Rising efficiency by taking passengers' demands and wishes into account

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Abstract
In order to be able to operate long distance rail travel efficiently, attempts are often made to increase the number of seats in the carriages, in order to increase the capacity. The consequence, however, of maximising the number of seats is that only the overhead racks are available for storage luggage. An extensive study at the Institute for Railway Engineering at the TU-Wien, which was carried out on long distance trains in Austria, Germany and Switzerland, deals with the actual behaviour of the passengers under a great variety of conditions. An intrinsic result of this study were the two following points. Firstly, travellers would like to avoid having to lift their luggage and so are prepared to put up with disadvantages for other passengers as well as themselves, in order to avoid the lifting up of luggage. Secondly, passengers always want to be able to see their luggage.
If these two basic principles are disregarded when a train is being built then serious disadvantages arise for the passenger and the operator during the daily operating of the trains, which lead not only to increasing dissatisfaction but also to a drop in efficiency.

1. Introduction

Efficiency of long-distance public transport usually means increasing the number of passengers at no extra expense in order to minimise the costs per traveller for the railway company. This concept of efficiency is also found in the manner of constructing coaches where providing a large number of seats per wagon increases the capacity. This approach minimises the effective costs per seat.
This idea seems to be theoretically correct but cannot and does not take into account practical considerations. This situation is shown by an extensive investigation of Austrian, German, Swiss long-distance trains.
Many ways of using available space in rolling stock usually disregard the actual behaviour of passengers. If the passenger behave differently from the assumptions of the manufacturer, the theoretical utilisation of the car will not be achieved.
In today's commonly used passenger cars, the actual utilisation rate is about 20% lower than intended due to ignoring passengers' behaviour (Table 1). Even at a utilisation rate of 80% there are no more free seats to be found.

Utilisation rate of passenger cars

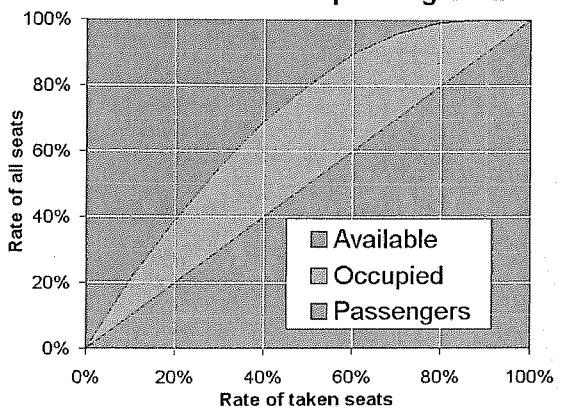

Table 1: Actual utilisation rate of typical open saloon passenger cars

2. Reasons for lower utilisation rates

Reasons for lower utilisation rates are passengers' demands of comfort and resultant behaviour.
If passengers are not satisfied with the provided environment, they will try adjusting the situation by achieving a comfort zone for themselves. This is done mainly by occupying additional/adjoining seats.
For example, if individual people or groups don't want to be disturbed, nearby seats will be artificially 'reserved' by luggage, clothes or other personal items; or if passengers want to be even more comfortable, they will put their legs on the seat opposite. These are only two examples of how demands of comfort can reduce the number of available seats.
The parameter which influences the actual utilisation rate most significantly is luggage and travellers' behaviour caused by luggage.

3. Requirements of modern railway interiors

In order to be able to arrange interiors efficiently, one has to pay attention not to optimizing individual ranges but to search for a total optimum. Therefore it is necessary to know exactly about the customer's needs as well as the actual behaviour of the passengers. From the investigations carried out by the Vienna University of Technology, the following basic rules can be derived which have to be kept in mind for designing efficient interiors.

3.1 Size of passenger groups

Individual persons or passenger groups do not usually want to be disturbed by other travellers. Therefore it seems to be worthwhile to take into account the sizes of groups. Only if sufficient space and appropriate seclusion is granted to each traveller or passenger group will one expect that further seats are not 'blocked' as a way of protecting a passenger's privacy.

