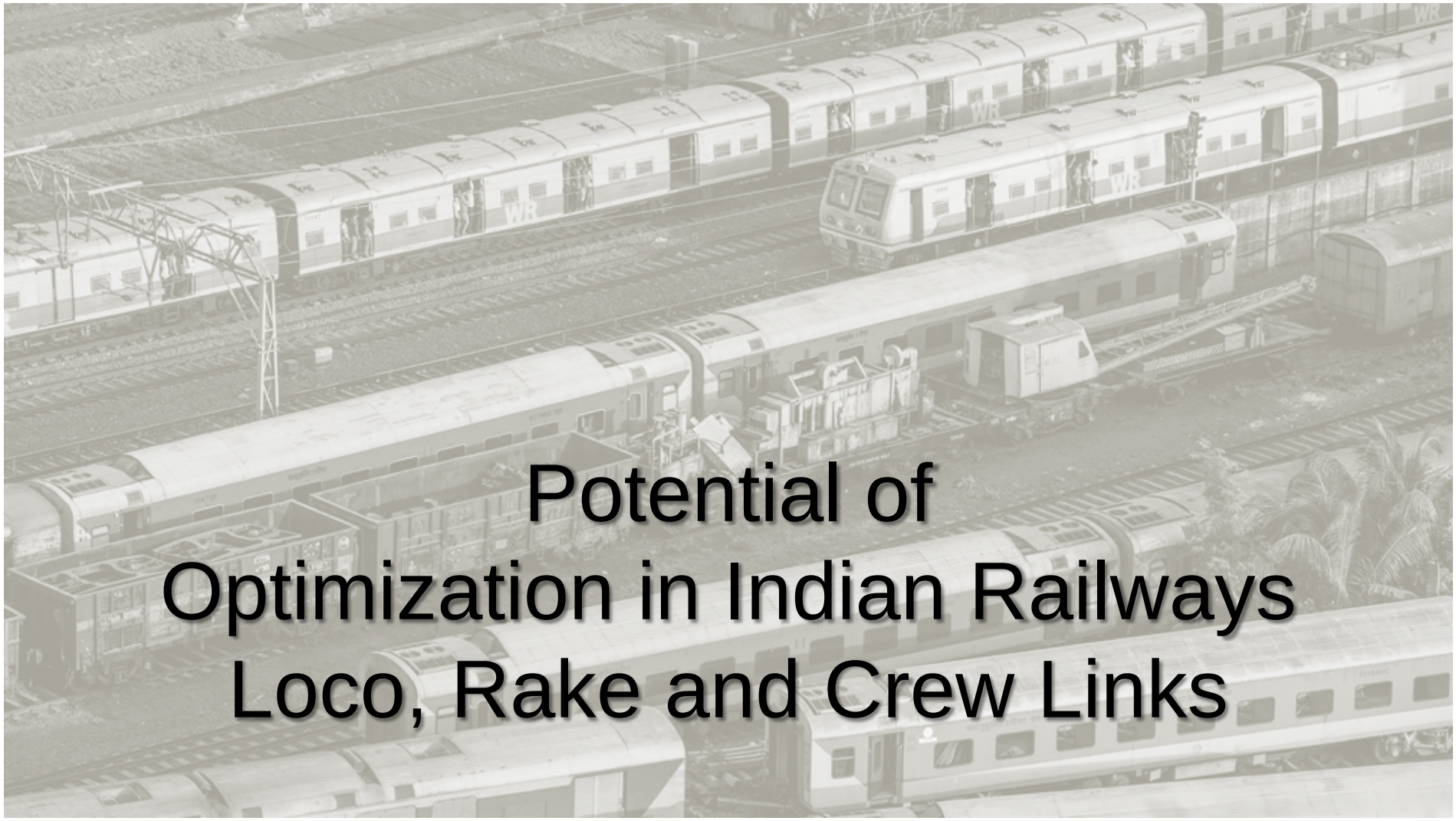

Potential of Optimization in Indian Railways Loco, Rake and Crew Links

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We will discuss

- Loco and Rake Links
  - Problem statement
  - Methods available
  - Challenges
  - Some examples

Something about Crew links

Databases in IR

Databases in IR

http://rbs.indianrail.gov.in/ShortPath/index.jsp

Rates Branch System helps the Indian Railways to find the shortest distance between the stations for coaching and goods traffic.

FOIS https://www.fois.indianrail.gov.in/FoisWebsite/jsp/RMS_Zonal.jsp?txtProjName=WR

PRS UTS http://dw.indianrail.gov.in/login.asp

ICMS http://icms.indianrail.gov.in/reports/ReportServlet?action=Login&subAction=doLogin

For Passenger Services

As on March 2016 as per RB's letters

Diesel Locos	2100
Electric Locos	1349
Total	3449

How many do we actually need???

ICMS Data on 20-3-16

LOCO / RB / BRC 1515DLoco Master Detail [ALL] [Loco type: ALL] [Traction: ALL] [Service: P] [Domain: ALL] [Gauge: BG]20-Mar-2016 11:42Total: 4451

This report shows 4451 used in Passenger Domain- 1000 more as in Rly Bd letter

Discrepancy in Databases

IMP: Databases must talk to each other

Rough Calculations from ICMS Data

Summary of Trains running Daily

	Column Labels									
Values	DRNT	GBR	JSH	MEX	PAS	PRUM	RAJ	SHT	SUF	Grand Total
Sum of Mon	23	19	36	931	2071	0	24	44	534	3682
Sum of Tue	26	21	31	928	2070	1	24	36	534	3671
Sum of Wed	17	17	35	934	2073	0	25	38	545	3684
Sum of Thu	20	16	34	946	2070	1	25	38	535	3685
Sum of Fri	21	19	38	932	2070	0	26	42	543	3691
Sum of Sat	21	17	34	944	2072	2	24	44	528	3686
Sum of Sun	16	19	30	910	2001	0	26	32	530	3564

Hour wise Summary of Trains running ALL

Hours			DRNT	GBR	JSH	MEX	PAS	PRUM	RAJ	SHT	SUF	Grand Total
0	to	3				69	840				14	923
3	to	6			3	170	685			20	102	980
6	to	9	11	3	33	172	259			28	102	608
9	to	12	7	7	2	136	138		2		92	384
12	to	15	4	8		128	81		4		88	313
15	to	18	8	15		141	52		11		69	296
18	to	21	5	7		69	15		5		24	125
21	to	24	5	4		69	11		4		58	151
24	to	27	2			78	3		4		45	132
27	to	30	6	6		72	2		2		71	159
30	to	33	2	2		69	1				64	138
33	to	36				71			4		56	131
36	to	39				52			1		33	86
39	to	42	1			52			2		16	71
42	to	45	1			27		2	5		26	61
45	to	48				38					21	59
48	to	51				22					18	40
51	to	54				22					10	32
54	to	57				11		1			6	18
57	to	60				3		1			6	10
60	to	63				6					2	8
63	to	66				6					4	10
66	to	69				4						4
69	to	72				3						3
72	to	75				2						2
75	to	78				1						1
78	to	81				1						1
			52	52	38	1494	2087	4	44	48	927	4746

Monday Trains
Sorted RUN_TIME wise

Count of Sub Type										ROUGH
Row Labels Fraction of Day	DRNT	GBR	JSH	MEX	PAS	RAJ	SHT	SUF	Grand Total	LOCOS
Time Interval	23	19	36	931	2071	24	44	534	3682	Needed
0-0.25			3	217	1512		18	105	1855	600
0.25-0.5	11	4	33	250	394	2	26	143	863	400
0.5-0.75	4	9		183	133	13		112	454	300
0.75-1	3	3		73	26	2		34	141	140
1-1.25	4	2		71	5	2		44	128	128
1.25-1.5	1	1		49	1	2		53	107	107
1.5-1.75				39		2		22	63	63
1.75-2				26		1		6	33	33
2-2.25				11				11	22	22
2.25-2.5				5				3	8	8
2.5-2.75				3				1	4	4
2.75-3				4					4	4
Grand Total	23	19	36	931	2071	24	44	534	3682	1804

The Perfect Way

- Previous estimate is inaccurate, just approximate- only to give an idea
- Use LOCOMOTIVE Assignment Models from Research and Practice

ERASMUS UNIVERSITEIT ROTTERDAM
ERASMUS SCHOOL OF ECONOMICS

ERASMUS UNIVERSITY ROTTERDAM

Solving the Locomotive Assignment Problem for a European rail-passenger and rail-cargo company

Master's Thesis
Econometrics and Management Science
Operations Research and Quantitative Logistics

Ivan Olthuis (359299)

November 4, 2015

Authors	Objective	Light Traveling	Problem Size	Solution
Florian et al. (1976)	Min investment and maintenance	No	Medium	Benders' Decomposition
Ziarati et al. (1997)	Min operational cost	No	Large	Branch-and-Price
Ziarati et al. (1999)	Min operational cost	No	Large	Branch-and-Price
Cordeau et al. (2000)	Min operational cost	No	Medium	Benders' Decomposition
Noble et al. (2001)	Min operational cost	No	Small	MIP solver
Ahuja et al. (2002)	Min operational cost and number of locs	Yes	Large	Two-Stage Heuristic
Ziarati et al. (2002)	Min operational cost	No	Large	Neural Networks
Ziarati et al. (2005)	Min operational cost	No	Large	Neural Networks with Genetic Algorithm
Powell et al. (2006)	Min operational cost	Yes	None	Approximate Dynamic Programming
Rouillon et al. (2006)	Min operational cost	No	Large	Branch-and-Price
Vaidyanathan et al. (2008)	Min operational cost and number of locs	Yes	Large	Consist Flow Formulation
Piu (2011)	Min operational cost and number of locs	Yes	Large	Consist Flow Formulation
Zhang et al. (2013)	Min locomotive turnaround time	No	Small	Two-Stage Heuristic
Teichmann et al. (2015)	Min operational cost	No	Small	MIP solver
Zhang et al. (2015)	Min locomotive utilization cost	No	Different instances	Graph Partition based Decomposition

