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An Optimization Model to Estimate Railway Network Capacity

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Abstract- *A continuous growth in passengers and freight creates a high demand to run an extra number of trains. A limited infrastructure is a bottleneck to fulfill the demand. As the investment in extending the infrastructure of therailway is so high and time-consuming so, it is economical to improve the capacity by efficiently utilizing the existing infrastructure. In this article,a capacity model is developed that estimate the absolute capacity of the network. If once the capacity is determined than capacity planning on particular corridor can be done accordingly.*

Keywords- Capacity, Optimization model, Railroad, Networks.

1. Introduction

Capacityis defined as the number of trains that canbe incorporated into a timetable that is conflict-free, commercially attractive, meeting regulatory requirements, and can be operated in the face of anticipated levels of primary delay while compliance with performance targets [1].

According to International Union of Railways (UIC), the capacity governs by speed, heterogeneity, thespeed of trains, and stability parameters that create a balance. Change in one parameter setting force to adjust the other parameters as shown in figure 1 working of mix trains and metro trains [2].

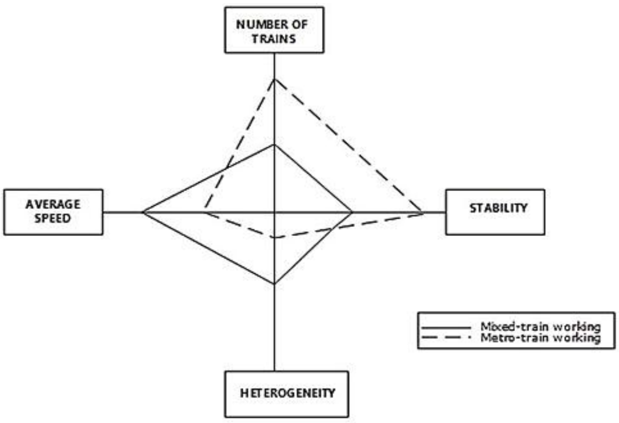

Figure 1. Capacity balance (UIC, 2004)

There are several methods to determine railroad capacity consumption. These methods can be dividedinto analytical methods, parametric methods, optimization methods, and simulation methods. In this paper, an optimization model is developed to determine theabsolute capacity of therailroad.

2. Literature Review

Optimization methods are extensively used to give the strategic solutions of sub problems (Train scheduling, routing, platform allocation, siding, etc.) of capacity utilization. These techniques search the optimal solution (generally in the form of thesaturated timetable) subject to constraints. In these techniques, the capacity is determined by bottleneck analysis approach, by multi-commodity flow approach, and by some heuristic approaches.

Changing in infrastructure and operation parameters of railway line brings an increased level of track capacity [3]. [4] Proposed an approach with a potential to explore the capacity of whole circulation system systematically and also analyze the bottlenecks with capacity constraints.

[5], [6] find the different applications of discrete time multi-commodity flow model in transportation problems. [7] Demonstrated the problem as Binary Multi-commodity network design model with the help of route arcs and node arcs.

The heuristic approaches are commonly used to determine the capacity of complex networks quickly but give the approximate results rather than exact. [8], [9], [10], [11] developed different heuristic for some issues of capacity.

The model developed in this paper determines the capacity of a network as well as individual corridor capacity.

3. Optimization model

An optimization model for capacity calculation is as follows:

Table 1 Model Parameters

i, j	Train type indices, set of train types I = {1, 2….}
m, n	Location of nodes
→	Direction
T	Time duration
t	Sectional running time
∅	Set of input output nodes
$\propto_i$	Proportional distribution of train type i
β_i	Directional distribution of train type i
μ^{m-n}	Proportional use of corridor m-n
$X_i^{m\to n}$	a number of train type i traverse from location m to n.

Objective function,

Maximize $\sum_{\forall m,n\in\emptyset}\sum_{\forall i} X_i^{m\to n} + X_i^{n\to m}$ (1)

Subject to,

$X_i^{m\to n} + X_i^{n\to m} = \propto_i \sum_{\forall j}(X_j^{m\to n} + X_j^{n\to m}) \quad \forall i, j \in I$ (2)

$X_i^{m\to n} = \beta_i(X_i^{m\to n} + X_i^{n\to m})$ (3)

$\sum_{\forall i}(t_i^{m\to n}X_i^{m\to n} + t_i^{n\to m}X_i^{n\to m}) \leq T$ (4)

$\sum_{\forall i}(X_i^{m\to n} + X_i^{n\to m}) = \mu^{m-n}\sum_{\forall m',n'\in\emptyset}\sum_{\forall i}(X_i^{m'\to n'} + X_i^{n'\to m'})$ (5)

$X_i^{m\to n}, X_i^{n\to m} \geq 0$ (6)

The objective function gives the absolute capacity of the network. Constraints (2) and (3) are for proportional and directional distributions of train types, respectively, on corresponding corridors. Constraint (4) is the

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bound on theoperational time of train types on tracks. Constraint (5) emphases the proportional use of all corridors. Constraint (6) is for positivity requirement.