3.2 Luggage racks

Although a sufficient number of luggage racks are provided in most passenger wagons, misplaced luggage often results in obstructing travellers or the railway staff. Another possibility is putting the luggage nearby or on the seats, which reduces the actual utilisation rate by about 50%.
There are different points of view regarding the storing of luggage because passengers have different behaviour and requirements than manufacturers expect. Railway carriage designers try to maximise the number of seats in order to increase capacity. This however leads to the fact that valuable luggage deposit areas are reduced and therefore in many passenger train carriages only overhead racks are available.
However, the majority of the travellers want to avoid lifting their luggage and prefer to store it at ground level. Even on days with high passenger volumes, a large number of luggage items are deposited on the floor, in the corridor, in front of or even on the seats. This leads to the fact that, as a rule, a maximum of only 80% of all seats are actually available for travellers. All other passengers have to either stand or sit on their suitcases. This does not only constitute a safety risk, it also contradicts all requirements for comfort!
For heavy luggage items, more than three quarters of the travellers indicate having had a medium to high level of difficulty when putting their luggage in overhead racks. Also the height of the rack gives rise to more than 50% of the problems. Even when lifting medium sized luggage, 40% of travellers have had problems (see table 2).

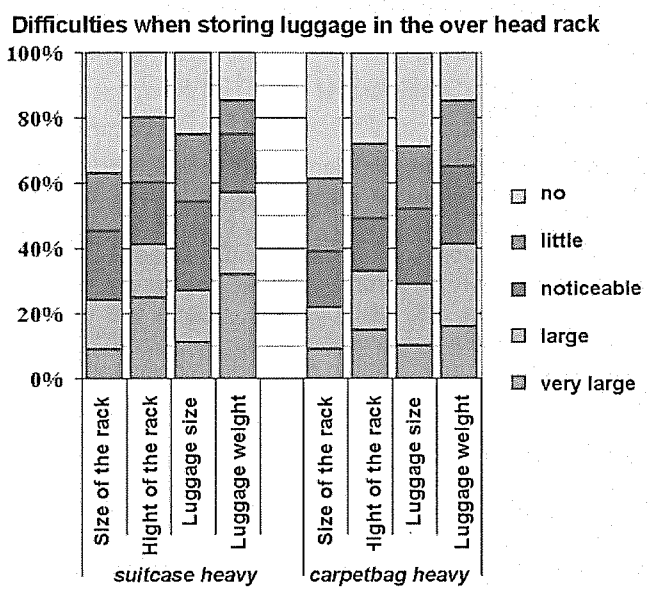

Table 2: Difficulties when storing luggage

These difficulties also lead to the fact that on main travel days, 40% of the heavy luggage items are left on the floor, on, in front of, or between the seats. Also, approximately 40% of medium-sized luggage items and even 60% of hand baggage are not deposited in the places planned for it (see table 3).

3.3 Comparison of two contrary railway interiors

In table 3, two types of interiors are given as examples. These are compared with each other with regard to the luggage storage possibilities and to the behaviour of passengers:
A 2nd class open saloon coach of the ÖBB (Austrian Federal Railways) (table 4) has two seats on one side of the aisle and one seat on the other side and these seats are arranged in a position facing each other. This arrangement is compared to a 2nd class open saloon IC/EC-wagon of the DB-AG (German Railway Company), having the majority of the seats in rows (table 5) all facing the same way.

