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Vehicle design – Influence on operational quality

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Abstract

The design of rail vehicles, in particular the boarding area and the interior, has a significant influence on the passenger exchange time. The vehicle design is overlaid with passenger-specific characteristics such as age, mobility restrictions and, in particular, baggage. Poorly designed vehicle layouts mean that some of the seats cannot be used and the degree of capacity utilization achievable and thus customer comfort are noticeably reduced. In particular, however, poorly designed vehicles significantly prolong passenger exchange times, which leads to frequent delays and thus to a decline in operating quality.

Based on almost twenty years of intensive research in the field of passenger behaviour in passenger trains, the technical paper will show clear approaches to solutions, how a good design of rail vehicles can increase the degree of utilisation and at the same time the customer comfort, how the passenger exchange time and thus the dwell time can be significantly reduced and thus the operational quality can be significantly increased in addition to other important advantages.

Keywords: efficient rail vehicles, interiors simulation, occupancy rate, dwell time

1 Introduction

The design and development of passenger coaches often follows the principle of seat maximisation, with the aim of transporting as many passengers as possible and thus increasing efficiency and economy. However, the intensive scientific investigation of passenger wishes and needs as well as actual passenger behaviour under real conditions prove that instead of the expected increase in efficiency, in reality there is a loss of efficiency! In addition to a decline in passenger satisfaction, in reality the achievable seat occupancy rate even decreases and the passenger changeover time increases noticeably in the opposite direction. This in turn leads to more delays, which have to be reduced with higher energy consumption, and to a decrease in operational quality.

2 Methods

Based on the twenty years of know-how which is based on extensive investigations and data collection in the field of passenger behaviour in rail vehicles (observations of the behaviour of around 300,000 passengers in about 100 different types of vehicles, surveys of about 50,000 passengers and analysis of about 20,000 passengers during passenger change over), the simulation software TrainOptimizer® at www.TrainOptimizer.com was developed by TU-Vienna and netwiss. By using TrainOptimizer® you can determine with just a few clicks the most efficient layout variants in terms of best possible baggage stowage, highest possible seat occupancy and shortest possible passenger change over times, which has also beein used for this paper.

3 Passenger behaviour versus operational quality

In two situations during a train journey the interaction of passengers with the existing vehicle layout has a significant impact on the quality of operation. This concerns boarding and alighting as well as baggage storage during the journey. Both influences are directly related to each other.

3.1 Luggage storage

Two factors have a significant impact on baggage accommodation. On the one hand, sufficient capacity must be available for the storage of baggage, on the other hand, the passenger needs must be considered extensively with regard to baggage storage, which, if disregarded, will lead to negative behaviour from an operational point of view.

Passenger needs are simple and understandable, but can become complex challenges when designing vehicles. The two main needs are:

- Passengers do not want to lift larger pieces of luggage
- Passengers want a visual contact with their luggage

3.1.1 Lifting and manipulating luggage

The primary distinction to be made is which luggage is to be lifted. Smaller and lighter items of luggage are more likely to be lifted than larger and heavier items. Parallel to the basic willingness to lift luggage, a distinction must be made as to the height to which luggage is lifted. In this respect, readiness to lift is differentiated into two heights, one to a height of about one metre, which is used for luggage racks, and the other to the height of an overhead rack, usually about 1.8 metres.

Furthermore, the willingness to manipulate luggage must also be considered. This refers to whether passengers are willing to tilt or turn luggage. This is particularly important for all those stowage spaces into which baggage must be "threaded", such as under seats or between seat backrests when seat spacing is tight. In general, passengers do not wish to manipulate their luggage for accommodation purposes and in practice do not do so. Trolleys transported in an upright position on two or four wheels must be parked in an upright position. Travel bags should be stored in a horizontal position if possible, ideally at a height of approx. one meter, which corresponds to the middle compartment in luggage racks. Smaller or medium-sized trolleys, which are more willing to be lifted, are often stored lying down in luggage racks, for example.

3.1.2 Visual contact with luggage

For about 90% of passengers it is important for reasons of subjective security to have their luggage in view during the journey. Approximately 75% of passengers are also explicitly prepared to place their luggage disturbingly (e.g. on or in front of seats or in the aisle) in order to establish visual contact.

3.1.3 Storage space dimensioning

In addition to the above-mentioned principles, it is also essential to provide sufficient luggage storage capacity. For this purpose, precise knowledge of the average luggage volume in the intended area of use of the vehicles is important. Furthermore, baggage must always be viewed in three dimensions. In practice, the volume of baggage is often taken as a basis, but this corresponds to a one-dimensional view. All volumes are summed up to form a total volume for luggage storage in the vehicle, which makes large luggage storage capacities seem likely. In practice, many of these areas cannot be used at all, as the dimensions of the luggage are larger than the respective areas!

