Application Of Operations Research In The Indian Railway Transport System

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INTRODUCTION

In this paper we are going to look at the different aspects in which Operations Research has helped the Indian Railway Industry, first let us see a brief on the Indian Railways to understand the magnitude of the Operations Research that is being applied.

The Indian railways is 164 years old and is one of the most important lifelines of India , transporting every day on an average 2,50,00,000 passengers, managing passage of 14,300 trains daily whose distance covered is greater than the distance to the moon times three , the total length of the railway tracks laid down are 65,000 kms, with an organisation so big and so vast the reliance on planning is necessary to study to understand just how the whole system works and what are the factors contributing to its design , we therefore are now going to take a look at the operations planning of the Indian railways starting with a brief about Operations research in the sector

We are going to study in this paper the

1. Optimal design of timetables, through which we will learn about how the whole system of 14,300 trains are scheduled and what is the logic in it all
2. Locomotive Assignment Problem, through which we can study how the minimum cost is determined for locomotives located in some central depots to a set of pre schedules trains in order to provide sufficient power to pull the trains from their origins to their destination
3. Dynamic Pricing, to allow pricing to be determined by market demand and supply without largely disturbing the passengers.

OPTIMAL DESIGN OF TIME TABLES

One of the most complex tasks of Indian railways is to design a train schedule. The scheduling process for railway systems involves a complex procedure that includes demand analysis, line planning, train scheduling, rolling stock planning, and crew scheduling. There are two types of scheduling – Static and Dynamic. When delays, interruptions, or failures, etc. occur, dispatchers in the traffic management centres supervise the railway network and they resolve the conflicts through rescheduling. In static scheduling, information of all the trains is with us beforehand. But in dynamic it is available, sometimes, only when it enters the network.

Researchers have used Integer Programming solved by Langrangian relaxation. Lagrangian relaxation is a technique well suited for problems. There are several decision variables and constraints in scheduling of trains.

Decision Variables on Trains

- Origin, destination and routes of trains
- Days of operation and train times
- Trip plans for all stock
- Locomotive assignment
- Crew assignment

Constraints are

- Yard capacity
- Line capacity
- Train capacity
- Rules and norms for operations
  The Indian Railways' Centre for Railway Information System (CRIS) is developing a Software Aided Train Scheduling and Network Governance (SATSaNG). This project is assigned with the task of constructing software tools to help with the planning process.

TIMETABLE DESIGNING

The scheduling process is started with estimating the customer demand of the service in a particular route i.e. volume per day between O-D pairs. Then we calculate the requirement of Trains between O-D pairs with frequency of operation. On the basis of that, a time-table is devised and resources required to follow the time tables are calculated. If the need of the resources is met with the availability of resources then the table is finalised. If the need of resources is more than the availability then there are two things that can be done- Short term action or Long term action. In short term action the schedule is revised to run on O-D pairs and in long term action we have to introduce augment resources.

Presently in Indian railways timetable is designed manually by feasible path construction and mapping train services. The problem with optimal timetable design is that there are large no. of trains and sections, there are many constraints, and no metrics is developed for schedule reliability, energy consumption, and rolling stock and crew requirements. Due to this entire mathematical model is not solvable because of its size. The resources needed for train services are:

- **Energy:** Energy Consumption depends on train speed, section terrain (ruling gradient & curvature), rolling stock resistance & locomotive efficiency, and regeneration. This is measured through total consumption of energy [TCE].
- **Sectional capacity** this is measured through Total slack index [TSI].
- **Rolling stock:** number of rakes required for a train service depends on the cycle time, maintenance requirements and running time of trip. This is measured through Rolling Stock Deployment Index [RSDI]

- **Crew:** This is measured through crew deployment index [CDI]

  The main objective function is to minimize the total energy consumption, maximize the slack index, minimize the rolling stock deployment index and minimize crew deployment index. This makes it a multi-criteria decision making problem.
  To solve the problem we have to determine relative weights of each objective using AHP(Analytic Hierarchy process) and then compute the distance function for distance from PIS (positive ideal solution),NIS (negative ideal solution) and closeness rating. Further we can either maximize CR using TOPSIS(Technique for Order Preference by Similarity to Ideal Solution) or minimize distance from PIS using GCA.

