REVENUE MANAGEMENT STRATEGIES IN THE RAILWAY INDUSTRY

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ABSTRACT

The article gives an introduction to the goals and conditions of Revenue Management systems as well as a classification of Revenue Management problems and an overview of potential application fields for Revenue Management systems in the guided traffic.

MOTIVATION

Within the last three years (1997-2000), the entire volume of traffic in Germany is increasing more and more (total passenger traffic +1.6%, freight traffic: +4.5% (1)), whereas the railway traffic as a part of the entire traffic volume is stagnating or even decreasing (passenger traffic -2%, freight traffic: -10% (1)). The rising number of secondary lines, which will be closed down due to their lack of profit, the increasing number of train delays, intensified by the overload of the main lines and the declining revenues of the railway transport operators compel for the development of new programmes for planning and marketing of the products and services of railway traffic. These plans must be consistently aligned to the customers’ needs and fulfil requirements like flexibility, competitive prices and the adaptation of supply according to the demand.

A programme to harmonise the use of track and vehicle capacity and to increase the profit for the railway companies, which takes this requirements into account, is Revenue Management, also called Yield Management. Revenue Management has its origin in the aviation sector, but in the meantime it is also employed in areas like hotel industry, car rental and ticket reservation for theatres and cinemas.
A requirement for the use of Revenue Management in business management is the existence of different conditions in the production process (2):

- The perishableness of the goods, that means, if the service is not requested within a certain timeframe, it will lapse.
- The service can be booked in advance.
- The capacity is relatively inflexible.
- High fixed costs of providing the service accompanied by low variable costs by selling an additional good.
- Considerable variation of demand.
- The possibility of segmentation of the customer into customer-groups according to their demand behaviour.
- The possibility of price differentiation.

These general requirements are valid for different parts of the railway business. On the one hand they describe the marketing of seats in trains of transit and passenger traffic as well as the cargo capacities in freight traffic. On the other hand they also apply for the marketing of railway slots in the scope of infrastructure provision. For the application of Revenue Management strategies to these sectors of railway management, the different characteristics of the application fields have to be investigated in detail.

**TAXONOMY OF REVENUE MANAGEMENT PROBLEMS**

Different production processes can be identified in the field of railway applications. The result of the production process is an immaterial and perishable inventory, which has to be consumed on a special date and is no more available afterwards, e.g.:

- from the view of the network infrastructure operator: railway slots or capacity of a certain railway line.
- from the view of a railway operator for passenger transportation: seats within the trains.
- from the view of a railway operator for freight transportation: single wagons or capacity within a wagon or a train.

Because of these distinguishing product characteristics, railway network operators as well as railway operators require special marketing methods, such as Revenue Management. Revenue Management is a technique that assists the allocation and pricing of perishable goods to different customer types at different times, in order to maximise both the revenue and the utilisation in a complementary manner (cf. (3), (4)).

By using Revenue Management techniques, the capacity is splitted into several classes with different price levels (e.g. full price and discount classes) and the clients are segmented into different customer groups according to their demand profiles. For each customer group a prognosis of their future demand is made. Based on these prognoses about the booking process, the number of units to be sold in each fare class as well as the fare of each class are dynamically determined in progression of the booking process. These strategies build a basic
Revenue Management model. In an advanced Revenue Management system, cancellations, overbooking and bumping strategies can be taken into account for optimising the utilisation and prices of service goods in order to maximise the total value of revenues for the railway network provider resp. the railway operator.

Weatherford and Bodily have introduced a taxonomy of Revenue Management problems which is shown in Table 1 (for detailed explanation of the taxonomy see (5) or (6)).