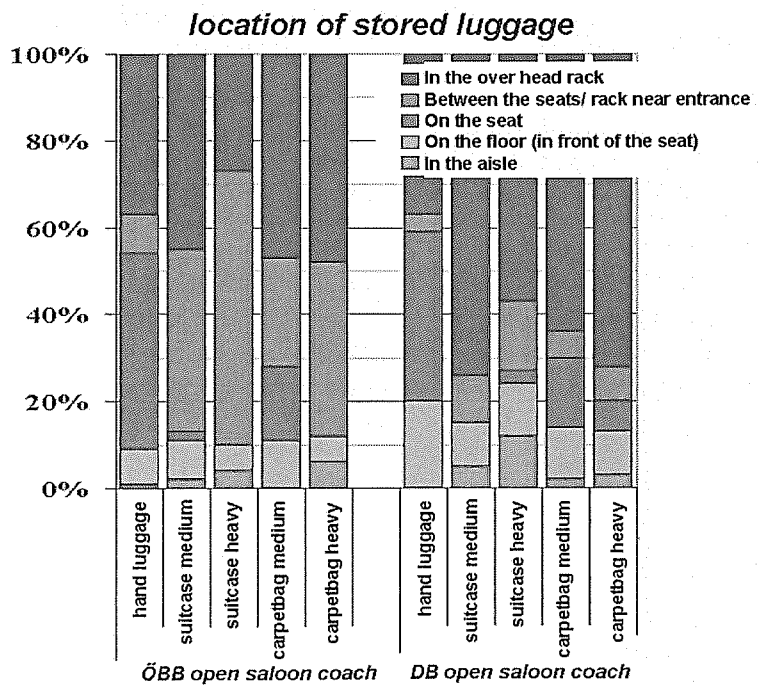

Fig. 3: Luggage stored by travellers - location

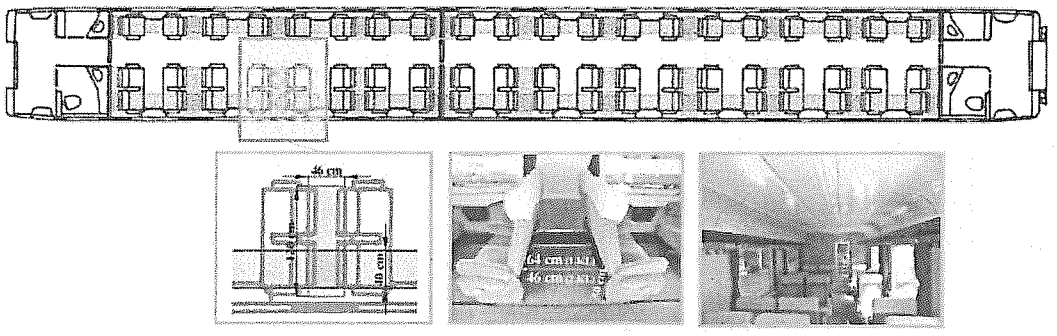

Fig. 4: 2nd class saloon coach of the ÖBB

green areas: luggage storing possibility on the floor
red areas: over head luggage racks

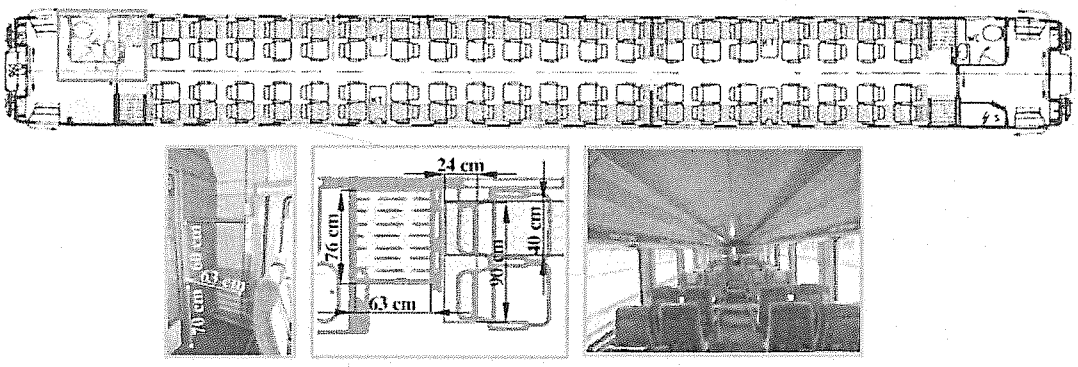

Fig. 5: IC/EC saloon coach of the DB-AG

In the ÖBB coach there is enough space for putting the luggage on the floor between the seats, whereas in the DB coach you can only find luggage racks overhead and at both ends of the carriage. On closer examination of the actually observed behaviour of the travellers in these two railroad car types, it becomes clear that where sufficiently storage possibilities on the floor are present, only a little more than one third of the luggage items are stored in the overhead rack (see table 6).

