:05 T.Lav= 4:50 | | | | dep vill viad | | par parm | | | | | | viad s.m | | | | | | | |
| 5-16 | | | | | | | | | Effic= 71% Nastro= 8:01 T.Lav= 7:26 | | | | dep guas viad | | mant | | viad | | par parm | |
| 6-16 | Effic= 62% Nastro= 12:35 T.Lav= 6:26 | | | | de b s.ma viad | | | | | | parm | | viad casa spin cas | | | | | | | |
| 7-16 | Effic= 69% Nastro= 12:45 T.Lav= 6:30 | | | | via casa | | | | | | viad | | parm | | viad | | p parm | | | |
| 8-16 | Effic= 70% Nastro= 12:30 T.Lav= 6:10 | | | | viad cas | | | | | | viad | | casa | | viad | | mant | | | |
| 9-16 | Effic= 67% Nastro= 9:15 T.Lav= 7:20 | | | | viad | | | | | | asl mant | | via vi viad casa spin | | c s s.a.c.a | | | | | |
| 10-16 | Effic= 68% Nastro= 9:20 T.Lav= 5:58 | | | | viad p parm | | | | | | viad | | parm | | viad vill | | | | | |
| 11-16 | Effic= 66% Nastro= 12:59 T.Lav= 7:20 | | | | depo b sabb | | | | | | parm | | viad | | | | mant | | | |

TURNI · by Double-Click

Input: stops and depots

- Definition of the network's stops / relief points and depots, entered and edited through the graphical interface (TI) as data grids.

2000	S	S	N	S	15	1	SIENA VIA TOZZI
2087	S	S	S	S	999		DUE PONTI Opp. Garag
4001	N	N	N	S	20		P.DLMINO TOSCANSTUCCHI
4003	N	N	N	S	20		LE CALDANE
4005	N	N	N	S	20		GRACCIANO OPP. N.BIXIO
4007	N	N	N	S	20	4005	V.F.LLI BANDIERA GRACCIAN
4012	S	S	N	S	200	5000	V.LE DEI MILLE
4014	N	N	N	S	20	4017	V.XXXV APRILE
4017	N	N	N	S	20		V.XXXV APRILE ESATTORA COM
4027	N	N	N	S	20		CAMPIGLIA
4034	N	N	N	S	20		P.TA NUOVA SCUOLE MEDIE
4062	N	N	N	S	20		STR. DI FONTANA
4073	N	N	N	S	20	4084	AGRESTONE V.FIRENZE N.7
4084	N	N	N	S	20		AGRESTONE V.MILANO N.
4085	S	S	N	S	6		OSPEDALE V.ELSA
4086	S	S	N	S	6	4085	OSPEDALE V.ELSA
4089	N	N	N	S	20		CALP
4113	N	N	N	S	20		STR.PROV. OPPOSTO CALP
4132	S	N	N	S	999		PIEVESCOLA
4185	N	N	N	S	20		CASTEL S.GIMIGNANO
4154	N	N	N	S	20	4003	LE CALDANE
4157	N	N	N	S	20	4001	TOSCANA STUCCHI
4204	N	N	N	S	20		PIAN DI CASOLE OP.STAB.O
4210	N	N	N	S	20		STR.CAVALLANO Stab.Floren
4243	N	N	N	S	20		BADIA ISOLA
4244	N	N	N	S	20		MONTERIGGIONI COMUNE
4245	N	N	N	S	20		CASTELNA COLO

Insertisci Elimina

Fernata 1/113

Unità Operativa Max turni lunghi Max media lavoro 6:55
Max lavoro Max media lavoro 6:55
Max nastro Max nastro non-lungo
Costo aggiuntivo T. lavoro forf. agg.

Fermate afferenti
☒ Deposito

Insertisci Elimina

43100 D. CAMPOSTAGGIA DEPOSITO

5000 N P. 22A MACZINI
5918 N CUSONA
5503 N CUSONA
5476 N FORMACELLE
5475 N FORMACELLE
4005 N GRACCIANO OPP. N.BIXIO
4347 N GRACCIANO V.NINO BIXIO
6043 N INCR. A. MORO-IL BERNINO
5979 N Incr. V.A.BORRI La Croce
5434 N L.90 GRANSCT
5465 N LAPPETO
4154 N LE CALDANE
4003 N LE CALDANE
5557 N MARCIALLA

inserito in deposito se area >= min.min
& durata allungata percorso <= HH-MM
Gestione circolare degli autobus (S/N/C)
Max n. di autobus stimati
Istante piccolo per stima bus
Massimo tempo di guida continuativa
Massimo tempo di lavoro "non" lungo
Massima sosta fuori residenza
Classe di compatibilità del gruppo
Tipi di autobus consentiti (1 caratteri)
Dimensioni consentite bus (PMGABLDEFH)
Tipi di corsa consentiti (NDVUB)

Gruppo 3/3

Stops / relief-points grid (left) and depot configuration window (right).