<table>
<thead>
<tr>
<th>Elements</th>
<th>Descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource</td>
<td>discrete / continuous</td>
</tr>
<tr>
<td>Capacity</td>
<td>fixed / non fixed</td>
</tr>
<tr>
<td>Prices</td>
<td>predetermined / set optimally / set jointly</td>
</tr>
<tr>
<td>Willingness to pay</td>
<td>build up / draw down</td>
</tr>
<tr>
<td>Number of discount price classes</td>
<td>1,2,3,...,I</td>
</tr>
<tr>
<td>Reservation demand</td>
<td>deterministic / mixed / random-independent / random-correlated</td>
</tr>
<tr>
<td>Show-up of reservations</td>
<td>certain / uncertain without cancellation / uncertain with cancellation</td>
</tr>
<tr>
<td>Turned down reservations</td>
<td>Lost / recaptured</td>
</tr>
<tr>
<td>Forecasting:</td>
<td></td>
</tr>
<tr>
<td>1. Seasonal data</td>
<td>no / yes</td>
</tr>
<tr>
<td>2. Used method</td>
<td>moving average / exponential smoothing / regression / quadratic spline / other</td>
</tr>
<tr>
<td>Group reservations allowed</td>
<td>no / yes</td>
</tr>
<tr>
<td>Diversion</td>
<td>no / yes</td>
</tr>
<tr>
<td>Displacement</td>
<td>no / virtual nest / bid price</td>
</tr>
<tr>
<td>Bumping procedure</td>
<td>none / full price / discount / auction / other</td>
</tr>
<tr>
<td>Asset control mechanism</td>
<td>distinct / parallel nested / serial nested / other</td>
</tr>
<tr>
<td>Decision rule</td>
<td>simple static / advanced static / dynamic</td>
</tr>
</tbody>
</table>

Table 1: Taxonomy of Revenue Management problems (5)

Many of the taxonomy aspects cannot be classified for the allocation of slot, passenger seats or cargo capacities yet, such as the customer's reservation demand profiles and therefore the number of fare classes, the willingness to pay or the turned down reservation, etc. These aspects have to be investigated by customer polls and will be the subject of further investigations on this topic.

**APPLYING THE TAXONOMY TO RAILWAY BUSINESS**

In the following chapters the Yield Management problems in railway business will be described by their special characteristics using the taxonomy of Weatherford and Bodily.
NATURE OF RESOURCE

The nature of the units of the perishable asset can either be discrete (e.g. seats in a plane) or continuous (e.g. electrical power).

Marketing of railway slots (RS): Although usually slots are regarded as discrete units like airline seats, the duration of a slot can be variable. Due to the train type and train set power, the duration of the occupancy of a railway line is variable. With respect to the train protection system the used capacity can vary continuously (driving in relative braking distance) or in discrete units (block protection system, driving in blocks). For this reason, the nature of the resource of railway slots can be characterised as continuous or discrete dependent of type of train protection.

Passenger Traffic (PT): The nature of units in passenger traffic - a seat in a train - is discrete.

Freight/Cargo Traffic (CT): The nature of the resource in cargo traffic is dependent on the production concept. For single wagon transportation the unit is a single wagon, a discrete unit. For regular service it is recommended to assume continuous units taking the size and weight of freight into account.

CAPACITY

The capacity of the resource can be fixed or non fixed. Most Yield Management problems are characterised by a limited capacity of the resources.

RS: This does also apply for the railway slot problem, because the capacity of a railway line can only be increased e.g. by installing an improved train control system or building a new parallel railway track, but this leads to a high time lag (and high cost) and can not be done to adapt short-term variations of the customer demand.

PT: For passenger traffic the capacity of the resource is fixed. After a timetable is constructed and the scheduling of trains is done, it is difficult to enlarge trains afterwards, in order to meet increased demand. But new production concepts - like automated driving - will allow an easy adaptation of capacity to actual demand!

CT: For single wagon traffic, the capacity of the resource is non fixed. One can freely choose the number of wagons to be sent to the customers. But for point to point freight traffic (called line traffic), the capacity is fixed.

PRICES

By using Revenue Management techniques prices are usually predetermined by a pricing group independently from the decision which is made in respect to the amount of discount units to be sold. Another alternative is to predetermine the amount of units at each fare level first, and then set the prices for each price level in an optimal manner. Lastly, pricing and allocating capacity to the fare levels can be done jointly.

