Crew Planning Tool for Mumbai Suburban Railways

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22 Mar, 2023

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4. Problem Statement
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   - Constraints
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Introduction - Mumbai Western Railways

- Western Railways uses 89 rakes to run 1355 services
- Crew Allotment - Each service requires a guard and motorman

Figure 1: Suburban Railways Map

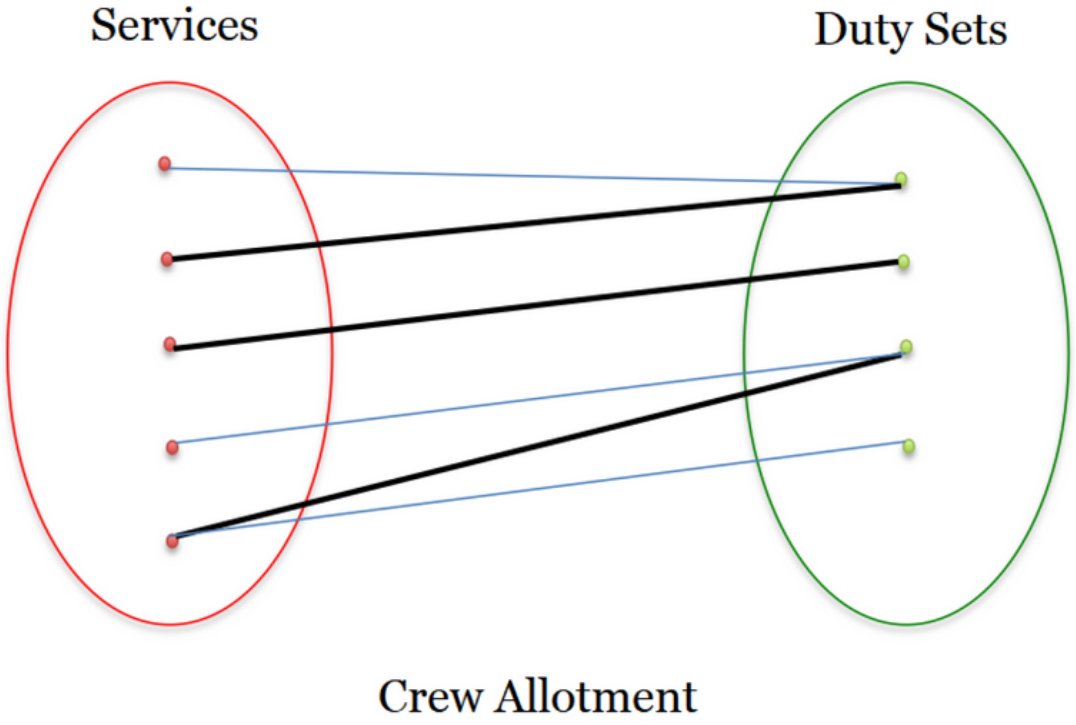

Figure 2: Matching Crew to Services

The Problem

- Shortage 132 guards, 90 motormen $\rightarrow$ Overtime is expense, vulnerable
- Currently done manually, 2-3 months long process
- Difficult to manually determine an optimal set allocation

The Problem

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- Need for an automatic and optimized crew planning tool to:
  - Reduce operating costs
  - Improve system efficiency
  - Provide better working conditions, safety