Input: trips

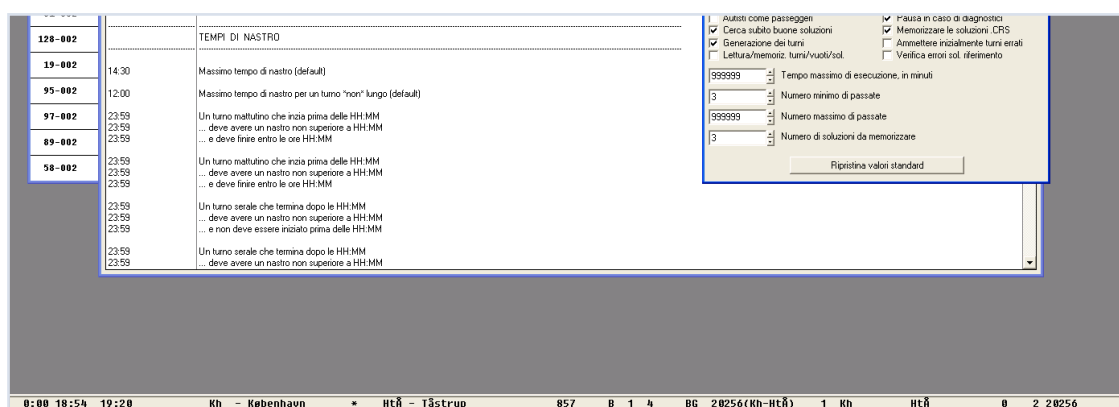
- Definition of the trips to be covered (the timetable).

The screenshot displays the TURNI software interface for defining bus trips. The main window is titled 'Corsa 3/707'. On the left, a grid lists trips with columns for trip ID, departure time, arrival time, and status. The central area contains a detailed form for trip configuration, including fields for 'Ora Fermana', 'Descrizione', 'Partenza', 'Arrivo', 'Targa', 'Lunghezza (km)', and 'Vincoli sui gruppi'. Below these are sections for 'Tipo' (Normal, Disponibile, Vuoto, Urbana, Bigliettaio, Altro), 'Copertura' (Richiesta, Permessa, Consigliata, Sconsigliata, Ignora, Altro), and 'Autobus' (Piccolo, Medio, Grande) with checkboxes for various types (A through H). At the bottom, there are buttons for 'Chiudi', 'Inserisci dopo', 'Inserisci prima', 'Elimina', and 'Cerca fermata'. The status bar at the bottom indicates 'Corsa 3/707'.

Trips input grid of the TURNI software.

Input: parameters

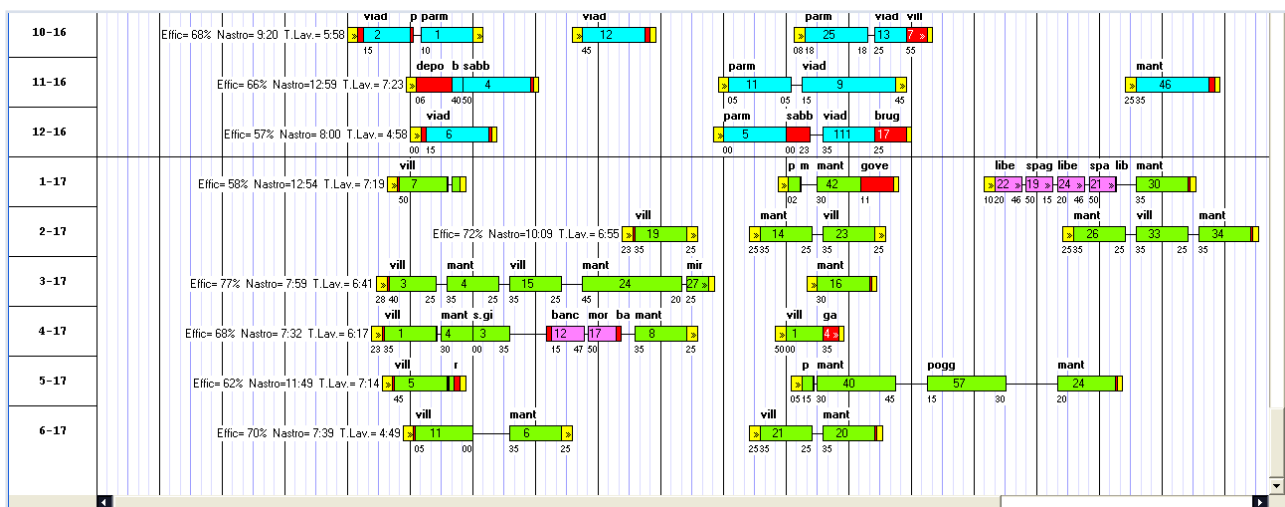
- Maximum average working time
- Maximum working time
- Maximum working time for a “non-long” duty
- Maximum spread-over time
- Maximum spread-over time for a “non-long” duty
- Maximum number of duties
- Maximum layover at the home depot
- Percentage credited for layovers at the home depot
- Standard PRE time
- Standard POST time
- Extra PRE time at duty start
- Extra POST time at duty end
- Extra working time on a lump-sum basis
- Extra working time for zero-buffer connections
- Amplification factor for the reduced allowance (Art. 21)
- ...