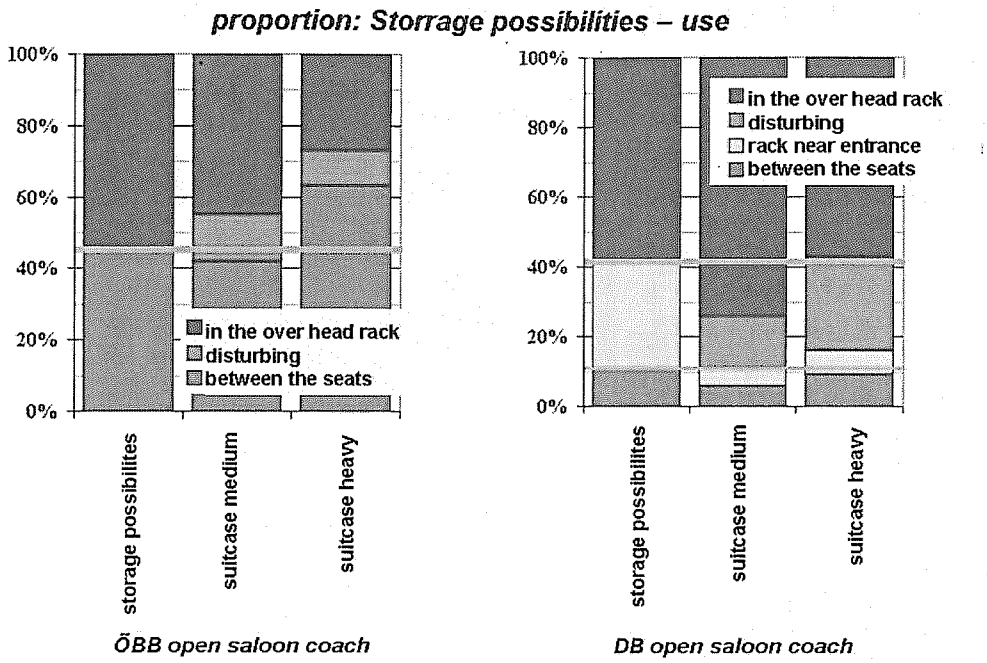

Table 6: ÖBB open saloon coach (type 4010); DB-IC/EC open saloon coach Storage possibilities - actual use

In wagons which practically only offer overhead racks, up to a third of the luggage items are still not stored there, but in places not planned for the luggage where it frequently disturbs other passengers.

3.4 Passenger behaviour - conclusions for efficient railway interiors

The following behaviour of the passengers and also customers' requests are shown by observations and surveys/questionnaires:

- **High acceptance of luggage racks on the floor or at floor level:** If travellers are able to store their luggage without having to lift it, they will for sure do this. If however travellers are in fact forced to lift their luggage, a majority of the luggage (above all for the heavy items) will be placed in a manner such that it often restricts other travellers and the railway staff (see table 6). With fully occupied compartments, up to 20% of the luggage items are left in the side corridor. This is an average of one to two suitcases per compartment. This does not only impair the passengers but also the guard or ticket inspector, and also of course the mobile on-board food & drink service! Therefore offering a sufficient amount of luggage storage possibilities at ground level is also important for compartment coaches.

- **Visual contact of their own luggage:** Passengers obviously want to see their luggage at all times for security reasons. This is clear when looking at the DB wagon (see table 6). About a quarter of all luggage racks in this type of railroad car fulfil the comfort criteria of those at ground level, yet these are used only for approximately 5% of all luggage items. This is because the luggage racks are located near the entrance and they cannot be constantly observed by the passengers.

- **Desire for taking luggage along in the train:** About 80-90% of the travellers would like to take their luggage along with them into their compartment or a distance close enough to keep an eye on it. Only with vacation trip journeys, which comprise only 12% of all train travel, can up to 40% of all travellers imagine alternative luggage transport systems such as registered luggage or check-in systems such as at airports.

3.5 Summary of passengers' behaviour

If it seems at all possible, passengers try to avoid lifting medium sized and large pieces of luggage. The consequence is that all those areas on the floor, or near to the floor, which can come into consideration, are used to deposit luggage. If there are no suitable areas, like sufficient room between the seats or individual luggage racks on the floor, then there are the areas in the aisle and the entrance, free seats and the floor in front of seats.

4 Effects of passenger behaviour and an incorrectly designed interior.

4.1 Utilisation rate

As a rule, the displacement of the free seats is done in such a way that they can only be made free at great expense, and so are unusable. As well as the passengers having to sacrifice comfort this has the result that the maximum possible utilisation rate of the seats in the carriage comes to between 70 and 80%. In this way at least 20% of the seats are unusable and this means that more passengers have to stand up, despite the fact that there are theoretically free seats.