LOCOMOTIVE ASSIGNMENT PROBLEM

In comparison with common aeronautics and street transport, railroad transport is a perceived vitality sparing, reliable, high-limit and minimal effort part. In this manner, railroad transport draws in governments and analysts around the world. Train Scheduling Problem and Locomotive Assignment Problem are two of the essential work in railroad administration. Train Scheduling Problem(TSCP) goes for deciding the departure and arrival time for trains at each station. With a given train schedule, most inquiries about in regards to Locomotive Assignment Problem (LAP) intends to introduce the optimal/sub-optimal train timetable to cover every single planned prepare with the thought of train-to-train connections.

Indian Railways has not yet fully utilized the potential of Operations Research. There is a lot of scope of improvement if the issues in the Railways are solved using OR methods. The specialists in the field of operational research are also motivated as there is increase in the computation capabilities of the modern day technology. There is also a debate on tonnage based versus schedule based approach to freight train operations. Participation operations of locomotive assignment and train schedule problems have less references in OR. Research has demonstrated that calendar based system particularly in Canadian Railways has been more productive. The accessibility of cutting edge processing power or potentially programming has empowered numerous Railways to receive this system. Extensive scale complex cargo prepare operations can't be dealt with by exhibit day programming attributable to the quantity of parameters and tremendous time taken for the computations. Along these lines in a way a problematic arrangement is forced as the issue must be sub partitioned into arranging, booking and directing and afterward being managed independently.
The key goal of the locomotive assignment problem is to allocate a group of locomotives to a set of trains and at the same time satisfying the of operational and budget constraints and optimizing objectives. The best instance would be of the United States Freight System where we can see the effects of competitiveness in the transportation sector. The whole array of modes of transportation - Waterways, roadways, airways, railways, offers best prices and services, and the freight rail element of this system is very important for the competition of many industries an economies.

Many ways can be found for differentiating locomotive assignment problems as used practically. For instance, problems may be differentiated considering the goal or objective pursued by the modeller. Some classical objectives are the minimization of operating costs (maximization of profits) or the minimization of the fleet size. Minimization of deadheading times is one more objective during which locomotives do not pull trains but are still repositioned over the network.

Problem Description:

The LAP is a very complicated issue and analysts and researchers of the world have been grappling with the problem. In order to give optimum power to pull the trains from the start to the final end, this problem is used to determine the minimum cost assignment of locomotives which are present at different central depots you a set of pre-scheduled trains. The problem includes a set of homogeneous locomotives, a set of depots where locomotives are initially located, and a set of pre-scheduled trains with different degrees of priority (e.g., normal passenger trains, high speed trains, freight trains, etc.).
A problem solved by Ahuja el al. (2005) has highlighted the extent of the problem. This problem is of CSX Transportation, a Class 1 railroad in United States.
An estimated saving of over 400 locomotives annually lead to the savings of over a hundred million dollars at CSX was calculated, when compared to the software at CSX.
CSX Transportation problem was Locomotive assignment for 538 trains, with differentiated weekly frequencies, 119 stations and 5 types of locomotives. In the course of 7 days, the number of total trains which differed in a running day was 3324 and the resulting weekly space-time network consists of 8798 nodes (events) and 30134 arcs (train trips)

The 2012-13 yearbook of Indian Railways mentions:

Asset	Total Number
Locomotives	10,499
Passenger Service Vehicles	59,600
Other Coaching Vehicles	6,792
Wagons	245,267

Number of passenger trains run daily in 2012-13 were 12961 and Goods train about 8637.

An annual run of a freight train about 390 million km on IR network carries almost a billion tonnes.

The size of the problem can be realized by these statistics. Iterative Partitioning is used to attempt this kind of problem. Ahuja (2002) mentions for solving such problems heuristic (approximation) algorithms have to be employed that can find nearly optimal solutions within a reasonable amount of computation time. Improvement algorithm, a self-learning algorithm that starts with a feasible solution and repetitively tries to get a better solution.
The local search algorithms are a wide class of improvement algorithms where an improved solution is gotten to by looking up for the “neighbourhood” of the current solution.