Work to be done by the tool

Train Timetable Book → Crew Schedule Book

Train Timetable Book

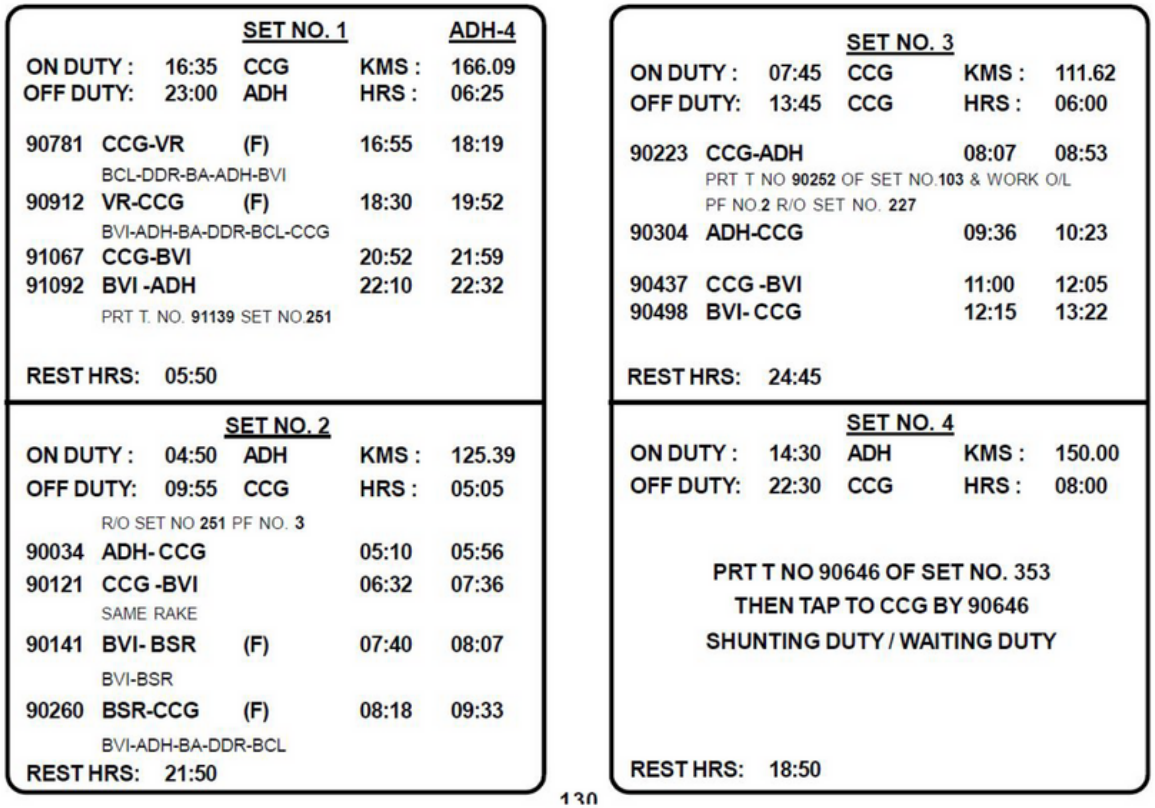
STATIONS		12926	VR	C. Rly.	BVI	BVI	VR	BVI
		ASR-	90590	98744	90592	90594	90596	90598
		BDTS	BQ	AD 44	BV	CF	R	C
		Pashchim	12 CAR		12 CAR	12 CAR	12 CAR	12 CAR
		EXP.						
VIRAR	**A**		**1**				**3**	
	D	**13:25**	**13:25**				**13:29**	
Nalla Sopara		T	13:31				13:36	
Vasai Road		**13:34**	**13:36**				**13:41**	
		T						
Naigaon			13:40				13:45	
Bhayandar		**13:44**	**13:46**				**13:51**	
Mira Road		T	13:51				13:56	
Dahisar			13:55				14:00	
BORIVALI	**A**	**13:57**						
	D	**14:00**	**14:01**		**14:01**	**14:04**	**14:05**	**14:08**
		8	**5/T**		**3**	**4**	**T**	**1**
Kandivli		ON STA			14:06	14:09		14:13
Malad		LINE BET			14:09	14:12		14:16
Goregaon		BVI-			14:12	14:15		14:19
Ram Mandir		BDTS			14:14			14:21
Jogeshwari					14:17	14:20		14:24
ANDHERI	**A**	**14:19**		**HB**				
	D	**14:22**	**14:17**	**14:20**	**14:22**	**14:25**	**14:21**	**14:28**
		BDTS	**T**	**2**		**T**	**T**	
Vile Parle		**ARRL.**		14:24	14:25			14:31
Santa Cruz		**14:45**		14:27	14:28			14:34
Khar Road				14:30	14:31			14:37
BANDRA			**14:26**	**14:34**	**14:35**	**14:35**	**14:30**	**14:41**
			T			**T**	**T**	
Mahim Jn.				14:37	14:38			14:44
Matunga Road					14:41			14:47
DADAR	**A**							
	D		**14:32**		**14:45**	**14:41**	**14:36**	**14:51**
Prabhadevi					14:47			14:53
Lower Parel				**CSTM**	14:50			14:56
Mahalakshmi				**Arr**	14:53			14:59
M'BAI CENTRAL(L)			**14:39**	**15:04**	**14:56**	**14:48**	**14:43**	**15:02**
			T			**T**	**T**	
Grant Road			14:41		14:58	14:50	14:45	15:04
Charni Road			14:43		15:00	14:52	14:47	15:06
Marine Lines			14:46		15:03	14:55	14:50	15:09
CHURCHGATE	**A**		**14:50**		**15:07**	**14:58**	**14:54**	**15:13**
From CCG at			**15:55**		**15:10**	**15:02**	**14:58**	**15:16**
TRAIN NO.			**90729**		**90689**	**90677**	**90671**	**90691**

Figure 3: Each column in the timetable book represents a service (total 1355)

Crew Schedule Book

Services are grouped into duty sets which define a motorman's daily work

- ON duty time and station, OFF duty time and station
- All services to be worked by motorman during duty time
- Rest hours (rest given after completing that day's work)