4.2 Risks to safety

Alongside the fact that unsuitably placed luggage blocks the flow of the passengers and also causes a great deal of difficulty for the staff like the on board service, they often block the various emergency exits which represents a high risk to safety in cases of danger. The emergency exits are further restricted by aisles, which are too narrow. The usual layout of the doors at both ends of the carriage has a similarly disadvantageous effect, since the emergency exits for people who sit in the middle of the wagon are a long way off.

Table 6&7: Luggage blocks the entrance and the aisle. This represents a high risk of safety because of blocked emergency exits. Passengers and the board service also will have many difficulties.

4.3 Queues

Luggage, which is left in the aisle and near the entrances, stops those passengers who wish to move about on the train. This problem gets worse when the passengers have luggage as well. A further difficulty turned out to be that the aisles were too narrow. With a constant width of less than 60 cm passengers find it a great deal more difficult to carry their luggage.

When people are getting on, these circumstances quickly lead to queues, which form even more quickly the more difficult it is for passengers to find free seats and suitable areas to put their luggage.

4.4 Passenger changeover time

The queue which is caused by the usual badly designed interior, as well as entrances which are too narrow and often the large number of steps to be negotiated (sometimes up to 5) when people are getting on and off, lead to increased passenger changeover times at stations and at peak travelling times. The delay of a train increases a few minutes with every station. Depending on the distance, this can add up to delays of up to one hour. This has effects on approaching and following trains and on the timetable arrangements for a whole day.

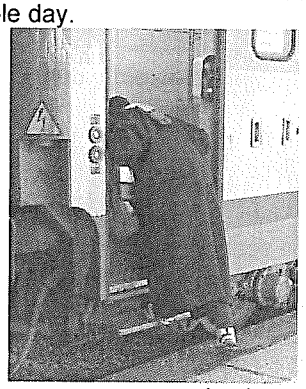

Table 8: Entrance with 4 steps; Many passengers caring luggage feel difficulties when getting on. Thus when a large number of passengers wants to get on the stop time needs much longer than planned.

4.5 Influences of changing time for passengers

There are several influences on the passenger change over time in a station like the age or handicaps of a person, also the number of steps. But one main influence is **luggage**. The needed time rises by the weight, the size and the number of luggage items. Another main influence is the number of stairs a passenger has to take when he enters the train. Especially the combination of both must be considered! (see table 9)

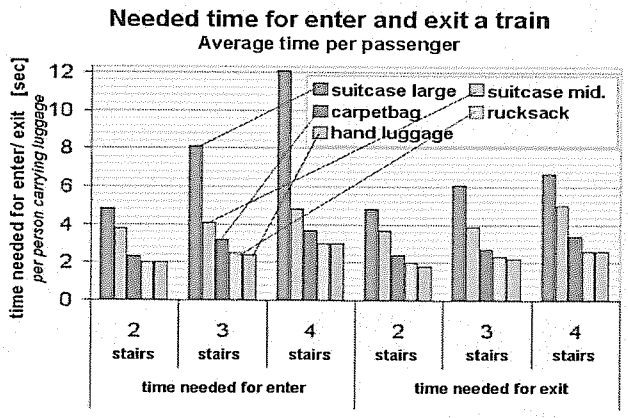

Table 9: Average of time needed for enter or exit a train subject to the carried luggage and the number of stairs.

Passengers who take along large luggage items need twice the time in the average than passengers with small luggage like rucksacks or hand baggage. Passengers who take along heavy suitcases will even need four times longer!

Another problem is the entrance area design and the railway interiors as told before. After a few travellers a holdup of passengers can be watched because of a wrong design. One reason is passengers have to search for free seats and they must store their luggage. If the aisle width in the saloon is too small passengers who have to carry luggage do have many problems when moving

along. If it is smaller than 60 cm passengers with large luggage items will need much longer compared to wagons with wider aisles.
Other problems are missing luggage storage possibilities. On the one hand passengers want to avoid lifting their luggage and therefore they want to store it at or near ground level. If there exist to few or no such storing possibilities many passengers put down their luggage on the floor and also in the aisle. This is an additional reason why travellers who enter the train and search for a free seat have got many troubles and need longer for moving along.
On the other hand they need much longer if they have to lift their own luggage in order to store it. The third problems are passengers who want to cross.
Those three reasons lead to a holdup. Therefore the time for a train stop does not increase linear by the number of passengers but above average.
In table 10 you can see increase of time needed by the number of passengers. This situation is significant for holiday makers with much luggage.