3.2 Effects of insufficiently dimensioned baggage racks

Failure to comply with the above-mentioned requirements for baggage storage means that travellers are either unable to store their baggage at all because there is too little storage space available in practice, or they do not make sufficient use of the available shelves because they do not meet the basic needs of visual contact or avoidance of lifting operations. This leads, for example, to overhead shelves remaining partially unused and yet luggage not being stowed properly. Pieces of luggage that cannot be stowed are placed close to the passengers on or in front of seats or in the aisle. Non-stowable baggage results in seats being blocked. On average, two to three pieces of luggage that have not been properly stowed will result in the effective loss of a seat.

3.3 Passenger exchange

Passenger exchange is a complex interaction between passenger characteristics and the overall vehicle layout. Passenger-specific influencing factors are age and gender, any physical restrictions and the luggage carried, which in turn depends on the chosen purpose of the journey. The vehicle layout gives rise to three main areas with different influences. These are the entrance door, the entrance area, which can also serve as a catchment area, especially in local traffic, and the entire interior, which essentially corresponds to the seating area. At the entrance door, the door width, the gap between platform and vehicle and the number of steps have a significant influence. The design of the boarding area determines how well the passengers can continue into the seating area and how many passengers can remain in it in case of a backlog so that the train can still depart.

There are several influencing variables in the interior. The stowability of the baggage has a significant influence. As described above, pieces of luggage that cannot be stowed are sometimes parked in the aisle area, where they block the flow of passengers. Another influence is the simplicity of luggage storage. Ideally, if passengers can deposit their luggage "in passing" and then go straight to the nearest seat, the flow of passengers is faster than if passengers have to manipulate their luggage several times for storage. Especially when luggage has to be lifted to be stored in the overhead storage or the distance between two seat backrests is too short and the luggage can only be stored by tilting, if at all, the passenger flow slows down considerably.

Furthermore, the aisle width and possible alternative spaces have an important influence on passenger flow. The width of the aisle is important for the ease of movement with luggage, as well as when people are busy putting down luggage and others may pass by.

4 Design principles in vehicles

In order to achieve a high degree of seat occupancy and at the same time the shortest possible dwell time, the following principles must be observed:

4.1 Baggage racks

The baggage racks shall comply with the principles of avoidance of lifting of large pieces and visual contact. When dimensioning baggage racks, reference may be made to the actual willingness of different passengers to lift baggage for reasons of efficiency. Smaller and medium-sized pieces of luggage, which tend to be lighter, are also placed in the overhead rack by the passengers to a larger extent, larger pieces of luggage only to a small extent of approx. 20%. This means that the calculation may well be based on overhead storage, but only to the extent that the passengers are willing to use it and not per se for all luggage.

Luggage racks must be well distributed in the seating area. This applies in particular to luggage racks and the space between the seats. A good distribution leads to appropriate use, as most travellers can see their luggage. At the same time, distribution also means that luggage can be more easily stored by passengers, thus allowing passengers to take seats more quickly.

Luggage racks must not be placed in the boarding area of vehicles, as these are only used up to approx. 30% for safety reasons. The same applies to luggage racks in the interior of the vehicle, which are located immediately after the entrance to the seating area. If they are used, the luggage being stowed very close to the boarding door, what leads to a backlog of boarding passengers.

In addition to the arrangement of the luggage racks, it is essential to know the exact quantity and type of luggage to be expected. The type of baggage or the appropriate mix determines the required dimensions of the baggage racks. Storage racks that are too narrow by only a few centimetres often mean that certain pieces of luggage cannot be stored at all or only in such a way that there is no further useable free space, which makes the racks inefficient.

4.2 Overall vehicle concept

The entire vehicle concept has a significant influence on the passenger change over time. This already starts with the car bodies. Shorter and thus wider car bodies have the advantage of allowing wider aisles, in addition to the advantage of up to 50% lower tare weight per seat and the resulting large energy saving effect. Aisles with a width of more than 60cm allow up to 25% shorter passenger change over times than those with a width of 50cm.

Another important factor is the arrangement of the doors. The classic arrangement at the two ends of the car means that an average of 50% of the passengers per car have to enter through one door walk through the same interior. Since the boarding time in the respective car interiors essentially follows a square parabola, a higher number of passengers passing through a cross-section leads to a disproportionate increase in passenger changeover time. If, on the other hand, the doors are arranged in such a way that the passenger flow can be divided up when passengers enter the boarding area, the passenger change over time can be significantly reduced. On the one hand, the number of people entering the respective passenger compartment through a cross section is halved if the doors are well located, which leads to a noticeable reduction of the boarding time. On the other hand, the division of passengers also reduces tailback effects from the seating areas. In the seating area, it must be considered to ensure good division and correct and adequate planning of the luggage racks. In addition, well-distributed spreading spaces should be created. This can be done by ensuring that tables in vis-á-vis seating groups do not reach as far as the aisle, but are approx. 10 to 15 cm shorter. Likewise, luggage racks should be moved away from the aisle, this creates equally good alternative space.