RS: Currently, the prices for railway slots are set predeterminedly taking into account the demand for slots in the last years. Corresponding to Revenue Management for the marketing of railway slots, one of the above mentioned strategies should be used in future, whereas the railway network operators are free to choose an appropriate method for the pricing of slots and assigning the railway capacity.

PT: Regarding the new pricing system for passenger traffic, different price levels are predetermined and the capacities are assigned to the different price levels.
CT: The present mechanism is unknown. Like for railway network operators, cargo railway companies are free to choose an appropriate method for pricing and assigning capacity for the cargo units.

WILLINGNESS TO PAY

Some customers are willing to pay more for the service as the availability date draws closer, for other customers the opposite applies.

RS: Today railway operators usually have to book their railway slots one year in advance so that the yearly timetable can be prepared. After the construction of the timetable, the resulting free line capacities are sold about 5 to 6 weeks in advance due to today's complex processes of slot construction. Up to now, the customer behaviour and the willingness to pay for railway slots has not been examined in detail yet. To apply adequate Revenue Management techniques to the marketing of railway slots, the customer behaviour has to be investigated first, but normally the willingness to pay of customers in the transport sector increases with the approaching date of the transport. Therefore, the discount fares for slots should be made available to those customers who are willing to book a slot early.

PT: A market segmentation was done in: families with children being more flexible, groups, frequent traveller/business traveller as well as commuters demanding more flexible connections.

CT: In cargo traffic different customer groups can be identified. Some customers have to send time critical goods (e.g. for just in time production or parcel express services) others have time uncritical services like e.g. mass products. The exact classification of customer groups can only be made based on the customers’ requirements, which have to be investigated by customer polls.

DISCOUNT PRICE CLASSES

Discount price classes refer to different groups of customers.

RS: The new pricing of railway slots takes into account the character of the line e.g. the technical standard (supported velocities), operational character (main line, feeder line, line for highly tacted traffic) and two classes of customers: railway operators of passenger trains who make use of higher train control standards of railway lines (which e.g. allow higher speeds) as well as railway operators of freight trains who use simple standards. We recommend that a future grouping of customers should also focus on the customer behaviour (booking behaviour, price sensitivity).

PT: The new pricing system takes into account four different price classes in respect to the advanced reservation restrictions as well as fees for cancellation and rebooking or rerouting.

CT: Information about different price classes are currently not known.

RESERVATION DEMAND

Each fare class can have a different demand (deterministic, random, dependent on other classes).

RS/PT/CT: For the different classes of customers of railway companies, there does not exist any information about the demand yet. Therefore this point of the customer's behaviour has to be investigated as well.
SHOW UP OF DISCOUNT AND FULL PRICE RESERVATIONS

The show-up of discount and full-price reservations describes the aspect whether a customer (discount-price or full-price customer) preoccupies the reserved good/service or not as well as whether cancellations are permitted.

RS: Today, railway operators in Germany can reserve different slots but they do not need to use them. In this case, a fee for the reservation is applicable but they do not have to pay for line usage. Cancellations are allowed from the day of booking up to the point of utilisation.

PT: In Passenger Traffic tickets are not only value for one train but for a specified route within a defined time slot (normally a few days). A reservation of seat in a train refers to a distinct train. Therefore tickets and reservations are independent of each other. Reservation in advance for a seat in a train is possible in all price classes. The cancellation of this reservation is not possible, so the customer has to pay the price for the reservation, no matter if the reservation is used or not, but not for the ticket.

CT: In cargo traffic the same rules as in marketing of railway slots are applied.

TURNED DOWN RESERVATION

RS: If a request for a special railway slot cannot be fulfilled because the slot is already assigned to another customer, the revenue of this reservation is lost for the infrastructure operator. In some cases the request can be switched to another slot (e.g. a different route or another time window) so that the revenue can be recaptured.

PT: If a single seat is sold, the seat cannot be sold to another person afterwards. But even if all seats are sold, another routing can be assigned to the customer so that the revenue can be recaptured.

CT: Regular traffic is a certain origin - destination connection. The revenue of an incoming request for freight capacity, which is already sold to another customer, cannot be recaptured.