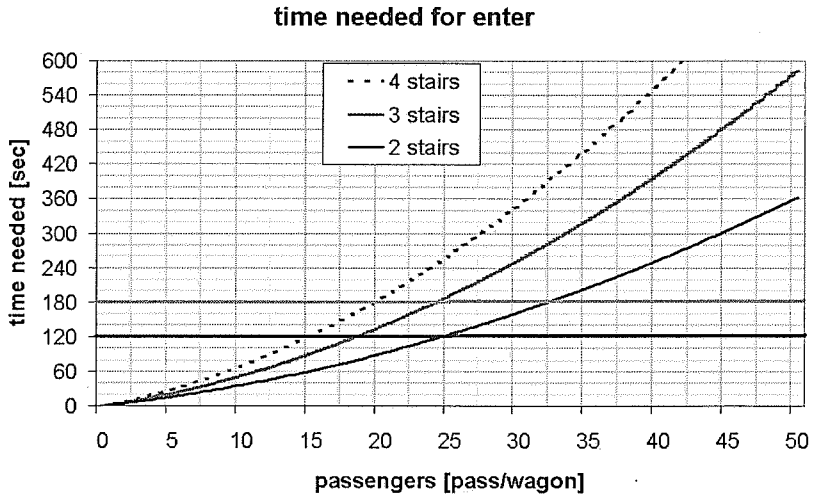

Table 10: Needed time for all passengers passing one door in subject to the number of stairs.

Do passengers have to pass 2 stairs because of the difference between the platform level and the wagon floor level, in the average 25 passengers need 2 min. in order to get into one wagon (with 2 doors). Do the same passengers have to take 4 stairs in order to get into one wagon, they will need more than double the time (more than 4 min.).
In order to limit the stop time by 2 min in average 15 travellers can get into one wagon. These are about 40 % less compared to situations where only two stairs have to be taken.

5 Optimising the interior of the space in the train

Suitable ways of optimising potential can be drawn from the study we have mentioned of passenger behaviour and if we pay attention to these they can lead to a marked improvement in those faults we have mentioned. The two main critical points refer to passengers getting on and the seating arrangements in general.

5.1 Entrance area

The position of the doors in newly built trains should be reconsidered. If the two entrances are put at the respective quarter points instead of at the end of the carriages the flow of passengers can be better spread, which leads to a tangible reduction in the queues. In order to speed up passengers getting on, the entrance doors must have a minimum width of 90 cm.
Of equal importance is the number of steps which need to be negotiated from the platform to the interior of the train. Depending on the luggage that is carried, negotiating four steps takes two to three times longer than two steps before one passenger can follow another. A passenger takes on average with a heavy case 12 seconds to negotiate 4 steps. The same passenger needs on average 5 seconds to negotiate 2 steps.

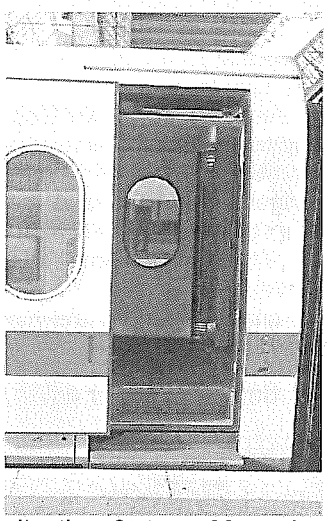

Table 11: ICE: Favourable entrance situation; 2 steps, 90 cm door width, gentler gradient in the angle of the steps.

A gentler gradient in the angle of the steps contributes just the same to a reduction in the changeover times. When getting on to an ICE train with a door width of 90 cm and a step ratio (height/depth) of 21:23 cm., a passenger needs on average 15 to 20% less time than when getting into a RIC-carriage with a door width of 80 cm and a ratio of 23:20 cm
In order to avoid queues, the immediate entrance area inside the train must fulfil the function of taking on and distributing passengers. It is therefore necessary that this area is not too narrow. Passengers with luggage must be able to pause there. As a further consequence, the width for access between the seats must be at least 60 cm in order not to restrict the passenger too much.

