AN OPTIMIZATION MODEL TO DETERMINE THE ABSOLUTE CAPACITY OF RAILWAY NETWORKS

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***Abstract*— Railway's limited infrastructure and continuous growth in passenger and freight demand worldwide creates a need for efficient utilization of railroad capacity. So, for this, it is important to know the actual traffic that can run over the railway lines. In this paper, an optimization model for estimating absolute capacity over defined infrastructural and operational conditions is developed. The inputs of the model are line attributes, proportional and directional distributions of train types and average velocity. A case study illustrates the fitness of the model. The model is suitable for the planning of new railway lines.**

***Index Terms*- Capacity, Railways, Optimization, Networks.**

I. INTRODUCTION

Railways have always played a distinctive role to accomplish transportation needs of people and simultaneously serving as a critical infrastructure facilitator for carriage of goods. Due to globalization and fast progression in the economy, an extensive growth is observed in transportation sector worldwide.

The limited infrastructure is serving as a bottleneck to grow railroad transportation up to demand. As the investment in infrastructure development to enrich capacity is extremely costly and time-consuming so, transportation planners focused on capacity enhancement techniques through improved operations. The goal of the capacity analysis is to best use the potentially available capacity to maximize the number of trains subject to constraints levied by heterogeneity in traffic, stopping patterns, etc.

II. 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 saturated timetable) subject to constraints.

Changing in infrastructure and operation parameters of railway line brings an increased level of track capacity [1]. [2] Proposed an approach with a potential to explore the capacity of whole circulation system systematically and also analyze the bottlenecks with capacity constraints.

[3], [4] find the different applications of discrete time multi-commodity flow model in transportation problems. [5] Demonstrated the problem as Binary Multi-commodity network design model with the help of route arcs and node arcs.

III. MATHEMATICAL MODEL

The absolute capacity is the number of trains that could traverse over the line sections of a corridor in both the direction. The absolute capacity of a network is the total number of trains that traverse all corridors. It is difficult to determine the absolute capacity of networks due to the interaction of corridors. Thus, an optimization model is needed to handle the complexity. The following model is used to determine the absolute capacity of network.

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
$\emptyset$	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
$X_i^{m\to n}$	number of train type i traverse from location m to n.

$$MAX = \sum_{\forall m,n\in\emptyset}\sum_{\forall i} X_i^{m\to n} + X_i^{n\to m} \quad (1)$$
$$X_i^{m\to n} + X_i^{n\to m} = \propto_i \sum_{\forall j}(X_j^{m\to n} + X_j^{n\to m}) \quad \forall i,j \in I \quad (2)$$
$$X_i^{m\to n} = \beta_i(X_i^{m\to n} + X_i^{n\to m}) \quad (3)$$
$$\sum_{\forall i}(t_i^{m\to n}X_i^{m\to n} + t_i^{n\to m}X_i^{n\to m}) \le T \quad (4)$$
$$\sum_{\forall i}(X_i^{m\to n} + X_i^{n\to m}) = \mu^{m-n}\sum_{\forall m',n'\in\emptyset}\sum_{\forall i}(X_i^{m'\to n'} + X_i^{n'\to m'}) \quad (5)$$
$$X_i^{m\to n}, X_i^{n\to m} \ge 0 \quad (6)$$

Equation (1) gives the absolute capacity of the network which is the sum of the individual capacity of corridors. Constraints (2) and (3) are for proportional and directional distributions of train types on corridors. Constraint (4) is to limit the operational time of service on tracks. Constraint (5) emphases the proportional use of corridors. Constraint (6) is to fulfill positivity requirement.

IV. A CASE STUDY

To illustrate the application of the capacity model, a network is considered (Fig. 1). The network has both single and double tracks. The network considers the four input-output points as A, B, C, D and four corridors as A-D, B-C, B-D, A-B. Four train types are running in this network respectively with velocities (KMPH) 30, 40, 60, and 80.

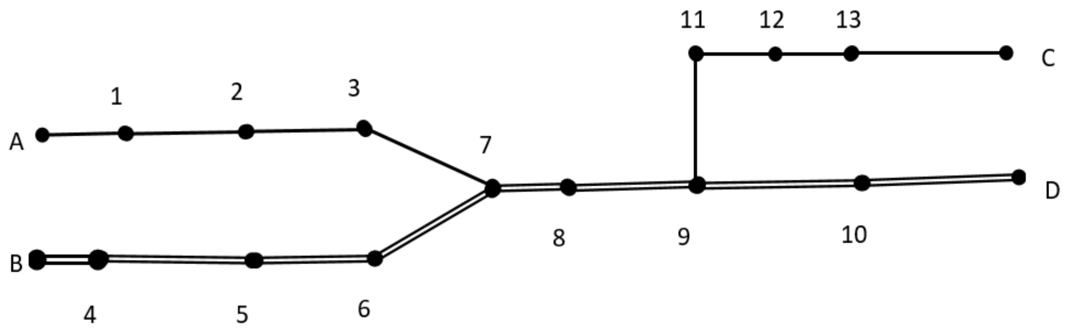

Figure 1 Network Layout

Table 2 shows the route attributes of the network. In this network total 16 number of sections. Table 3 shows the proportional distributions of train types according to the corridor. Directional distributions are shown in the forward direction. The model is solved in CPLEX software and results are shown in Table 4. The network capacity is the sum of independent corridor capacity. So, the total number of trains that can run in 24 Hrs. in the network are 233.94.

Table 2 Route Attributes

S. No.	Corridor	No. of Sections	Sec. No.	Section	Length	Line
1	A-D	8	1	A-1	8	1
2	B-C	10	2	1-2	10	1
3	B-D	8	3	2-3	10	1
4	A-B	8	4	3-7	12	1
			5	B-4	6	2
			6	4-5	12	2
			7	5-6	11	2
			8	6-7	10	2
			9	7-8	6	2
			10	8-9	11	2
			11	9-10	12	2
			12	10-D	12	2
			13	9-11	10	1
			14	11-12	8	1
			15	12-13	6	1
			16	13-C	13	1

Table 3 Proportional and Directional distributions

Proportional distributions					**Directional distributions (forward)**				
Corridor	**Train types**				**Corridor**	**Train types**			
	1	**2**	**3**	**4**		**1**	**2**	**3**	**4**
A-D	0.40	0.07	0.30	0.23	**A-D**	0.45	0.50	0.48	0.47
B-C	0.39	0.06	0.29	0.26	**B-C**	0.42	0.50	0.67	0.50
B-D	0.34	0.00	0.40	0.26	**B-D**	0.42	-	0.50	0.50
A-B	0.42	0.18	0.18	0.22	**A-B**	0.40	0.50	0.67	0.55

Table 4 Absolute Capacity of Corridors and Network

Corridor	**Absolute Capacity**
A-D	51.48
B-C	16.10
B-D	132.62
A-B	33.74
Network Capacity	**233.94**

V. CONCLUSION

In this paper, an optimization model for evaluation of absolute capacity is presented. The objective of the model is to find the maximum capacity of the network in the given circumstances under specified period. The results show the Absolute Capacity of individual corridors and whole network. So, this model can be used in planning phase by Railway managers to estimate the Absolute capacity.

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