Table 1: Summary of the characteristics of the problem which is being solved and the proposed methodology of different LAP related papers. Small problems are problems with less than 250 activities, medium sized problems contain between 250 and 1,000 activities, and large problems contain over 1,000 activities

IMP PAPER

Törnquist, J. (2006). Computer-based decision support for railway traffic scheduling and dispatching: A review of models and algorithms. In *OASIcs-OpenAccess Series in Informatics* (Vol. 2). Schloss Dagstuhl-Leibniz-Zentrum für Informatik.

http://vesta.informatik.rwth-aachen.de/opus/volltexte/2006/659/pdf/06001.ToenquistJohanna.Paper.659.pdf

Diesel Loco Links

- WR, CR and WCR – Combined for only Daily Trains
- NR, NCR, NER, ECR - Combined for only Daily Trains

- Used **NEIGHBOURHOOD SEARCH ALGORITHM**

Example courtesy – OPTYM India

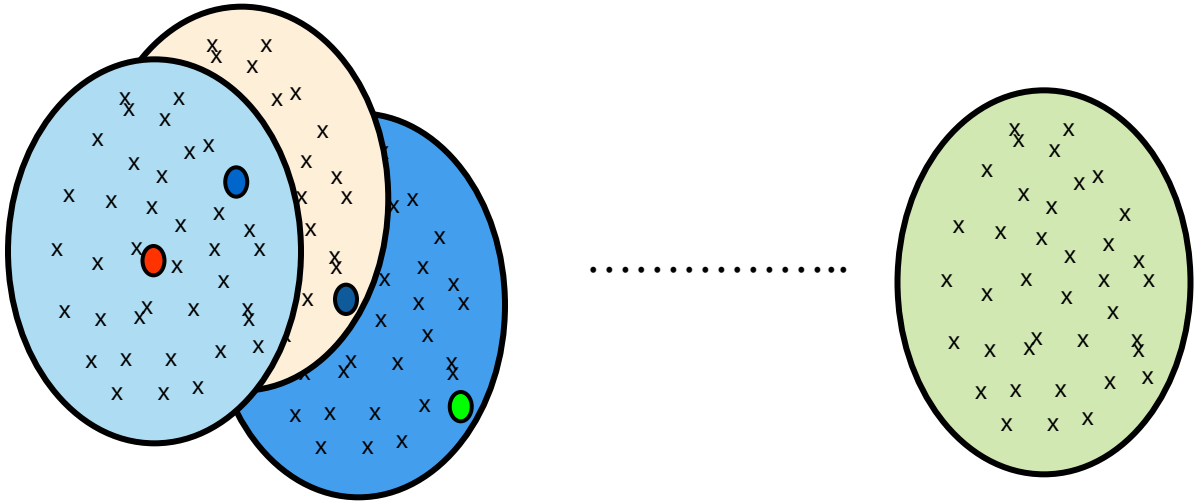
Algorithmic Approach: Neighborhood Search Algorithms

Start with a feasible solution x

Define a neighborhood of x

Identify an improved neighbor y

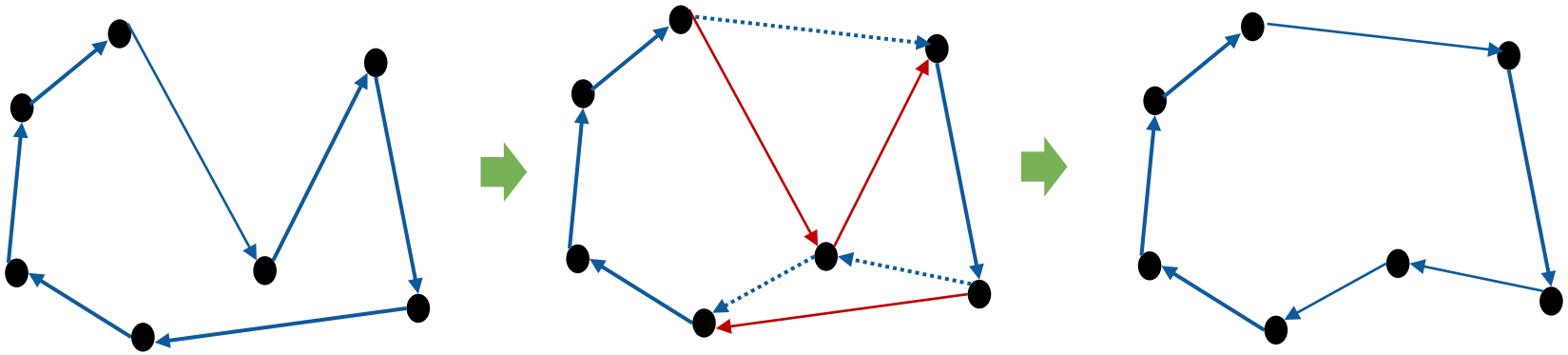
Replace x by y and repeat



Neighbourhood Search 1: Changes within Route

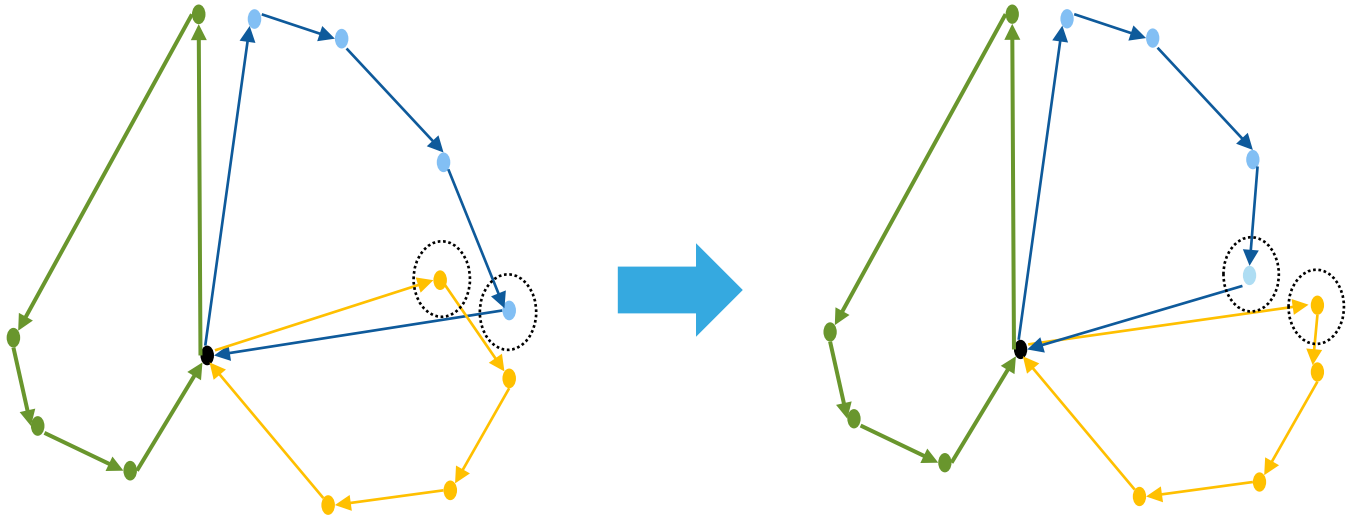
Remove a given number of links and try all possible ways to re-link disconnected stops.

This neighbourhood search helps in linearizing routes.



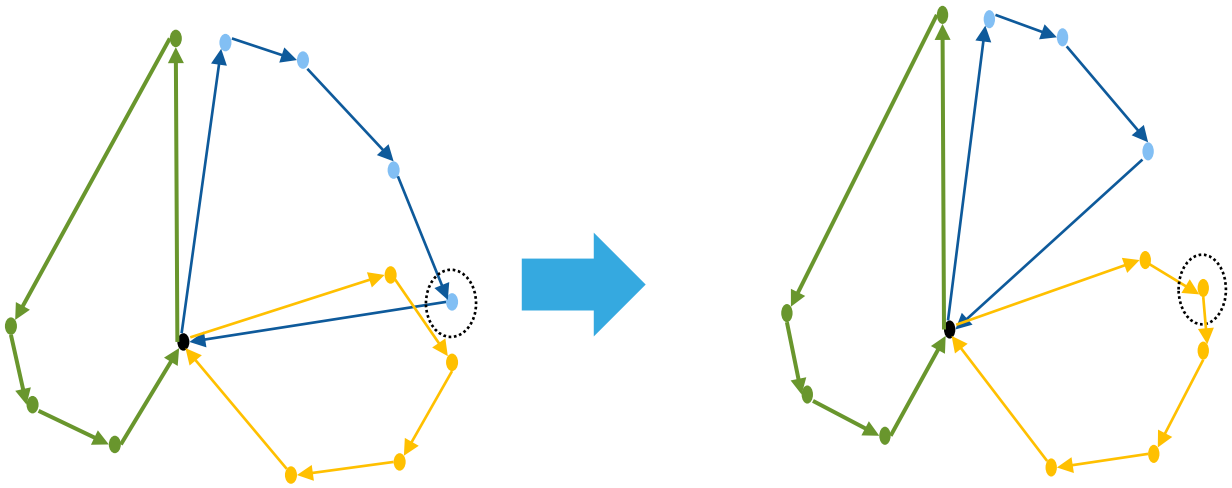
Neighbourhood Search 2: Swap across Routes

Exchange the position of two shipments (same or different routes).