The optimization / parameters window in the TI interface.

Output: graphical solution

- The solution shown as a Gantt chart (duties over the day).



Gantt view: each row is a duty; blocks are trips (green), dead-heads and passenger transfers.

Output: textual solution

- The detailed textual output: for every duty, the sequence of trips with times, lines, vehicles, costs and key performance indicators.

```
--> DUTY No. 1    COST: 50670.00    Name 1-02    GROUP 2    "Mantova Extra depot"
T-WAIT DEP.  ARR.  TYPE  |- FROM -----|  |- TO -----|  LINE  BUS
      5:34  5:44  #PRE
0:00  5:50  7:45          MANTOVA - Bus stat.  BRESCIA - Bus station  340  EG
* 0:35  8:20  10:10        BRESCIA - Bus station MANTOVA - Bus stat.    340  EG
0:00  10:20  10:46  URBAN  LIBERTA' 3          SPAGNOLA              269  UG
      12:16  12:21  #POST
NASTRO=8:54  TLAV=8:00  EFFIC=74%  KM=32.9  TCON=4:01  BUS=1  DIARIA=9%
```

Legend — NASTRO: spread-over time · TLAV: working time · EFFIC: efficiency · KM: kilometres · TCON: driving time · DIARIA: daily allowance.

Italian transport companies (bus and/or rail)

- ARFEA – Alessandria
- Province of Venice (Mobility & Transport)
- APAM – Mantua
- TRENTINO TRASPORTI (ex ATESINA) – Trento (regional, urban, rail)
- ATVO – San Donà di Piave (VE)
- SAF – Udine
- SAB Group (SAB Bergamo, SIA & SAIA Brescia, SAL Lecco)
- ATAP – Biella
- APT – Gorizia
- TRA.IN – Siena
- DolomitiBus – Belluno
- LaMarca – Treviso
- SADEM – Turin
- SAPAV – Pinerolo (TO)
- ATAM – Reggio Calabria
- Autostradale – Milan
- STIE – S. Vittore Olona (MI)
- STAR – Lodi
- ATP – Carasco (GE)

International use & recognition

- The program is also used as both an operational and an analysis tool by:
 - Netherlands Railways (Department of Logistics, NS Reizigers);
 - Danish Railways (DSB and DSB S-TOG, Copenhagen).

Franz Edelman Award 2008

In 2008, applying the TURNI software to the Netherlands Railways case won the prestigious international Franz Edelman Award — the foremost international recognition for the application of Operations Research to real business problems.

Solution scheme

- An operating cost is associated with each single duty.
- A global cost is associated with each overall solution (sum of the duty costs + penalties).

SOLUTION SCHEME

- generate all the feasible duties (how many are there?);
- among the generated duties, choose those that define an overall minimum-cost solution (how to make the choice?).

Unfortunately, in its “theoretical” formulation this scheme cannot be applied in practice.

Mathematical model

- Construction of a mathematical model that effectively describes the problem and makes it possible to restrict the set of possible choices.

MINIMIZE

1448 X7 + 1312 X17 + 1319.5 X19 + 1404.5 X20 + 1363 X38
+ 1289 X39 + 1379 X84 + 1491 X87 + 1464 X88 + 1402 X89 + ...

SUBJECT TO

R1: X339 + X340 + X3626 + X3627 + X3709 + X5768 + ... ≥ 1
R4: X339 + X3463 + X3627 + X3709 + X4195 + X4841 + ... ≥ 1
...

- The MODEL is then solved automatically through advanced Operations Research techniques.