SET NO. 1 ADH-4

ON DUTY : 16:35 CCG KMS : 166.09
OFF DUTY: 23:00 ADH HRS : 06:25

90781 CCG-VR (F) 16:55 18:19
BCL-DDR-BA-ADH-BVI
90912 VR-CCG (F) 18:30 19:52
BVI-ADH-BA-DDR-BCL-CCG
91067 CCG-BVI 20:52 21:59
91092 BVI -ADH 22:10 22:32
PRT T. NO. 91139 SET NO.251

REST HRS: 05:50

SET NO. 2

ON DUTY : 04:50 ADH KMS : 125.39
OFF DUTY: 09:55 CCG HRS : 05:05
R/O SET NO 251 PF NO. 3
90034 ADH- CCG 05:10 05:56
90121 CCG -BVI 06:32 07:36
SAME RAKE
90141 BVI- BSR (F) 07:40 08:07
BVI-BSR
90260 BSR-CCG (F) 08:18 09:33
BVI-ADH-BA-DDR-BCL
REST HRS: 21:50

SET NO. 3

ON DUTY : 07:45 CCG KMS : 111.62
OFF DUTY: 13:45 CCG HRS : 06:00

90223 CCG-ADH 08:07 08:53
PRT T NO 90252 OF SET NO.103 & WORK O/L
PF NO.2 R/O SET NO. 227
90304 ADH-CCG 09:36 10:23

90437 CCG -BVI 11:00 12:05
90498 BVI- CCG 12:15 13:22

REST HRS: 24:45

SET NO. 4

ON DUTY : 14:30 ADH KMS : 150.00
OFF DUTY: 22:30 CCG HRS : 08:00

PRT T NO 90646 OF SET NO. 353
THEN TAP TO CCG BY 90646
SHUNTING DUTY / WAITING DUTY

REST HRS: 18:50

130

Figure 4: Each box in the crew schedule book is a set, 4 sets shown

Types of Sets

- Working sets:
  - **Day working sets**
  - **Halting working sets** - Always in pair, small rest at night
    Required for morning services
  - **Night sets** - On-duty time after 22:00
    Required for unassigned night services, shunting and morning services
- Waiting duty and shunting duty sets:
  - Emergency work
  - Taking rake to/from stabling depots

Set Generation Constraints

- Total working hours in a set $\leq$ 8 hours
- No unnecessary breaks between services, Break $\leq$ 30 minutes
- About 40 minutes break for meals
- Protection and work overlap for services that:
  - Require rake to navigate in opposite
  - Run during peak timings $\rightarrow$ 7:00 to 11:00 and 17:00 to 22:00

  Change of crew as same crew cannot continue running the same rake
- Halting sets:
  - Rest between pair $\geq$ $max(5, \frac{2}{3}$ * Working hours of first part) hours
  - Total working hours for pair $\leq$ 14 hours
  - Second part should be lighter

Set Linking Constraints

- Total working hours for last 14 days $\leq$ 104 hours
- Rest between sets $\geq$ 12 hours (except between halting pairs)
- Rest after night duty $\geq$ 30 hours
- Allocate sets for waiting duties and shunting duties:
  - Number at such sets predefined
  - Required only at Churchgate, Bhayandar, Bandra, Borivali stations
  - In time slots of 7:00 to 15:00, 15:00 to 23:00 and 23:00 to 7:00