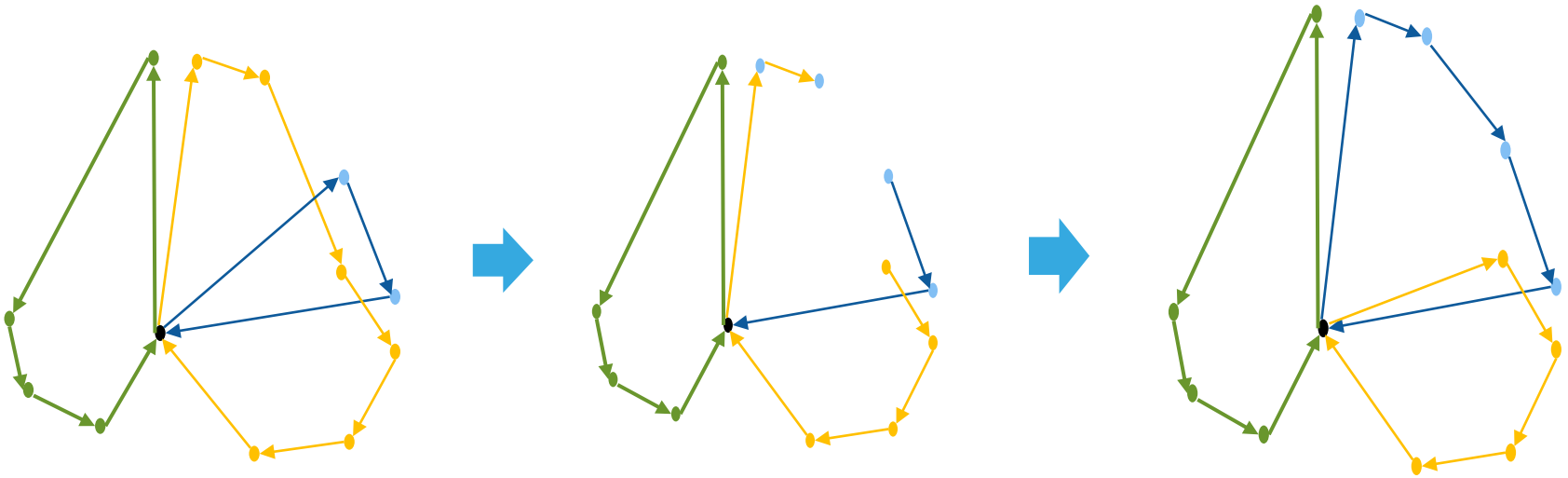
Neighbourhood Search 3: Relocate across Routes

Move one shipment to a different position or/and different route.



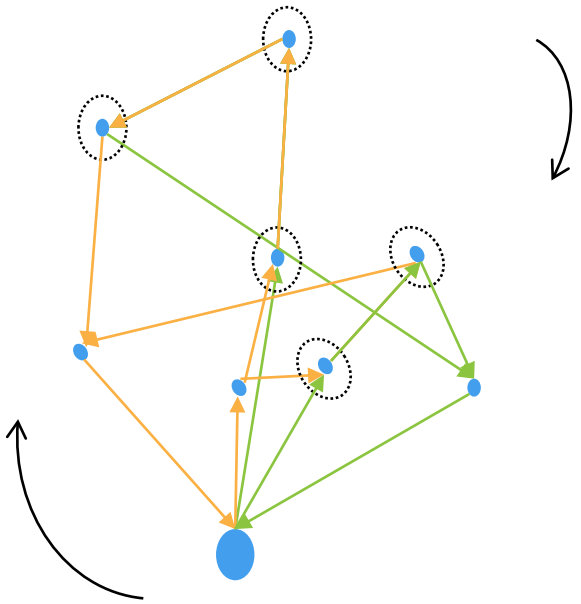
Neighbourhood Search 4: Cut and Combine across Routes

Cut two routes in four pieces and recombine them in a better configuration.



Neighbourhood Search 5: String Exchange

Select two strings of at most k consecutive stops in each of the routes. Exchange the string between the routes.



The Problem Statement

(in collaboration with OPTYM India)

- Locomotive to train assignment is a complex problem which must meet several business/practical requirements
  - Locomotive periodic maintenance in shed
  - Locomotive fueling requirement
  - Minimum connection time between trains for robust plan
  - Locomotive type-train and/or locomotive type-track compatibility

- Locomotive shed assignment
  - Each zone has one or multiple sheds.
  - Each locomotive is assigned to a shed, and must be serviced there.

- Current practice
  - Plans are created manually.
  - Each zone does their locomotive planning separately.

Model Solution – Locomotives Required

Northern Railway, North Eastern Railway, North Central Railway and East Central Railway Combined

Minimum Connection Time (in minutes)	No. of Locos Needed
0	375
10	**439 (Current)**
10	**377 (LocoMAX)**
30	383
60	394
120	**411**
240	434

- For **same minimum time** allowed between two trains to connect a locomotive, LocoMAX generates a solution with **much less number of locomotives**.
- **More than 10% Savings.**

Current Plan Loco Cycles

Cycle #	Trains in Cycle
1	18233-(230)-12853-(560)-12854-(295)-18234-(480)-12322-(355)-12296-(535)-15017-(620)-15018-(1335)-18233
2	12141-(360)-12142-(530)-13202-(580)-13201-(285)-11471-(110)-51701-(35)-51702-(170)-11472-(675)-12295-(607)-12321-(780)-12141
3	11093-(400)-11094-(365)-22187-(320)-22188-(160)-11055-(595)-11056-(560)-11093
4	12791-(1040)-12792-(840)-19045-(865)-19046-(1080)-12791
5	12167-(395)-12168-(245)-12191-(630)-12192-(290)-12159-(535)-22181-(1075)-11071-(625)-54263-(505)-54264-(330)-53522-(172)-18611-(415)-11072-(285)-12185-(745)-12186-(435)-22182-(740)-15206-(480)-15205-(820)-12160-(280)-51671-(125)-51767-(10)-51765-(25)-51766-(500)-51763-(20)-51764-(10)-51768-(65)-51672-(970)-12167
6	51673-(50)-51674-(150)-14010-(25)-14009-(355)-59385-(210)-59396-(30)-59395-(280)-59386-(145)-51253-(30)-51256-(25)-51255-(30)-51254-(250)-59386-(355)-51189-(220)-14217-(550)-54326-(180)-54327-(745)-54330-(355)-54329-(595)-54328-(95)-54325-(595)-14218-(340)-54107-(495)-54108-(495)-51190-(225)-12061-(425)-12062-(1105)-51673
7	11061-(900)-11062-(630)-11061
8	51188-(1350)-11271-(880)-58229-(860)-58230-(310)-15160-(580)-15159-(260)-51754-(680)-12427-(620)-12428-(420)-51753-(540)-12182-(390)-11651-(405)-11652-(325)-11451-(500)-11452-(600)-12181-(440)-11271-(330)-51187-(1135)-51188
9	51602-(455)-51883-(595)-51884-(995)-51612-(65)-5614-(540)-5613-(15)-51611-(640)-59342-(25)-59341-(905)-51601-(1215)-51602

- How to read a cycle: The cycles are in format Train 1 – (Connection Time) – Train 2 – …
- Observations:
  - Current Plan has very long cycles which will imply that if one connection is missed, then a large number of trains are potentially impacted.
  - LocoMAX plan makes smaller cycles which would imply a more robust plan.

LocoMAX Optimized Loco Cycles

Cycle #	Trains in Cycle
1	11471-(630)-22188-(320)-11471
2	18233-(230)-12853-(275)-11093-(345)-12168-(205)-18233
3	14010-(160)-51256-(1465)-51255-(250)-59386-(455)-51253-(325)-51254-(250)-59386-(255)-12322-(917)-12321-(265)-14010
4	12159-(535)-22181-(1075)-11071-(955)-11094-(160)-51673-(210)-51765-(790)-51764-(140)-51674-(155)-12159
5	12191-(815)-12160-(130)-12191
6	51671-(125)-51767-(1160)-51768-(520)-51188-(295)-12141-(360)-12142-(165)-51671
7	22187-(730)-11472-(225)-22187
8	51189-(535)-51190-(135)-12854-(295)-18234-(580)-51189
9	13202-(580)-13201-(125)-11055-(540)-15018-(450)-13202
10	12167-(120)-54263-(505)-54264-(330)-53522-(172)-18611-(415)-11072-(375)-15160-(680)-19046-(400)-12167
11	12295-(320)-12428-(165)-51702-(590)-12062-(320)-12295
12	11271-(310)-1127-(240)-11271
13	51187-(680)-51672-(200)-11061-(1040)-11062-(235)-51187
14	12061-(515)-51701-(170)-12427-(345)-12296-(400)-12061
15	19045-(765)-15159-(535)-22182-(565)-12192-(160)-12791-(1040)-12792-(840)-19045
16	59385-(345)-14009-(355)-59385
17	15017-(675)-11056-(1070)-15017
18	59395-(720)-59396-(1470)-59395
19	59342-(1465)-59341-(275)-59342
20	51601-(155)-51602-(220)-51601
21	51612-(770)-51611-(1045)-51612
22	51883-(595)-51884-(1070)-51883
23	11651-(405)-11652-(215)-11651
24	11451-(500)-11452-(400)-11451
25	12181-(585)-12182-(700)-12181
26	15206-(480)-15205-(810)-15206
27	51754-(800)-51753-(175)-51754
28	58229-(825)-12186-(270)-58229-
29	12185-(780)-58230-(220)-12185
30	51763-(695)-51766-(500)-51763
31	5613-(745)-5614-(450)-5613
32	54326-(1230)-54325-(580)-54326
33	14218-(145)-14217-(565)-14218
34	54107-(495)-54108-(375)-54107
35	54329-(700)-54330-(355)-54329
36	54327-(640)-54328-(485)-54327

Model Solution – Locomotives Required

West Central Railway

Minimum Connection Time (in minutes)	No. of Locos needed
0	63
10	**64 (LocoMAX)**
10	**76 (Current)**
30	71
60	73
120	77
240	86

- Combined 3 Zones
- (Western Railway, West Central Railway and Central Railway)

Minimum Connection Time (in minutes)	No. of Locos needed
0	196
10	**201 (LocoMAX)**
10	**237 (Current)**
30	225
60	247
120	261
240	304

- For same minimum time allowed between two trains to connect a locomotive, LocoMAX generates a solution with much less number of locomotives.