DYNAMIC PRICING IN INDIAN RALWAYS

Dynamic pricing is a strategy by which companies do not set fixed prices for goods or services but vary it according to the market demand. Different algorithms are used to fluctuate the prices and a variety of causes such as competitor pricing, supply and demand, and other external factors in the market are taken into account. This is a common practice in many sectors and each takes a slightly different approach to repricing based on its needs and the demand for the product.

McAfee and Te Velde have defined dynamic pricing, also referred to as yieldor revenue management, as a set of pricing strategies aimed at maximising revenue. They are most effective if the product characteristics co-exist. First, the product should be perishable like bus tickets, hotel bookings, generated electricity etc.Secondly capacity is defined before hand and can be amplified only at a very high cost.

Dynamic pricing is a strategy by which companies do not set fixed prices for goods or services but vary it according to the market demand. A variety of algorithms which are put to use result in the fluctuation of prices due to a number of different causes like prices prevailing in the market, supply with respect to the current demand and other external factors. All of these have to be taken into account while setting the final price.

These practices are common in several sectors however sector uses a slightly different approach based on the needs and the demand for the product

Now research in dyanamic pricing contains 2 specific parts

- **Dynamic pricing strategy under social learning**

  Social learning is a concept where people purchase products based on the buying habits or behaviour of other customers. This directly affects their perception of the product and plays a vital factor while they contemplate the price they have to pay and perceived utility which they will in turn receive.

- **Pricing with strategic consumers**

  Different prices for different consumer requirements have to be taken into consideration

Introduction of dynamic pricing in Indian Railways

In the interim budget speech by Railway Minister in Feb 2014, it was mentioned that an independent Rail Tariff Authority is being set up to rationalise fares and there was a proposal to expand dynamic pricing of tickets similar to the airline industry.

The adoption of dynamic pricing system is a positive step. The announcement – under which base fares will jump by 10% for every 10% berths sold in AC-II and AC-III compartments on these trains, with a cap of 50% hike on the original fare -- seeks to address the “fare versus freight” distortion of the Indian Railways.

IRCTC brought in several premium trains with dynamic ticket pricing that can only be booked through the website. The pricing pattern is like the strategy adopted by airlines where prices are directly proportional to demand. The current prices to each transaction is available at the time of reserving a seat on the IRCTC’s e-ticketing website.

Fare Structure for Rajdhani and Duronto category of Trains										
Charges % of berths	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
2S	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
SL	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
3A	1X	1.1X	1.2X	1.3X	1.4X	1.4X	1.4X	1.4X	1.4X	1.4X
2A	1X	1.1X	1.2X	1.3X	1.4X	1.5X	1.5X	1.5X	1.5X	1.5X
1A	1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
X= Base Fare										

How does dynamic pricing work?

The main aim of such a pricing strategy is to maximise occupants for the trains while increasing revenue. Occupancy is a commonly used measure in the logistics industry. Dynamic pricing algorithms work to ensure higher load factors via pricing differentiation. This is done by giving incentives to customers with confirmed travel plans and charging extra from customers with an uncertain travel itinerary. However, this is possible only if there is a high demand.