  Night is when majority movements to/from stabling depots happen

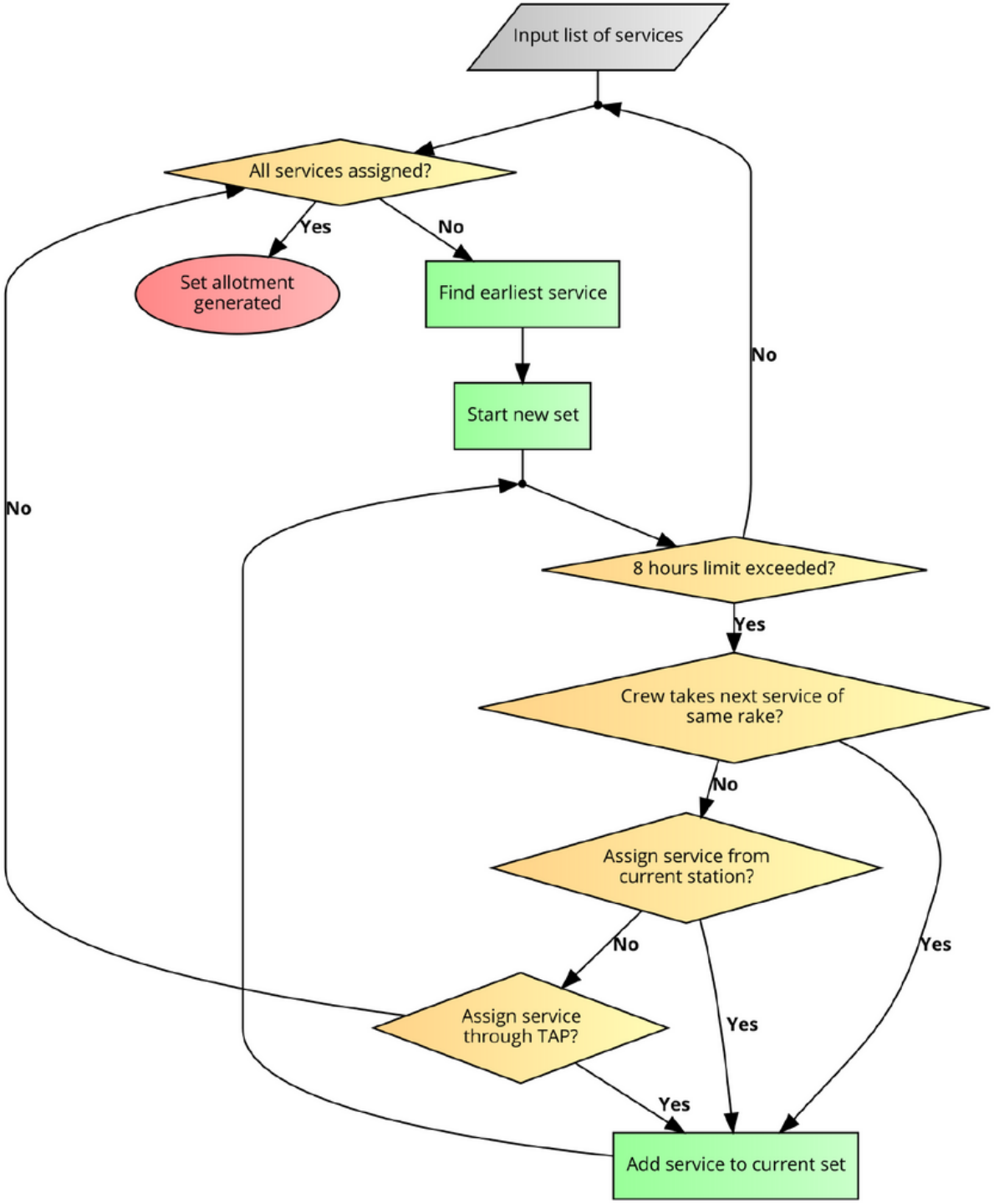
Problem Formulation

The overall problem has been decomposed into the following 2 stages:

1. **Set Generation Stage**
   To group services into work days → Daily work
2. **Set Linking Stage**
   To arrange work days into a sequence → Monthly work

Objectives (decreasing order of importance):

- Tight packing of services → Maximizes average working hours, kms
- Tight linking of sets → No unnecessary rest
- Sets should start/end close to headquarters - Churchgate, Borivali
- Minimize TAP (Travel as a passenger) between services
- 2:3 ratio of number of sets for Churchgate and Borivali headquarter


Input list of services
All services assigned?
Yes
No
Set allotment generated
Find earliest service
Start new set
No
No
8 hours limit exceeded?
Yes
Crew takes next service of same rake?
No
Assign service from current station?
No
Yes
Yes
Assign service through TAP?
Yes
Add service to current set

Work and Results

Crew Duty Generation Tool

Easy-to-use tool for generation of efficient crew duty sets

STATISTIC	ALGORITHM	MANUAL
Number of Halting Sets	129	192
Number of Day Working Sets	209	161
Number of Night Working Sets	30	29
Total Sets	**368**	382
Average Kms	**135 kms**	125 kms
Average Working Hours	**6:29**	6:16 (CCG DEPOT) 6:23 (BVI DEPOT)

Comparison of duty sets generated by the tool vs manual preparation

Technical Details

- Python 3 programming language used
- Compatible with Linux and Windows
- 30+ constraints programmed in the algorithm
- Efficient, flexible and quick

HOER rules, policies and on-field expertise modelled into the tool to automatically generate work duties that are operationally feasible and ensure safety of staff

Conclusions

- Services and their station/timing details as input
- Crew work duties in desired format as output
- Preparation of work duties within minutes
- Customizable and flexible tool that can easily adapt to changes in:
  - Services
  - Lobby locations
  - Any other parameters within the policy/constraints
- Analysis before making changes in policy, operations, infrastructure
  For example, introducing Virar station as a third headquarter in WR
- Tool under preparation since 1 year, currently under final review

Associations

Department

- Western Railway Mumbai Division

People

- Ms. Suhani Mishra, Senior Divisional Operations Manager
- Mr. Shamit Monga, Divisional Operations Manager
- Mr. Abhisek
- Mr. Rajvir
- Mr. SG Sagar
- Mr. PK Majumdar

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