Current Plan

Cycle #	Trains in Cycle
1	18233-(230)-12853-(560)-12854-(295)-18234-(480)-12322-(355)-12296-(535)-15017-(620)-15018-(1335)-18233
2	12141-(360)-12142-(530)-13202-(580)-13201-(285)-11471-(110)-51701-(35)-51702-(170)-11472-(675)-12295-(607)-12321-(780)-12141
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6	51673-(50)-51674-(150)-14010-(25)-14009-(355)-59385-(210)-59396-(30)-59395-(280)-59386-(145)-51253-(30)-51256-(25)-51255-(30)-51254-(250)-59386-(355)-51189-(220)-14217-(550)-54326-(180)-54327-(745)-54330-(355)-54329-(595)-54328-(95)-54325-(595)-14218-(340)-54107-(495)-54108-(495)-51190-(225)-12061-(425)-12062-(1105)-51673
7	11061-(900)-11062-(630)-11061
8	51188-(1350)-11271-(880)-58229-(860)-58230-(310)-15160-(580)-15159-(260)-51754-(680)-12427-(620)-12428-(420)-51753-(540)-12182-(390)-11651-(405)-11652-(325)-11451-(500)-11452-(600)-12181-(440)-11271-(330)-51187-(1135)-51188
9	51602-(455)-51883-(595)-51884-(995)-51612-(65)-5614-(540)-5613-(15)-51611-(640)-59342-(25)-59341-(905)-51601-(1215)-51602

- How to read a cycle: The cycles are in format Train 1 – (Connection Time) – Train 2 -…
- Observations:
  - Current Plan has very long cycles which will imply that if one connection is missed, a large number of trains can potentially be impacted.
  - LocoMAX plan makes smaller cycles which would imply a more robust plan.

LocoMAX Optimized Loco Cycles

Cycle ID	Trains in Cycle
1	11471-(630)-22188-(320)-11471
2	18233-(230)-12853-(275)-11093-(345)-12168-(205)-18233
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4	12159-(535)-22181-(1075)-11071-(955)-11094-(160)-51673-(210)-51765-(790)-51764-(140)-51674-(155)-12159
5	12191-(815)-12160-(130)-12191
6	51671-(125)-51767-(1160)-51768-(520)-51188-(295)-12141-(360)-12142-(165)-51671
7	22187-(730)-11472-(225)-22187
8	51189-(535)-51190-(135)-12854-(295)-18234-(580)-51189
9	13202-(580)-13201-(125)-11055-(540)-15018-(450)-13202
10	12167-(120)-54263-(505)-54264-(330)-53522-(172)-18611-(415)-11072-(375)-15160-(680)-19046-(400)-12167
11	12295-(320)-12428-(165)-51702-(590)-12062-(320)-12295
12	11271-(310)-1127-(240)-11271
13	51187-(680)-51672-(200)-11061-(1040)-11062-(235)-51187
14	12061-(515)-51701-(170)-12427-(345)-12296-(400)-12061
15	19045-(765)-15159-(535)-22182-(565)-12192-(160)-12791-(1040)-12792-(840)-19045
16	59385-(345)-14009-(355)-59385
17	15017-(675)-11056-(1070)-15017
18	59395-(720)-59396-(1470)-59395
19	59342-(1465)-59341-(275)-59342
20	51601-(155)-51602-(220)-51601
21	51612-(770)-51611-(1045)-51612
22	51883-(595)-51884-(1070)-51883
23	11651-(405)-11652-(215)-11651
24	11451-(500)-11452-(400)-11451
25	12181-(585)-12182-(700)-12181
26	15206-(480)-15205-(810)-15206
27	51754-(800)-51753-(175)-51754
28	58229-(825)-12186-(270)-58229-
29	12185-(780)-58230-(220)-12185
30	51763-(695)-51766-(500)-51763
31	5613-(745)-5614-(450)-5613
32	54326-(1230)-54325-(580)-54326
33	14218-(145)-14217-(565)-14218
34	54107-(495)-54108-(375)-54107
35	54329-(700)-54330-(355)-54329
36	54327-(640)-54328-(485)-54327

Conclusion

Study only for Diesel Loco on Daily Trains (NR,NER,NCR,ECR combined – WR,CR,WCR combined)

- Individually all links are very well made
- By combining zones- saving of about 5-10% is achieved.
- Loco cycles can be shortened for a robust plan.
- If operations can be managed in such manner that MINIMUM CONNECTION TIME between two trains for Loco attachment is reduced from 120 minutes to 60 minutes, phenomenal reduction in number of locos needed
- This will be a strategic decision.

Some more observations on Loco links

WAP7 – 6000 hp loco running Pass. Trains

Link No. LGD-12; Loco Type: WAP-7 Loco Base: LGD No. of Locos: 1						
12975/76 Exp & 54793/94Pass						
	KCG		**SWM**		**MTJ**	**KMS**
Fri 02.20	**12975**		3.40 Sat			1543
		Sun 5.05	**54793**		10.45 Sun	216
		Sun 19.00	**54794**		14.00 Sun	216
		Mon 5.05	**54793**		10.45 Mon	216
		Mon 19.20	**54794**		14.00 Mon	216
		Tue 5.05	**54793**		10.45 Tue	216
		Tue 19.20	**54794**		14.00 Tue	216
		Wed 5.05	**54793**		10.45 Wed	216
		Wed 19.20	**54794**		14.00 Wed	216
Thu 23.45	**12976**		21.40 Wed			1543
					Total Link Kms =	**4814**
	Repeat				**kms/day/loco=**	**688**
Note:	Trip schedule to be carried out at SWM for I/C 12975 and 57494 pass on Tue					

Lie Over of 24 hours

END-1

REVISED LOCO LINK OF ET/WCR BASED LOCO

NON DAILY

DAY	TIME	ET	PNBE	DBG	DAY	L/O	KMS
THR	19:15	**12741**			THR		
FRI			12:10		FRI	25:50	966
SAT		**12742**	14:00		SAT		966
SUN	07:50				SUN	09:05	
	16:55						
MON		**12578**		14:25	MON	24:45	1165
TUE				16:10	TUE		1165
WED	12:55	**12577**			WED		
▲					THR	**30:20**	
THR	19:15	LINK PICK-UP					

Current Problem
Pan India Loco Links

Assuming only kind of Traction – which is the future – ELECTRIC

Using **mySQL** for database

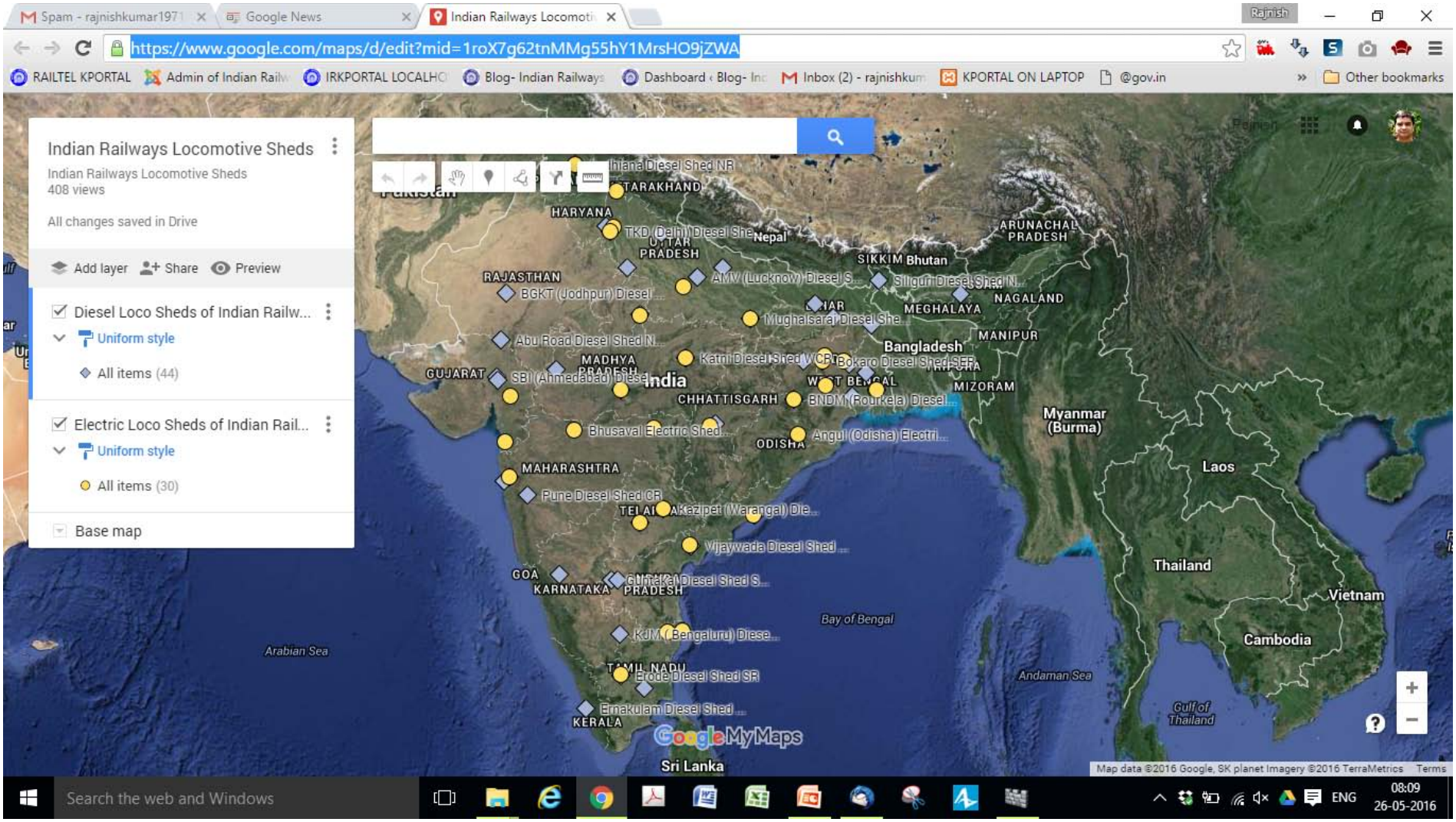
Python – programming language for coding the algorithm