4. A Case Study

A case study is selected to show the application of the capacity model. A network is considered as illustrated in figure 2. The networkconsiders both single and double tracks. The networkconsiders the four I/O points as (A, B, C, D).In this network there are five operating corridors as {(A-D), (A-C),(B-C), (B-D), (A-B)}. Three train types are running in this network with velocities (KMPH) V = (40, 60, 80).

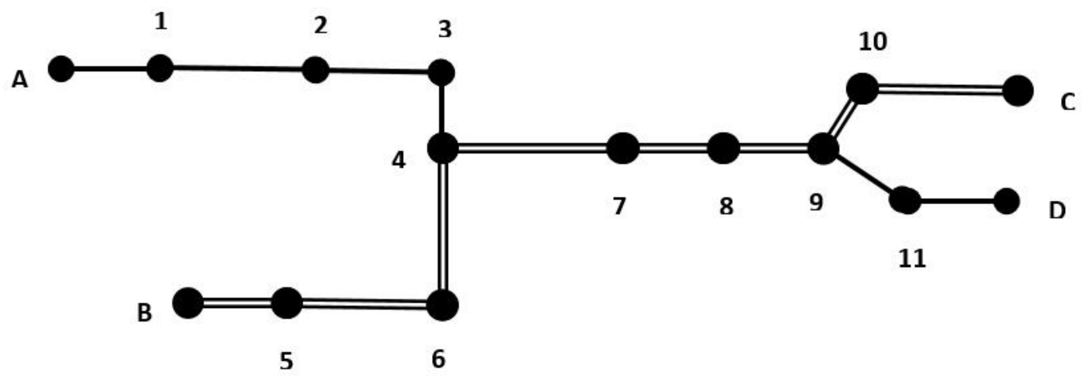

Figure 2. Network Diagram

Table 2 shows the data of the network. In this network total 14 number of sections. Table 3 shows the proportionaland directional distributions of train types according to the corridor.The time window is selected 1440 minutes. Solve the model in CPLEX and corridors capacity is shown in Table 4. The network capacity is the sum of independent corridor capacity, which is 495.995.

Table 2 Route Attributes

Corridor No.	Corridor	Section. No.	Section	Length	Line
1	A-D	1	A-1	4	1
2	A-C	2	1-2	7	1
3	B-C	3	2-3	5	1
4	B-D	4	3-4	3	1
5	A-B	5	B-5	4	2
		6	5-6	7	2
		7	6-4	6	2
		8	4-7	6	2
		9	7-8	4	2
		10	8-9	3	2
		11	9-10	4	2
		12	10-C	4	2
		13	9-11	3	1
		14	11-D	6	1

Table 3 Proportional and Directional distributions

Proportional distributions				**Directional distributions (forward)**			
Corridor	**Train types**			**Corridor**	**Train types**		
	1	**2**	**3**		**1**	**2**	**3**
A-D	0.40	0.40	0.20	**A-D**	0.45	0.50	0.48
A-C	0.30	0.55	0.15	**A-C**	0.50	0.50	0.50
B-C	0.32	0.40	0.28	**B-C**	0.42	0.50	0.67
B-D	0.45	0.20	0.35	**B-D**	0.42	0.50	0.50
A-B	0.26	0.64	0.10	**A-B**	0.40	0.50	0.67

Table 4 Absolute Capacity of Corridors and Network

Corridor	**Absolute Capacity**
A-D	50.018
A-C	120.27
B-C	190.18
B-D	90.424
A-B	62.056
Network Capacity	**495.955**

5. Conclusion

This paper provides the optimization model for estimating network capacity. The objective function of the model provides the maximum available capacity subject to operational and infrastructural constraints.Any complex network can be analyzed through this model. The capacity of sections can also be accessed without significant modifications in the model. So, this model can be used by Railways to determine the Absolute capacity of networks.

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