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Heavy Haul Corridor Selection and Service Design Models

by

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Abstract: Heavy haul corridors are capital intensive and are relatively expensive to maintain. It is therefore imperative that heavy haul corridors are chosen with care, such that sufficient traffic is available on the corridors to ensure adequate returns. The strategic choice will be dictated by projected pattern and volume of freight traffic, projected pattern of passenger traffic and terminal facilities. Various choices may be obtained with different rolling stock and locomotive capacity to obtain scenarios with existing and future fleet characteristics, as well as future terminal facilities.
Further, tactical operating plans for networks with heavy haul corridors should be designed properly to ensure maximum utilization of such corridors with a given set of customer demands, rolling stock and locomotive size and capacity, terminal facilities and capacity of peripheral networks. Such operating plans which might span from a fortnight to three months, include decisions regarding routes, frequency of services, aggregation and disaggregation policies, empties repositioning policies and direct or consolidating train service policies. These operating plans may also depend on the service level committed to a customer, which is again tied to a particular pricing.
This paper proposes two operations research based models: (i) a model for choosing a heavy haul corridor(s) within an existing network and (ii) a model for design of an optimal operating plan for an existing network with a designated heavy haul corridor(s). The models are further demonstrated on a hypothetical railroad network with test data.
The contributions of the proposed models are manifold, few of which are: scenario analysis with various combinations of demand patterns, fleet size and characteristics and terminal facilities; enabling investment decisions for up gradation of track, fleet or terminal facilities through comparative analysis of scenarios; and enabling service design to meet specific customer needs.

1.Introduction

1.1 Heavy Haul corridors generally have the following characteristics: (a) corridors have entirely freight traffic movement with little or no passenger traffic (b) corridor tracks capable of handling high axle load wagons (c) corridor stations/yards are capable of handling long train lengths and (d) corridor track side power carriers and equipment are capable of catering to multiple locomotives with high horsepower. Thus heavy haul corridors have higher capital cost of (i) tracks which must be capable of handling high axle load wagons, (ii) high axle load wagons, and (iii) locomotives with higher horse power and better braking systems. The operating costs of heavy haul corridors are also higher due to increased maintenance costs of tracks and fuel costs incurred by high horse power locomotives. However the favorable economics of heavy haul corridors lie in the reduction of unit costs due to longer trains and higher payload wagons [1] as well as higher average speeds than mixed freight and passenger train corridors. Thus heavy haul corridors are economical through extension of all the three major limiting factors of railway transport- axle load, train length and speed [2].

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1.3 Further, tactical operating plans (or service designs) for networks with heavy haul corridors should be designed properly to ensure maximum utilization of such corridors with a given set of customer demands, rolling stock and locomotive size and capacity, terminal facilities and capacity of peripheral networks. Such operating plans which might span from a fortnight to three months, include decisions regarding routes, frequency of services, aggregation and

Decision variable:

x_s =1, if the section s is retained as a normal section

=0, if the section s is upgraded to a heavy haul section

The annual traffic flows (in million tons) for each route (origin-destination pair) are given in the Table 2. Thus the annual traffic on route BG is 1000 million tons.

	A	B	C	D	E	F	G	H	I
A	-	500	400	10	10	30	50	10	20
B	300	-	10	500	200	600	1000	300	20
C	300	50	-	10	20	70	20	10	30
D	10	600	20	-	10	30	50	20	50
E	10	300	100	20	-	40	70	80	10
F	200	20	1	10	50	-	3	30	40
G	40	20	10	40	200	50	-	10	100
H	100	10	500	2	30	100	20	-	50
I	20	80	700	100	30	200	10	80	-

Table 2

2.3.1 We use the model for the network in Figure 1 along with shortest routes given by Table 1 and annual traffic flows given by Table 2 for two different scenarios, with different cost functions for heavy haul corridor and normal railway corridor. We assume the following data for both the scenarios: CCN=70, CCH=100, TN=60,TH=120.

In the first scenario, we assume that FN=10, FH=30, VN=7, VH=12 for all sections. Solving2 Tw[(scen=6mnons. Sc certification of wagons after accruing certain mileage, restrictions on maximum traction power drawn (thus limiting maximum traffic on certain routes) , terminal operation hours (say 16 hours operations in a yard necessitating all wagon pickup and drop off exercises to be restricted within those 16 hours) and terminal constraints (say only four lines in the reception yard, resulting in limits on maximum number of trains that can be received).

Service Design is a tactical planning exercise carried out for the entire network-wide movement for all customers [1]. This is generally done on a fortnightly or weekly basis, taking into consideration the latest information on (a) traffic demand patterns (b) resource availability (considering track, wagon and locomotive maintenance schedules and forecasted availability) and (c) external influencers (say forecasted inclement weather which might slow down train movement in certain sectors). It must be distinguished from strategic planning, in the sense that the planning is done considering existing resources over a medium time frame (say one to three weeks), which rules out long-lead options such as augmentation of resources (say doubling of track or adding wagons to the fleet). A service design is similar to a passenger train timetable which allows the dispatcher to form appropriate trains and dispatch them at the proper time.