This is only to project the potential

Otherwise a very complex and dynamic problem.

Location of Loco Sheds on IR

Loco sheds on IR – Google Maps



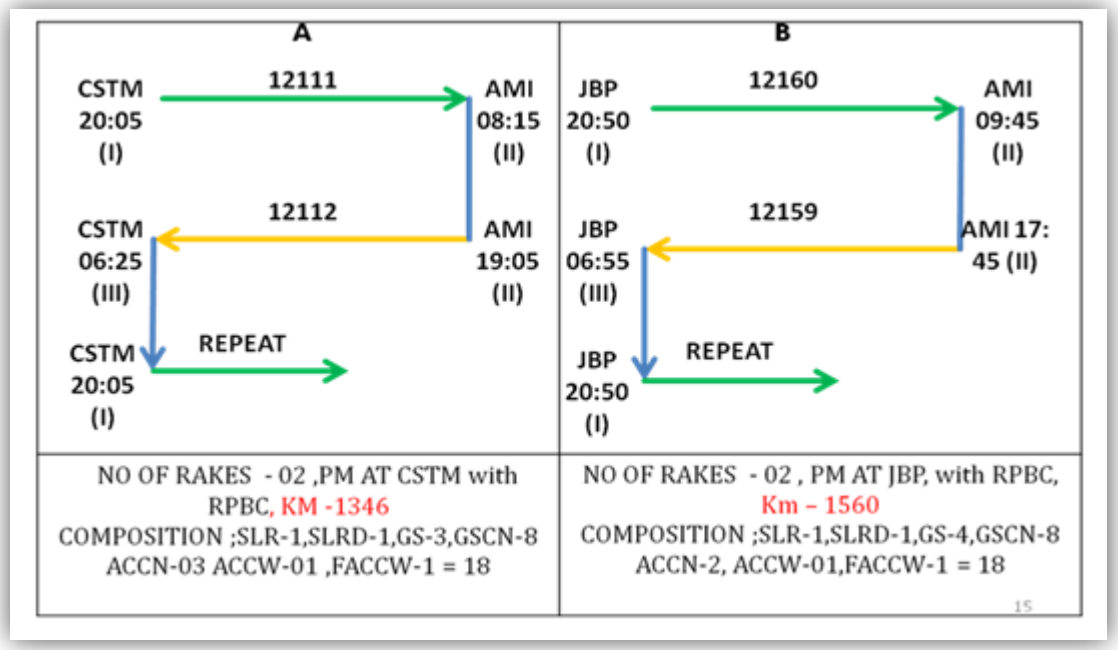
Something about Rake Links

- Based on ICMS Data
- About 1415 (on 29-3-16) Train Rakes with lie over of more than 6 hours
- Not possible to have all optimized, as trains are running at some gaps
- But possible to find links mathematically to reduce stabling time of rakes.

COIS / RB / BRC 702	Rake Lie Over Period [Train Type : Mail express] [Maintenance Type :ALL] Lie Over>=[6]	29-03-2016 23:06

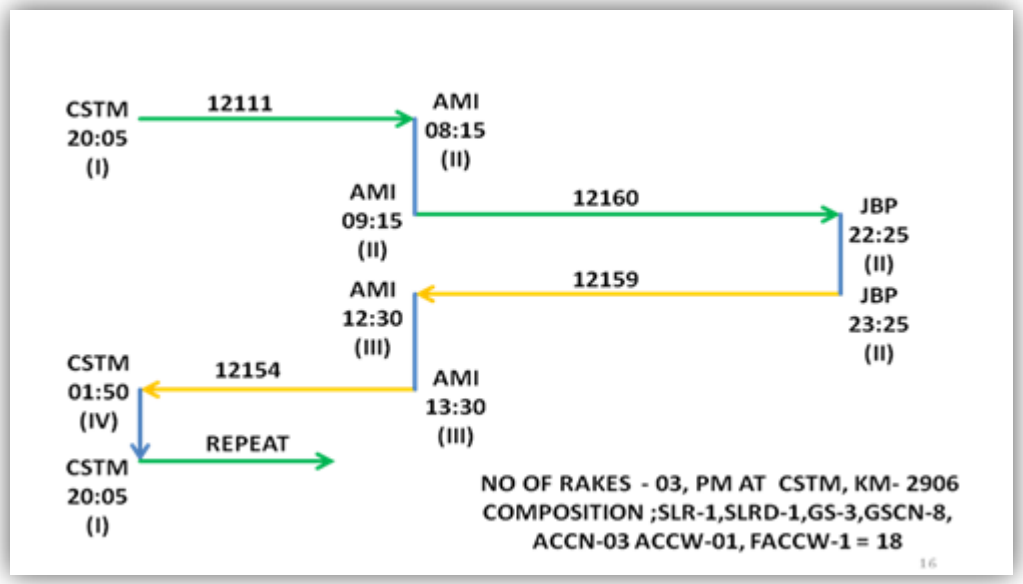
Sr.	Division	Depot	PM			SM			RBPC		
			No. of Train Count	Total Lie Over Time [HH:mm]	Average Lie Over Time [HH:mm]	No. of Train Count	Total Lie Over Time [HH:mm]	Average Lie Over Time [HH:mm]	No. of Train Count	Total Lie Over Time [HH:mm]	Average Lie Over Time [HH:mm]
1. Zone : CR											
1	BB	CSTM	1	09:35	09:35	13	192:00:00	14:46	12	180:41:00	15:03
2	BB	DR	12	216:40:00	18:03	1	29:30:00	29:30:00			
3	BB	LTT	51	1682:45:00	32:59:00	18	343:15:00	19:04	4	62:10:00	15:32
4	BB	WB	11	135:45:00	12:20				1	12:35	12:35
5	BSL	AK							1	15:10	15:10
6	BSL	AMI	1	10:50	10:50	1	15:55	15:55	2	15:45	07:52
7	BSL	BSL	1	35:50:00	35:50:00	1	13:50	13:50	1	11:50	11:50
8	BSL	MMR	3	26:30:00	08:50				1	14:05	14:05
9	NGP	AJNI	3	93:15:00	31:05:00						
10	NGP	NGP	9	192:40:00	21:24				6	95:10:00	15:51
11	PUNE	KOP	7	149:35:00	21:22				1	09:25	09:25
12	PUNE	PUNE	23	500:40:00	21:46	3	48:08:00	16:02	9	76:35:00	08:30
13	SUR	LUR							1	16:00	16:00
14	SUR	SNSI				2	25:50:00	12:55	7	74:45:00	10:40
15	SUR	SUR	7	106:45:00	15:15						
Zonal Total:			129	**3160:50:00**	**24:30:00**	39	**668:28:00**	**17:08**	46	**584:11:00**	**12:41**

Sr.	Train type	Description	Owning Railway [No. of Rake Links]																	Total
			CR	ECOR	ECR	ER	KR	NCR	NER	NFR	NR	NWR	SCR	SECR	SER	SR	SWR	WCR	WR	Mix Rly.	
1	DMU	DMU	1	2	5	5	2	2	3	2	19		11	3		7	4		7		73
2	DRNT	DURONTO EXPRESS	3			3		1			3		3		2	2			2		19
3	EMU	EMU									1				2						3
4	GBR	GARIB RATH	1	2	1	1			1	1	6	1	2		1	2	1	1	1		22
5	HSP	HOLIDAY SPECIAL	6	6		2			2	1	3	1	9	5	2	10	4	1			52
6	JSH	JAN SHATABDI	1	1	1					1	2	1		1	1	4	1	2			16
7	MEMU	MEMU			1	9					7		5	3	6	8	1	1	3		44
8	MEX	MAIL/EXPRESS	34	16	30	37	1	14	25	24	53	19	33	6	23	35	27	7	29	1	414
9	PAS	PASSENGER	14	12	20	29	2	18	12	18	36	12	29	6	20	23	19	9	24	3	306
10	PRUM	PREMIUM			1												3				4
11	RAJ	RAJDHANI		1	1	2					8						1		2		15
12	SHT	SHATABDI	1	1		1		1		1	9	1				2	1		1		19
13	SUB	SUBURBAN	871			1129					3		2		29	183			8		2225
14	SUF	SUPERFAST	24	11	16	22		9	9	8	25	18	21	4	18	39	7	10	23		264
15	SUVD	SUVIDHA TRAIN		2	1	1				1					1						6
16	MIX TRAIN TYPE		13	14	6	11		1	8	11	24	12	9	6	13	27	11	6	18	4	194
		Total:	969	68	83	1252	5	46	60	68	199	65	124	34	118	342	80	37	118	8	**3676**



THIS PROPOSAL SAVEs

ONE RAKE
and 1 Primary Schedule



Rajdhani Example
(Project in NAIR by Gr B Foundation Prog.)