FORECASTING

Forecasting the future demand is a very important task in every Yield Management problem.

RS/PT/CT: The forecasting data for railway slot, seat or cargo capacity management has to be described as seasonal data. Both short seasonal variation intervals (such as freight traffic operators' demands on weekdays in contrast to weekends) and long seasonal variation intervals (such as reinforced passenger traffic operators' demands on holidays) can appear in railway slot marketing (7). The type of the forecast method should be as easy as possible but as sophisticated as needed and has to be determined appropriately to the customer's reservation demand.

GROUP RESERVATIONS

Usually group reservations are not considered in most Yield Management problems.

RS: Group reservations by railway operators are applicable for two reasons: First, railway operators offer their customers a certain service, which means a certain timetable. Therefore railway operators usually ask not for one single slot but for a certain number of slots. Secondly due to the increasing competition in guided traffic and the open access to the railway infrastructure for railway companies, smaller railway operators found alliances in order to enhance their negotiation power.
PT: Group reservations are possible in passenger traffic. In the new pricing system group reservations are supported. Groups profit from highly discounted prices, but the prices refer to a certain number of connections.

CT: Group reservations in cargo traffic are very common. Usually, most customers of a cargo railway companies ask for a certain schedule valid for a certain period.

DIVERSION
The diversion refers to the booking behaviour of the customers who are willing to pay the full price for a service. A distinction is drawn between "full price customers" who also take a discount price unit in case it is available, and those who won't take a discount price unit. In the given railway Revenue Management problems, the customers can't be separated into two different classes: full price customers and discount price customers. All customers in the railway business who are willing to pay full prices for a certain service, would also take a discount price service if it is available and applicable.

DISPLACEMENT
Yield Management systems can take the displacement of different kinds of reservations into account.
RS: For the railway network provider, this means that he has to contemplate different origin-destination combinations, which bring different revenues. For instance, he has to decide whether to give away a slot (e.g. Hamburg to Hanover at a special time) at a discount price level to a customer taking a long route (e.g. Hamburg to Munich) and therefore needing more than one slot, or to prefer reserving this slot for a customer booking only this distinct slot for a short trip (e.g. Hamburg to Hanover), but willing to pay the full price.
PT/CT: Displacement is applicable and useful for both: passenger and freight transportation. But actual pricing systems do not consider this attribute.

BUMPING PROCEDURE
This aspect handles the situation that sometimes demand exceeds capacity. Airlines for example, usually overbook their planes taking the expected no shows into account. Today's timetable construction tools of railway network operators do not allow conflicts of slots. For this reason, an overbooking of slots is not possible in theory. In reality, some special situations in railway traffic (irregularly scheduled) occur, which cause slot conflicts, therefore overbooking of railway lines in a very low extent is possible nowadays. Taking into account the lately planned production concepts of railway operators like for example modular freight train (cf. (8)), it is expected that no shows of railway slots will increase and therefore overbooking becomes more and more important for the railway network provider. Further investigations will have to evaluate, which bumping procedure in case of overbooking should be used.
PT/CT: Overbooking in passenger trains is possible and very common. However, in cargo traffic today overbooking is not common, but theoretically possible.

ASSET CONTROL MECHANISM
The asset control mechanism describes whether the number of requested units of one fare class exceeds the defined limit of units to sell in this fare class. For the marketing of services in the railway industry, it seems to be reasonable that the units are serial nested. That means that
each fare class has a certain limit of units to be sold. If the limit of a higher fare class segment is reached before the limits of the lower fare classes are reached, the requests of high-fare-class-bookings are satisfied by using slots of the lower fare classes. Therewith the full price class has access to the whole capacity (slots, seats or freight capacity). The other fare classes have only access to the determined number of units of their own class as well as the contingents of the lower fare classes.

**DECISION RULE**

In conjunction with the asset control mechanism, the decision rule determines in which way the entire Yield Management problem - that means the assignment of slots/seats/cargo capacities to prices and customers - is solved. Further investigations have to consider which decision rules are adequate for selling railway capacities by using Revenue Management strategies.