3.2 In order to appreciate the complexity of network design let us take a linear network consisting of four consecutive stations P,Q,R and S spaced 200 km apart. Let us assume that the traffic forecasts for the following few weeks are as follows: (a) 20 wagons of customer A are to be transported from P to Q on Monday, Wednesday and Friday (b) 10 wagons customer B are to be transported from P to S on Tuesday, Thursday and Sunday (c) 40 wagons of customer C are to be transported from Q to S on Friday and Saturday (d) 30 wagons of Customer D are to be transported from Q to R on Thursday and Sunday (e) 30 wagons of customer E are to be transported from R to S on Monday and Sunday (f) 50 wagons of customer F are to be transported from S to Q on Friday and Sunday (g) 20 wagons of customer G are to be transported from R to P on Wednesday and Friday. Customers are prioritized as X, Y and Z, with X being lowest priority, Y as intermediate priority and Z as highest priority. Customers A,E and G have priority X; B and D have priority Y; and customers C and F have the highest priority Z.

If we analyze the problem, we come across a wide range of options of service network design. For example, if we take customer A alone, there are numerous options available. Few of the options for Monday's indent of customer A would be (i) run a train with only 20 wagons from P to Q on Monday (ii) run a train on Wednesday with 40 wagons from P to Q combining Wednesday's indent of customer A (iii) run a train on Friday with 60 wagons from P to Q combining Wednesday's and Friday's indent of customer A (iv) run a train on Tuesday with 30 wagons from P to S combining Tuesday's indent of customer B; the train will drop off 20 wagons of customer A at Q (v) run a train on Tuesday with a maximum of 40 wagons from P to S combining Tuesday's indent of customer B and earlier Sunday's indent of customer E; the train will drop off 20 wagons of customer A at Q and pickup 30 wagons of cust w this index is used for day of week, on which a train is operated with w=1,2,….,7 and w=1 denoting Monday

v this index is used for day of week, on which an indent is raised by customer or wagon is loaded by the customer

j this index is used for customers

Notation for data elements:

Q	total number of customers; there are 8 customers in the example
C_R	cost of running a train
C_j	cost of wagon waiting for train formation and dispatch, for each day for customer j
C_T	cost of picking up and dropping each wagon at terminals en route
R	total number of routes; thus r=1,…,R and s=1,….,R the total number of routes in the example is 12, wherein routes are PQ,PQR,PQRS,QR,QRS,RS, SRQP,SRQ,SR,RQP,RQ and QP
h_{rs}=1,	if route r is included in route s (for example route QR is included in route PQRS)
=0,	if route r does not include route s
p_{rs}	number of pick up and drop off terminals for train run on route s for customer demand for transport on route r (for customer demand of transport on route QR, the train operated on route PQRS has a pickup at Q and a drop off at R; thus p=2 for r=QR, s=PQRS)
D_{jvs}	indent raised (in terms of wagons) by customer j on day v for transport on route s
M	maximum number of wagons in a train

Decision variables:

x_{wrjvs} =1, if freight train is operated on day w on route r with customer j's load indented on day v on route s

=0, if freight train is not operated on day w on route r with customer j's load indented on day v on route s

y_{wr} =1, if freight train is operated on day w on route r

=0, if freight train is not operated on day w on route r

We wish to minimize the sum of cost of running the trains, cost of wagon waiting for train formation and dispatch for each day for different priority customers and the cost of picking up and dropping each wagon at terminals en route. The objective function is thus given by the summation of three expressions pertaining to the three costs:

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Subject to the constraints,

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assuming maximum number of wagons in a train M=70. The service design given below omits the movement of empties required for wagon balancing. The integer programming model requires approximately 4 seconds for solution using IBM-ILOG CPLEX software on a 1.33 GHz laptop.

Scenario	**Costs**	**Optimal Service Design**
1	C_R=1, C_j=4,6,8 for priority X,Y,Z C_T=10	16 trains operated as follows: (a) 3 trains from P to Q on Mon, Wed and Fri with 20 wagons of A (b) 3 trains from P to S on Tue, Thur and Sun with 10 wagons of B (c) 2 trains from Q to S on Fri and Sat with 40 wagons of C (d) 2 trains from Q to R on Thur and Sun with 30 wagons of D (e) 2 trains from R to S on Mon and Sun with 30 wagons of E (f) 2 trains from S to Q on Fri and Sun with 50 wagons of F (g) 2 trains from R to P on Wed and Fri with 20 wagons of G.
2	C_R=500, C_j=4,6,8 for priority X,Y,Z C_T=10	9 trains operated as follows: (a) 1 train from P to Q on Wed with 40 wagons of A's Mon & Wed indents (b) 1 train from P to S on Sat with 20 wagons of A's Fri indent and 40 wagons of C's Sat indent (c) 1 train from P to S on Fri with 30 wagons of B's Tue, Thur & Sun indents and 40 wagons of C's Fri indent (d) 1 train from Q to R on Thur with 30 wagons of D's Thur indent (e) 1 train from Q to R on Sun with 30 wagons of D's Sun indent (f) 1 train from R to S on Mon with 60 wagons of E's Sun and Mon indents (g) 1 train from S to Q on Fri with 50 wagons of F's Fri indent (h) 1 train from S to Q on Sun with 50 wagons of F's Sun indent (i) 1 train from R to P on Fri with 40 wagons of F's Wed and Fri indents
3	C_R=500, C_j=4,6,8 for priority X,Y,Z C_T=200	operated as follows: (a) 1 train from P to Q on Fri with 60 wagons of A's Mon, Wed

References

1 Zhuan, X and Xia, X. Cruise Control Scheduling of Heavy Haul Trains. IEEE Transactions on Control Systems Technology (2006), 757-766.

2 Meulen, RD. Railway Globalization and Heavy Haul. In Proceeding International Heavy Haul