MERGER OF RAKES OF 12423/12424 NDLS-DBRT RAJDHANI EXPRESS WITH 12425/12426 NDLS-JAT RAJDHANI EXPRESS

EXISTING RAKE LINK

A. RAKE LINK

NDLS	DBRT	
D.13.55 (I)	12424	A. 4.50 (III)
A.10.15 (V)	12423	D.20.35 (III)
D.13.55 (VI)	12424	Repeat

EXISTING COMPOSITION

LWFAC-1, LWACCW-5, LWACCN-10, LWCBAC-2, LWLRRM-2 =20

No. of Rakes	...	...	5 (N. Rly.)	
P.M.	...	...	NDLS	
SM	...	...	DBRT	
LOAD	20	Total Kms.	4876	

B. RAKE LINK

NDLS	JAT	
D. 20.40 (I)	12425	A 5.45 (II)
A. 05.00(III)	12426	D. 19.40 (II)
D. 20.40(III)	12425	Repeat

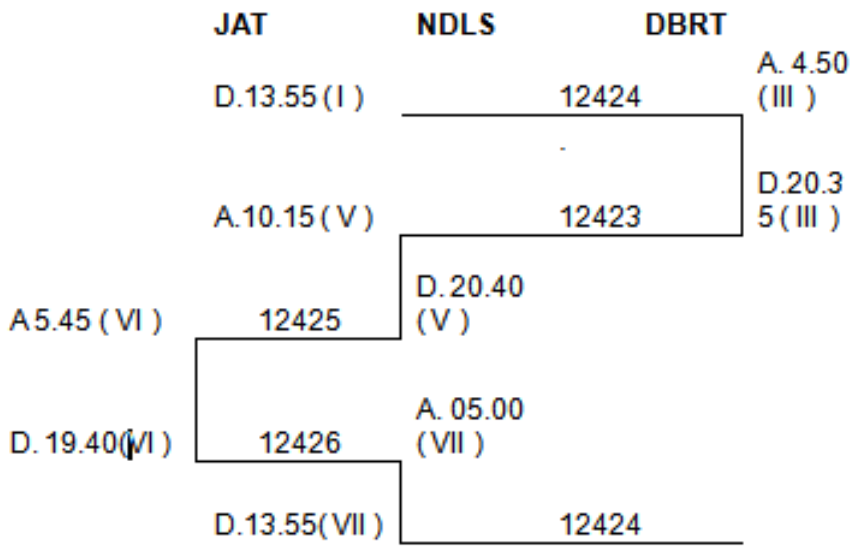
EXISTING COMPOSITION

LWFAC-1, LWACCW-4, LWACCN-10, LWCBAC-1, LWLRRM-2 = 18

No. of Rakes	...	...	2 (N.Rly.)
P.M.	...	...	NDLS
SM	...	...	JAT
LOAD	18	Total Kms.	1154

PROPOSED RAKE LINK

RAKE LINK



PROPOSED COMPOSITION

LWFAC-1, LWACCW-5, LWACCN-10, LWCBAC-2, LWLRRM-2 =20 **(12423/12424)**
LWFAC-1, LWACCW-5, LWACCN-10, LWCBAC-2, LWLRRM-2 = 20 **(12425/12426)**

No. of Rakes	...	...	6(N. Rly.)
P.M.	...	...	**NDLS**
SM	...	...	DBRT/JAT
LOAD	20/19	Total Kms.	6030

SUMMARY

Stock required to make rakes identical	LWACCW-1 (for augmentation of 12425/12426)
Remarks	1. To make rakes identicals load of 12425/ 12426 will have to be augmented by LWACCW-1
SAVINGS	
RAKES	**Saving of one rake** (LWFAC-1, LWACCW-4, LWACCN-10, LWCBAC-1, LWLRRM-2 =19*) *+ LWACCW-1 , LWCBAC -1 will be required for augmentation of 12425/12426)
SLOTS	**Reduction in stabling hours of 12424 by almost 20 hours and that of 12425 by 8 hours**

This has been implemented

Rake link Project

Challenges

- Rake composition to be made uniform- economics to be understood
- Capacity of Depots to be reassessed
- Development work in existing depots to be identified
- Conditions of FOG, disruptions to be simulated, so that ROBUST plan is made.

CREW LINKS- TRICKY AREA

Decision Support System to Make Crew Links by MATHOLOGIC

Company by a former Railway Officer

Crew Scheduling - Objectives

- To optimize total Crew needs
- To minimize excess out of station rest
- To maximize head quarter rest
- To adhere existing business rules related to periodic rest, head quarter rest, out station rest, sign on and sign off

- Contextual Need

  Each and every train, how it is worked by different crew lobbies, is a subject of discussion. Thus software should be able to evaluate the impact of different alternatives. This will help in accepting best possible alternative.

Stakeholders Needs

More time with family, minimum out-station rest, more long trips and more mileage

New links should not lead to transfer of crew, equitable distribution of trains between divisions

Slight delay in trains should not lead to link break, the less the crew the better it is

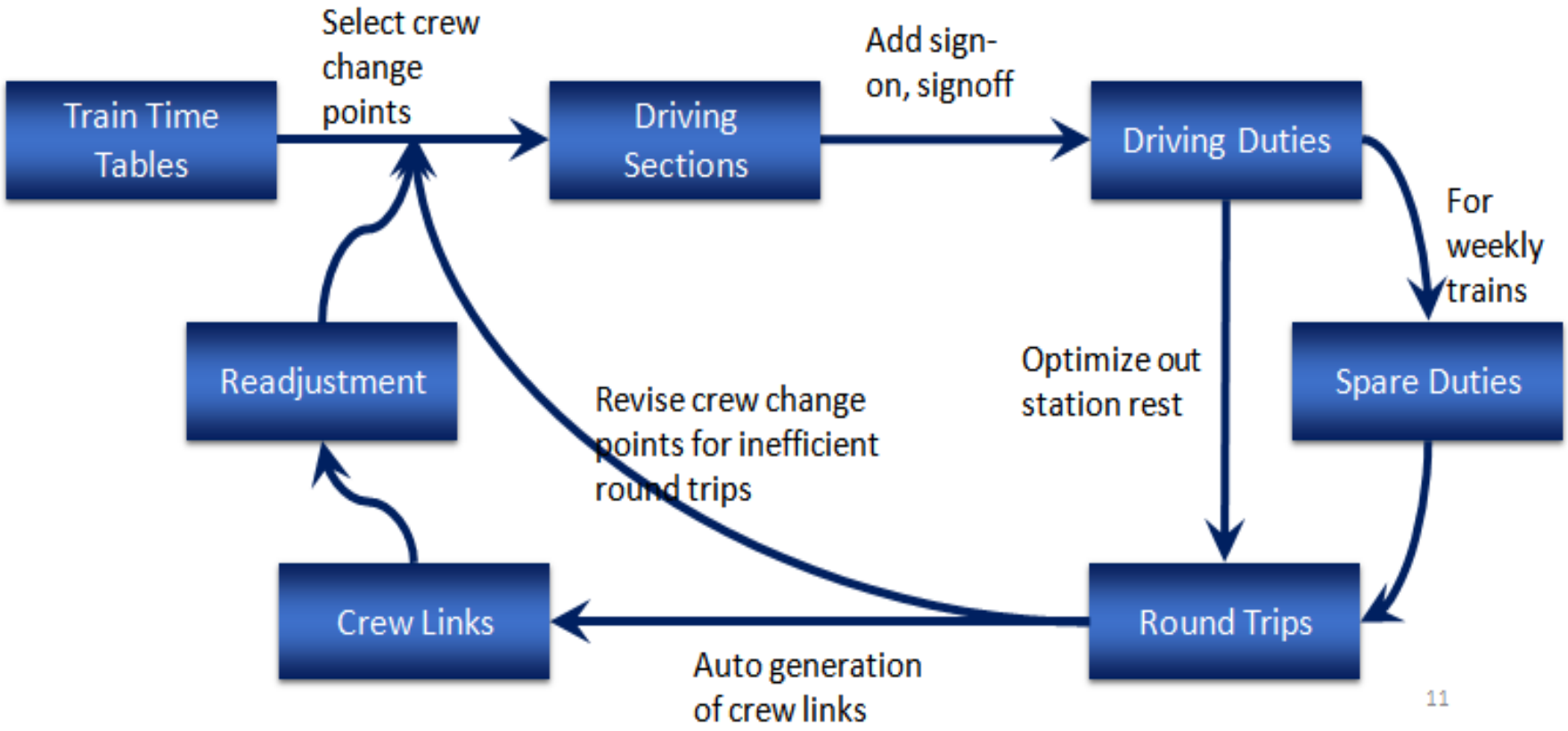
Crew Scheduling - Complexities

- The Local factors which are difficult to capture and specify beforehand
- Manual planning in any division which has 200 crew sets, 600 round trips per week and 1200 driving sections (one way journeys) is extremely difficult job for the planner
- Study to check the impact of any new idea, say extending the crew run on two three trains which affect the links on adjacent divisions also increases the complexity further
- Adherence to zonal or divisional boundaries for creating driving sections, makes the links inefficient. One should be able to calculate the impact of such things
- Resistance for change in the organization, the optimization method and application software can help to overcome that by facilitating a dialogue