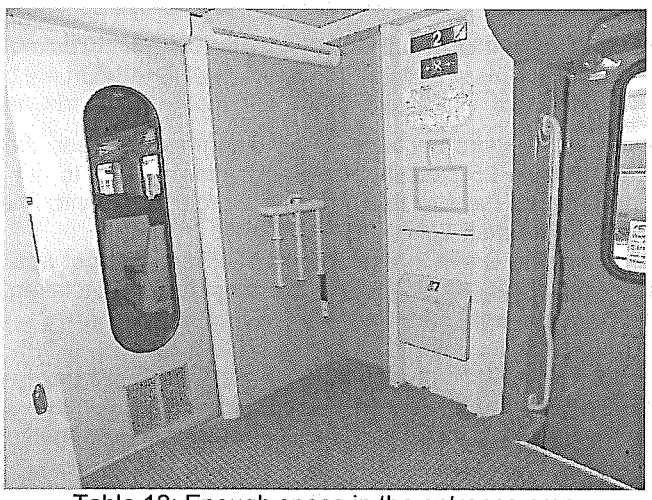

Table 12: Enough space in the entrance area

5.2 Maximum number of seats/ number of luggage racks

The maximum number of seats should not be aimed at on the wishes of the operator, which is to offer as many seats as possible. The basis for the maximum sensible number of seats is set by the passenger and his behaviour under various conditions. Most passengers have luggage with them, which sometimes takes up a lot of space. This is to be observed especially in trains, which serve airports or holiday destinations. The amount of luggage however on business journeys may in no way be underestimated. The figures referred to here show the average distribution of passenger destinations, which is the rule on long distance trains in Austria. These are 12% holiday journeys, 15% longer private journeys, 38% short journeys and the rest are business trips of one or several days.

Each traveller has on average 0,8 pieces of luggage. These are big or medium sized cases, travel bags or rucksacks. Each passenger has in addition 0,7 pieces of hand luggage. These are small cases, travel bags and rucksacks with a volume like the normal hand luggage allowed for air travel.

The area needed to deposit luggage will be demonstrated on a new, fictitiously chosen train. We are dealing with a second-class open saloon coach with some face-to-face seating and some seating in rows. The seat grid pattern is about 92 cm. Making full use of the seating arrangements, a maximum of 88 seats can be built in the compartment and in this case there is no space to deposit luggage near the floor and only overhead racks are available for depositing luggage.
If you transfer the actual behaviour of passengers to this train, then depending on the distribution of the destinations, 20 to 30% of the seats are unusable, since as we have said before, are blocked off by luggage. Even if all passengers were prepared to lift their luggage and stow it in the overhead racks, there would not be enough luggage space on those days with an increased number of holidaymakers. Since there are many passengers anyway who are not prepared and often not in the position to lift up their heavy luggage, then only the light pieces of luggage and clothing are lifted up and the heavy luggage stays on the floor on or in front of the seat.
Accordingly, in this compartment only 70 of the 88 seats would be available. On holidays there would be even less!
If you took out 6 seats to create space for 3 luggage racks, you could put in 82 seats, but of these however only a maximum of 77 could be used. According to this you would have 7 more seats, but in point of fact there are 6 less available. The degree of efficiency to be expected is 94% on holidays to 89%. The upper limit for seats to be built in, in order to get around 100% efficiency, is about 80 in this type of carriage on an average travel day. In this case 4 luggage racks can be built and on the basis of the analysis of passenger behaviour, you can reckon a possible seating efficiency of 100%.
Thus, by giving up 8 of the 88 seats, there will be 10 more available seats! This increases not only the efficiency, and with this the economy, but also passenger comfort and customer satisfaction!

5.3 Arrangement and formation of the luggage racks

The luggage racks must not be situated in the immediate vicinity of the entrance areas at both ends of the carriage. Passengers only accept these racks grudgingly even though they offer storage space on the floor. The reason lies in the fact that the passengers always want to keep an eye on their luggage and this is not the case when the racks are arranged near the entrance.
In normal trains (with doors at both ends of the compartment) it is best to arrange the luggage racks in the quarter points of the carriage opposite each other, whereas to get optimum efficiency they should be placed next to each other. This arrangement guarantees the best possible flow of passengers who are getting on and in this way reduces the queues.