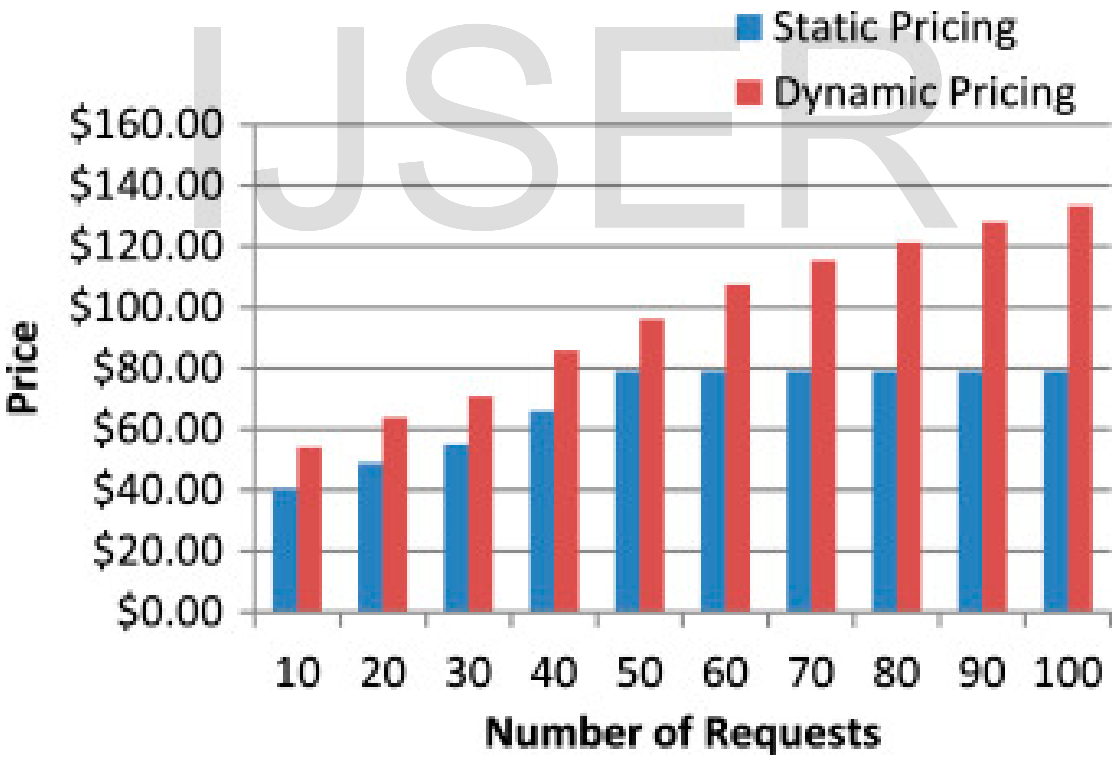
It divides the resources present into sub-resources or buckets. Some of these DP algorithms have a additional features like:

Dynamic bucket sizes: Based on past, present and future demand values buckets sizes constantly change. According to this even the same bucket would not have the same number of seats available during various points in the year.

Switching between buckets: Based on different factors, such as percentage of bookings as compared to past figures, proximity to the travel date, seats can alternate between buckets. For instance, if a train is expected to depart in a few hours and few tickets from the premium category are still unsold the tickets would then in turn be made cheaper by transferring them to a lower category bucket that is why it is sometimes possible to get cheaper tickets even right before our travel time as compared to if they had been booked in advance

Quantity of buckets:According to the different prices offered by the provider the number of buckets can vary. This results increase in quantity of sale as well as the revenue.

Price discrimination within bucket: If seats are sold fast it indicates that requirement is higher therefore prices within the bucket would rise which in turn would intern affect the other buckets and lead to an increase in their price as well. This means that the tickets sold at the start of sale of the bucket would be cheaper than the ones sold right at the end of the same bucket.



The key issue is how to decide the tariffs?

The main problem with dynamic pricing is figuring out the maximum limit that the prices can be set to and also how much premium a customer would be willing to pay before he starts considering other options. One of the strategies used is compete with airlines by using a similar structure where the prices increase in proportion to the demand curve. This also involves setting up a base price and the increasing according to proximity to departure and corresponding demand. The prices of the air tickets are also simultaneously monitored to ensure that the fares of premium trains is always less than that of airlines.

CONCLUSION

From the above Research it is clearly visible how operations research is vital to the survival and prosperity of the Indian railways and the success of the Indian railways as an organisation greatly depends upon the planning, scheduling and pricing of the rail system

The total prowess of the application of Operational Research in the field of Rail systems management has still not been harnessed but it has helped the Indian railways greatly, pulling it back from a near certain death in 2001, to a complete turnaround in its financial capabilities one of the major reasons for that turnaround was the effective use of Operations Research and we have demonstrated in this paper what was one of the main strategy (operations management) the Indian Railways used for the major turnaround that they achieved and what it entails.

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