Research involved in making DSS

- Various methods exist in research literature to partially solve it, none of them can be directly applied in Indian Railways' context
- Modeling the crew problem in nice mathematical equations is extremely difficult
- We have tested many approaches for their practicality in Indian context
- Negotiations with adjacent divisions and drivers add to complexity which must be assisted by the method and application

Crew Scheduling - Problem



DSS Features

- Accessible over internet from anywhere
- Very interactive User Interface
- Rational for each and every decision and that is exposed to the user
- Sub-Optimal solutions can be arrived at to suit the context
- Cloud based application which ensures very high availability

TRIAL RESULTS OVER NR-MAIL EXPRESS CREW LINKS

Results of Trial over Mail Express Crew Links in Northern Railway

1. Zero Based Plan (done)

2. Improvement Plan (under Progress may’16)

Results of Zero Base Planning

Method

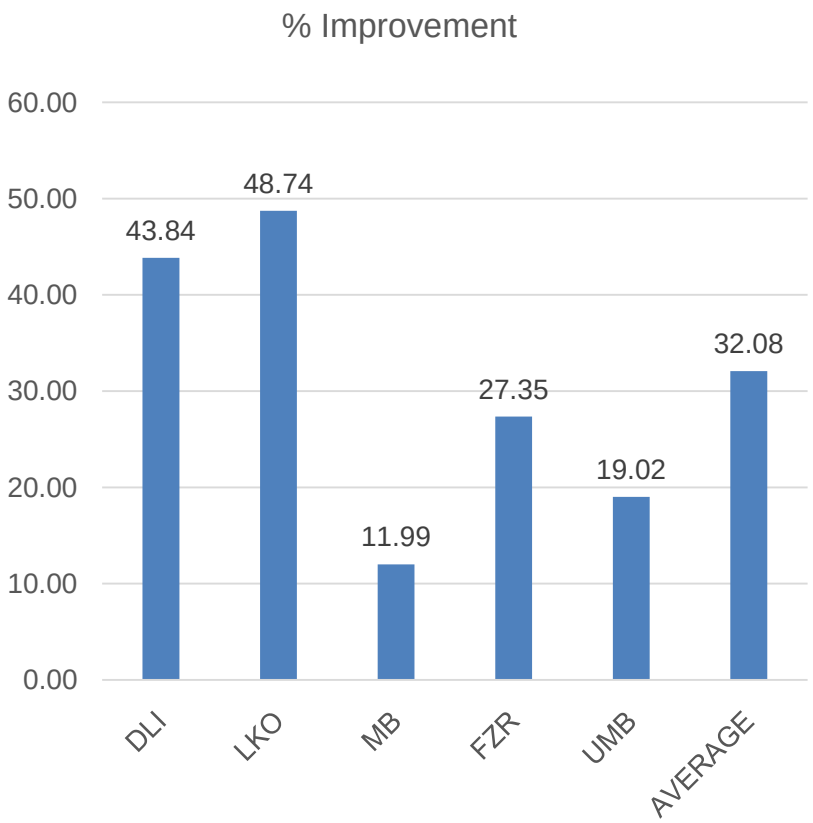
- All India Time table of mail express trains was taken. To Identify the trains which can be worked by NR crew we selected all the mail express trains which touch any of the given stations
  - JAT, PTK, JUC, LDH, ASR, FZR, BTI, UMB, SRE, KLK, CDG, DDN, HW, MB, BE, MTC, FD, PBH, SLN, BSB, PRG, (LKO and CNB both together)
- Following trains were excluded
  - Trains originating in Delhi Region and Going towards Jaipur, Kota, Jhansi or Kanpur
  - Trains originating in LKO, LJN and going towards GKP (assuming they will be run by NE crew)
  - Trains originating in BSB and going towards GKP or MGS (assuming they would be run by NE and ER crew)
  - All the trains which touch CNB and LKO both were considered.

Results of Zero Base Planning

Method…2

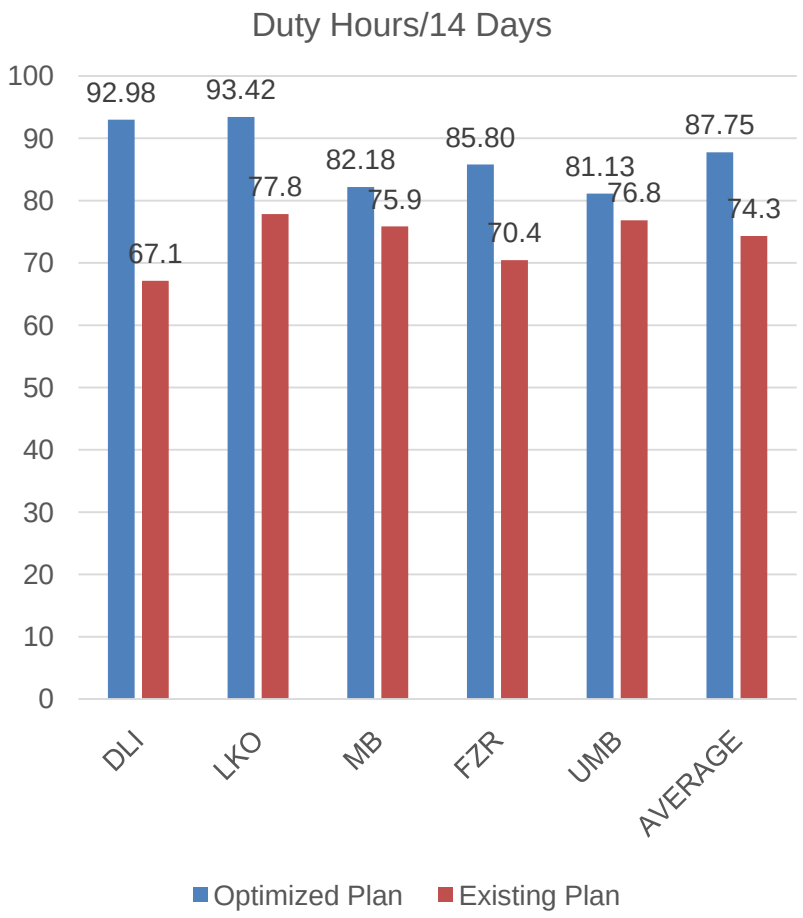
- All the major stations were taken as potential candidates for crew booking points
- The ideal crew run was taken as 6 to 8 hours journey but if it reaches a major crew booking point in 9 hours than it was allowed. 30 minutes was taken for sign on and 30 minutes for sign off. We assumed all crew are duel crew and all of them can run diesel or electric trains
- A train was assigned to a crew lobby at either end of driving section based on minimum excess out station rest principle
- In some cases in weekly trains the crew performed two train journeys and a spare journey. Spare journey was never allowed to work daily trains

32.08% more output per crew



Duty Hours per 14 days

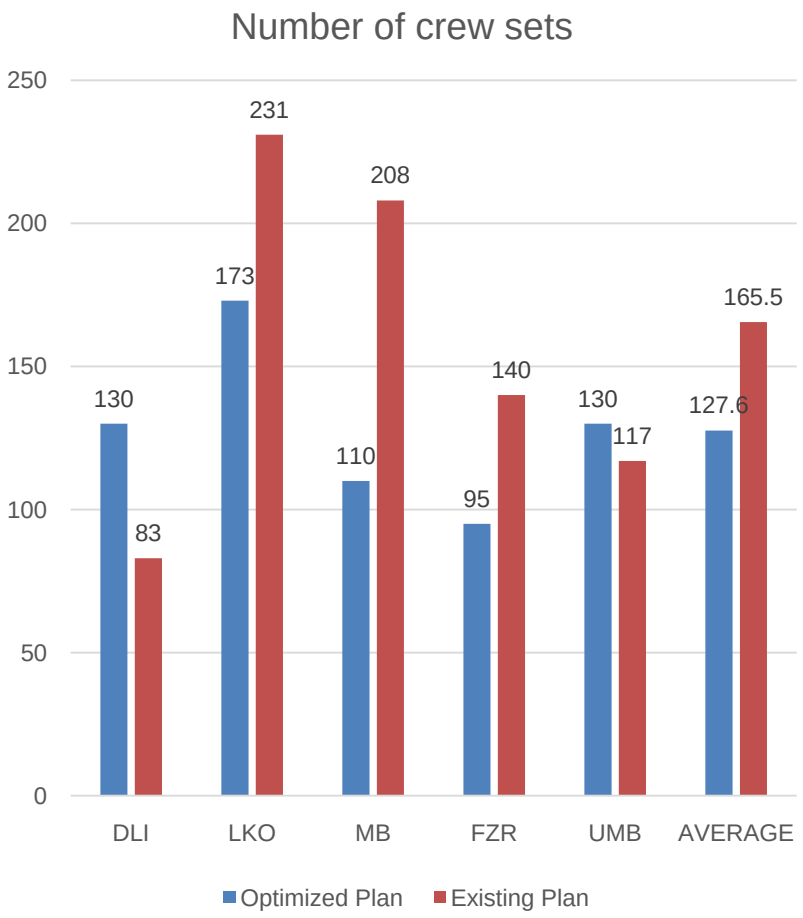
- 18.09% more utilization in duty hours



Number of crew sets

- Optimized Plan needs 638 crew to run 1187894 driver KM per week.
- In current links 779 crews run 1098153 driver KM per week
- To run same KM we would need 590 crew at optimized rate thus a saving of 189 crew.