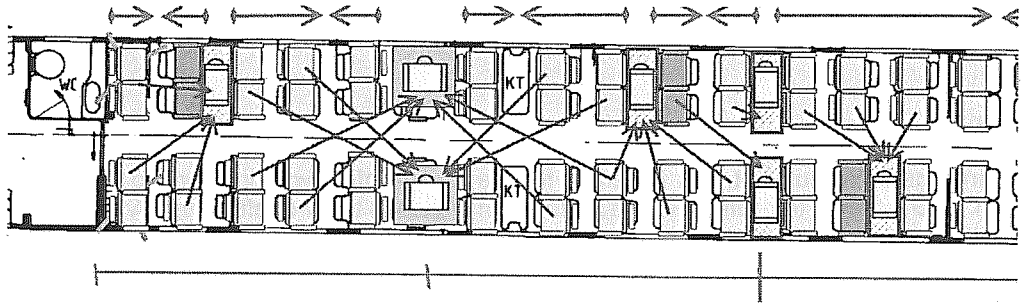

Table 13: Right arrangement of storing possibilities, luggage rack in the quarter point, additional space between seats, blue arrow: direct view to luggage

5.4 Implementation of the luggage racks

The final choice of number and size of luggage racks depends on the respective conditions e.g. the distribution of the destinations. As a general rule the installation of 4 luggage racks each with an inside width of at least 100 cm has proven to be most advantageous. One must be aware that the bottom rack, which is mainly meant for large and heavy pieces of luggage, is at least 75 cm height. Above this

are 2 racks arranged with an interior height of 55 cm and 45 cm and here the smaller upper rack is suitable for travel bags and rucksacks.
It has turned out that you need to keep to the minimum measurements mentioned here, since otherwise the racks cannot be used efficiently.
When building the racks one must take care to have them sloping backwards so that the luggage does not fall down.

5.5 Using the angle of the seat/Racks between the seats

Since the backrests have a certain angle, one can use the space that is left between the 2 back rests for storing luggage. The passengers like these areas and gladly make use of them. One must not make the mistake however, that the headrests of the seats are next to each other. In this case the space left is much too small and cannot in any sense be used. The seating arrangement is only efficient if there is space left, measuring from the floor, to a height of 60 cm and a width of 35 cm.
If the side fittings of the racks do not go down to the floor then the load is carried through to the back area, then the angle of the seats can be used for a broader area on the floor to store luggage.

Table 13&14: Space between the backrests; DB-1st-Cl open saloon coach: enough space for storing luggage; SBB-2nd-Cl. Open saloon coach: The space is much to small for storing medium or large luggage items!

6. Summary

These findings point out that it is essential for the design of railway interiors to aspire to a total optimum. Each attempt to optimize only a certain domain leads to lower efficiency. **A maximisation of seats without contributing to the aforementioned considerations will always cause a reduction of utilisation!** However, by removing 10% of the maximum possible number of seats and instead offering sufficient luggage rack options that will be accepted by customers, a majority of the currently unusable seats would be available and thus the rate of utilisation increases! But the luggage racks should not be in the entrance areas but in the quarter points, that is to say placed opposite and next to each other. Furthermore, the measurements in this article should be adhered to.

Moreover, if the group sizes are taken into consideration and storage possibilities for clothing (coats, hats, etc.) and pieces of hand baggage are also offered, even more currently blocked seats will be available. Efficiency and attractiveness are therefore not compelling contrasts, but valuable additions. Design of attractive railway interiors for passengers maintains more available seats and simultaneously increases the actual utilisation rate!

Furthermore it must not be forgotten that two thirds of non-rail users assess the current situation of luggage transport as a substantial reason for not using the train. Even if only a small amount of the

non-rail users can be won as new customers, it will inevitably increase the utilisation rate. In consideration of all these criteria, appropriate customer friendliness also affects increasing efficiency of the railway company, whereby attractiveness leads to an increase of the effectiveness and does not limit it!

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