According to the classification of the Revenue Management problem, there are different algorithms and/or heuristics on forecasting, determination of optimal class size as well as optimal class fares to maximise the enterprise's revenue. Each special Revenue Management problem requires special algorithms. For most of the Revenue Management problems, such algorithms do already exist in other domains (see for example (8) or (9)). At present these algorithms are examined whether they can - in a modified form - be adapted to the railway problem.

**CURRENT REQUIREMENTS TO INFRASTRUCTURE CHARGING SCHEMES RESULTING FROM EU DIRECTIVES**

Directive 2001/14 (cf. 11) concerns European railway network operators and regulates pricing schemes for track usage as well as for assigning track capacity. The application of these schemes should

- enable a balanced relationship between costs for providing the trackside infrastructure and revenue of track usage as well as subsidiaries (§6),
- allow the marketing of free and available track capacities in such a way, that the capacity is used as effective as possible (§1).

Each railway operator is entitled to have a discrimination free access to the services of a so called “minimum access package” (MAP), comprising the right to use trackside infrastructure (for a complete list of services referring to this package, see appendix 1 of the EU directive 2001/14). §7 describes the required principles of track pricing:

- The pricing of MAP services should be orientated by marginal costs, that means by direct costs caused by a train ride (§7.3).
- For overloaded lines the price can include an additional pricing component taking the shortage of available capacity in certain time windows as well as certain track segments into account (§7.4).
In order to achieve cost-covering operation, §8 allows railway infrastructure operators to charge an extra fee based on efficient, transparent and non-discriminating charging schemes. Nevertheless, the infrastructure charge must not exceed the marginal costs plus a rate of return, which the market could bear.

Moreover in §11 the infrastructure charging schemes have to encourage railway operators as well as railway network providers to invest in a better performance of the railway network, e.g. to penalize delays and disruptions or to provide bonuses for a better than planned performance. Furthermore railway network operators are allowed to claim a reservation fee even if the reserved track capacity is not used (§12).

§10 requires that the principles of charging schemes as well as the calculations must be publicly available.

One main requirement of the railway capacity management is given by §22 of the EU directive. In case of refusing a slot request - e.g. due to the fact that the slot is already booked by another railway operator - the infrastructure manager has to declare the infrastructure as congested. Furthermore he has to analyse the reasons for the congestion and has to find a possibility to reduce this congestion. In revenue management systems the phenomenon of turned down reservations is usual and can be reported and used for further customer demand prognosis (see chapter).

Summarising the above mentioned requirements for slot pricing and assigning capacity in railway systems, it can be said, that revenue management is applicable and fulfils the legal stipulations of the respective EU directive.

**CONCLUSION**

In future, railway capacity management systems are required to achieve an efficient marketing of line, cargo and passenger capacity. An appropriate system architecture for such a system has been presented in previous publications (see for example (10)). Revenue Management algorithms for the pricing of services already exist (airline seats, hotel rooms). One main research field is the implementation of appropriate algorithms for the pricing of railway services (in this context the assignment and use of a slot/seat/cargo capacity is understood as a main service).

For the migration of a Revenue Management system as a global distribution system, the authors suggest the following way:

- The first step will be the implementation of an information system for railway customers as part of the global distribution system. By means of this information system, railway customers will be able to plan their (Europe wide) trips in a more efficient way than today.
- The second step will be the implementation of a reservation system. Inquiries/bids for slots, seats and freight capacities can be priced by the reservation system and appropriate offers can be generated directly by the reservation system (such as airline reservation systems). Moreover, inquiries/bids can be passed over to the service providers’ slot management system, where offers will be generated automatically or manually and then forwarded to the railway customers via the reservation system.
The authors’ objective is to enable a reservation of a railway slot, a seat or cargo capacity as fast and easy as the reservation of an airline seat via a computer reservation system. Efficient pricing algorithms such as those which are currently used in airlines reservation systems will effect a higher and more evenly distributed utilisation of the network.
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