%saving = 24.28



* In DLI Division 83 crew does not include electric crew. KM mismatch also due to data unavailability.

Financial Benefit

- Estimating the INR Benefit Per Crew Set
  - Leave Reserve-15%, Training Reserve-15% (Total 30%)
  - Salary per crew set per year(1 Mail Express Driver + 1 Mail Express Guard+ 1Senior Assistant Driver)= 12+12+6=30Lacs
  - Perks per person per year House (HRA-30%), medical, Pass/PTO= 4lacs
  - Total per crew set per year= 42 Lacs
  - Plus pension (30%)= 54.6 Lacs/year.
  - One LI for 25 driver and assistant drivers, one DTI for 50 Guards. Thus overhead of LI and DTI per crew set- 4% LI and 2% DTI
  - Administrative overhead per employee- 5%
  - Thus if we save 1 crew sets in planning, we save

    1 X 1.3(LR+TR) X 54.6 (salary + perks + pension) X 1.06 (LI+DTI) X 1.05 (Admin Overheads) Lacs

    = 79 Lacs per year.
- Total Rs. Saving for 189 crew = 149.3 Cr per year. (this excludes passenger trains of NR)
  - Less time in running rooms will reduce running room operating cost which is not calculated

Next steps as per Mathologic

- We will input all the crew change point data for MB, DLI and LKO divisions. Then we will be in a position to give precise improvement advice for all the divisions.
- Software is available for use by Railways.
- We can make a zero base plan for all Indian Railways, the way we have done for northern railway. This will give us upper limit on utilization of crew.
- We are sure that on all India basis we should be able to save more than 1000 crew sets which should save 790 crore Rs per year. It is like 2 Cr per day or like price of 56 Locomotives. Every week we can buy a new locomotive with that money.
- IIM Calcutta is interested to write a case study on crew link optimization exercise. This will be useful to record the learnings from this innovative work which will help other such innovative works in railways. This will also improve the image of the railways.

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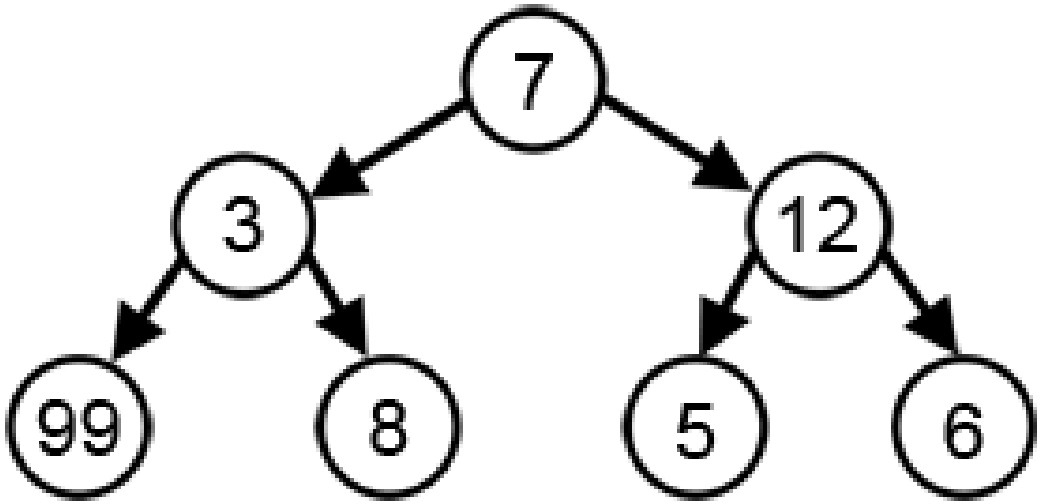
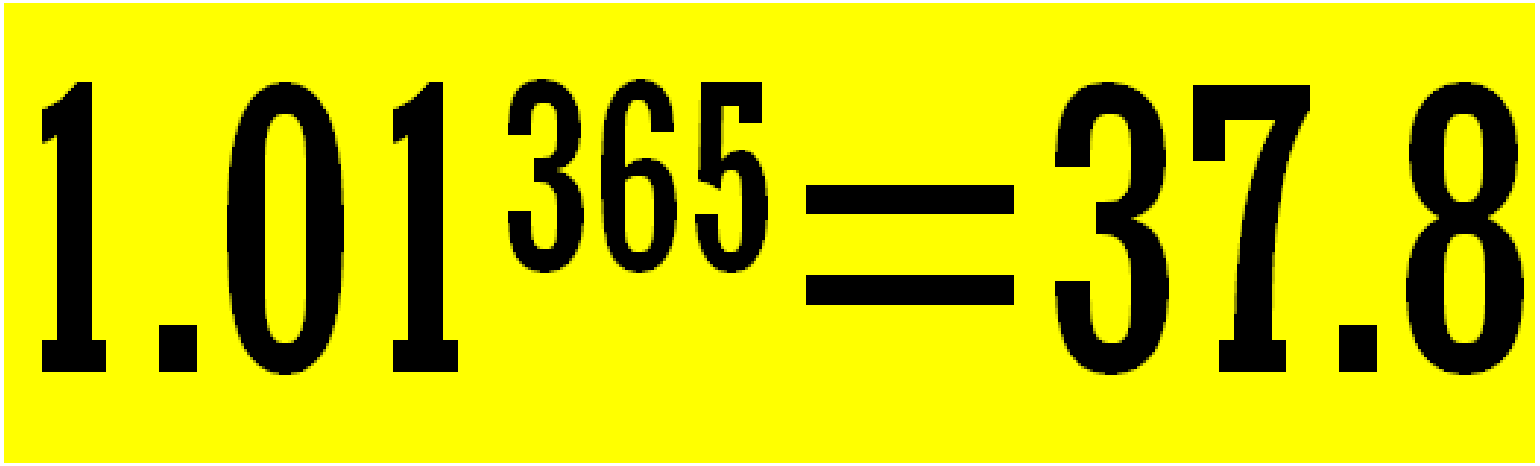
Challenge of Railways

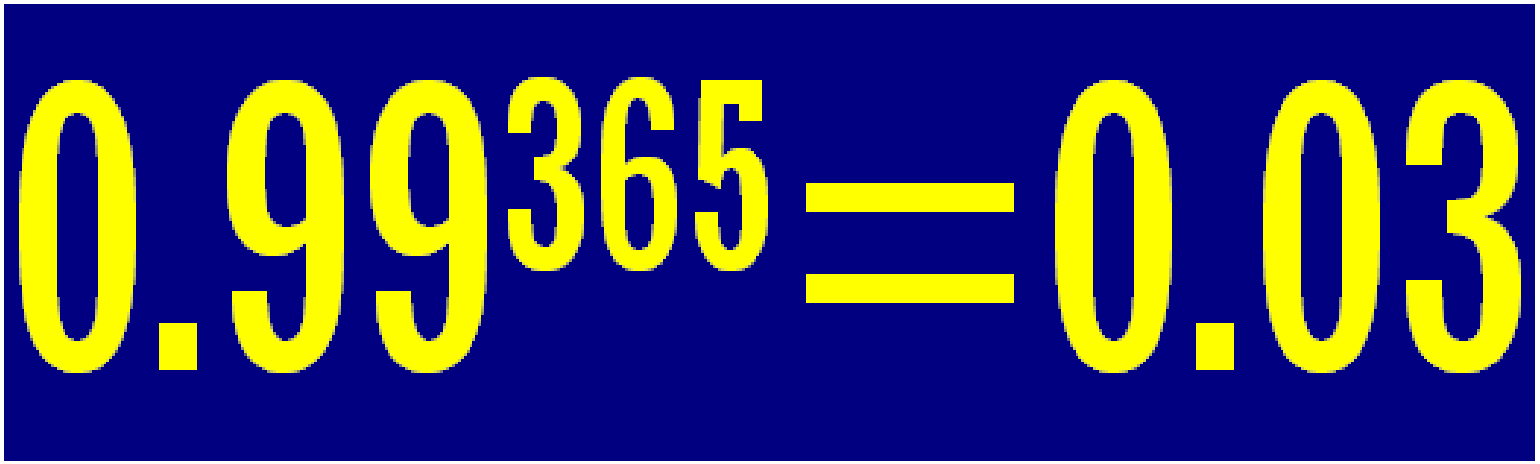
- Local optimization is done manually and the larger picture is missed.
- https://en.wikipedia.org/wiki/Greedy_algorithm



Discussion….
Possibility of Optimization in other areas

- Use DEMU/EMU for short distance Passenger Trains
- Where to locate DEMU/EMU sheds
- Location of Freight Hubs/ICDs
- Location of Loco and Coach Maintenance Sheds – Capacity assessment
- Time Tabling
- Empty Wagon movement and fare structure
- Mega Block Planning
- etc. etc.





The power of increment

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End of Document