5 Example layout comparison

In the following, two layouts, which are deliberately similar in structure, are compared with each other in order to illustrate the effects that the correct consideration of luggage racks has on the achievable seat occupancy rate and passenger changeover time. If the overall concept is fundamentally revised, for example by shortening the car body and changing the arrangement of the entrance doors, even more significant differences can be seen.

The two layouts are fictitious examples and are not in actual use in the form shown. In both cases they are classic passenger coaches, in layout 1 with 100 seats and, except for two small racks, mainly overhead racks for luggage storage. In layout 2, only 88 seats are available, and there are more suitable baggage storage options to meet passenger requirements (see Figure 2 and Figure 3). The baggage racks have three compartments in all cases, measured from below at a height of 80 - 40 - 40 cm, with the overhead rack above.

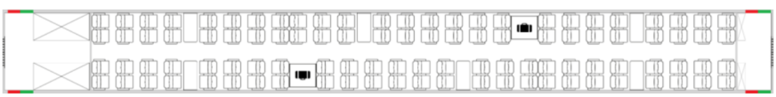

Figure 1. Example layout 1: netwiss - Layout creation in Beta - TrainOptimizer

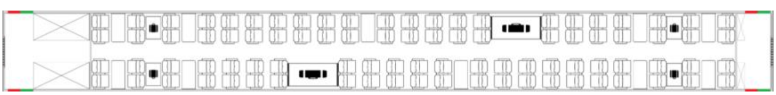

Figure 2. Example layout 2: netwiss - Layout creation in Beta - TrainOptimizer

Three equally fictitious travel purpose mixes are given below. In one the majority of business travellers use the train, in a second example these are mainly holiday travellers and in a third example it is additionally assumed that an international airport is served, which on average also induces a 20% higher luggage volume.

5.1 Baggage accommodation and seat occupancy rate

Figure 4 shows that 31 pieces of baggage are stowable in layout 1 and 66 in layout 2, on days with a higher proportion of business travel every second piece of baggage is not stowable in layout 1, but all pieces of baggage are stowable in layout 2. On days with a higher proportion of vacationers, two out of three pieces of baggage are not stowable in layout 1, while only 17 pieces of baggage are not stowable in layout 2.

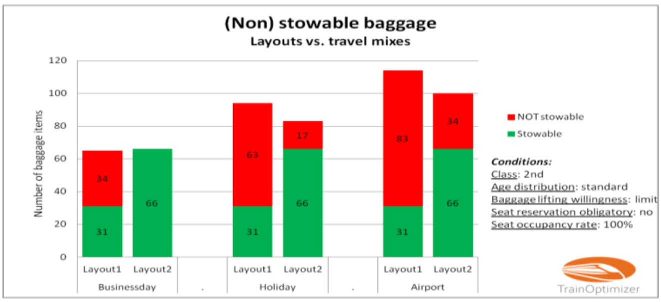

Figure 3. (Non-) stowable aggage in layout comparison: *netwiss - Evaluation with Beta - TrainOptimizer*

In addition to severe comfort restrictions and general problems caused by pieces of luggage that cannot be stowed properly, such as security problems or delays in passenger transfer, the pieces of luggage that cannot be stowed result in the fact that with layout 1 not all seats can be used in any of the travel purpose scenarios. Even on days with a higher proportion of business travel, only 89 of the 100 seats are available, and in layout 2 all 88 seats are available. On days with a higher proportion of vacation travelers, only 77 seats are actually available on average for layout 1 and at least 82 seats for layout 2 (see Figure 5).

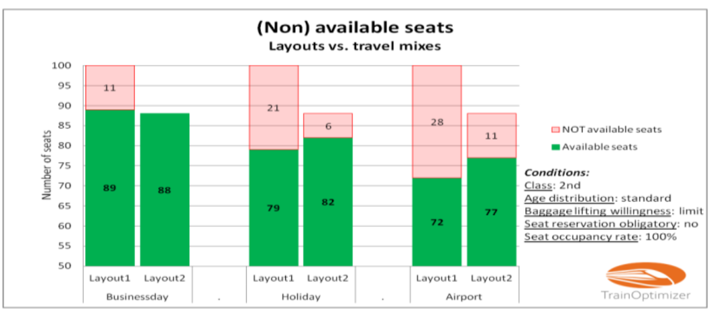

Figure 4. (Non-) available seats in layout comparison (depending on travel purposes): *netwiss - Evaluation with Beta - TrainOptimizer*

This analysis clearly shows that there is no added value in maximising the number of seats, since in any case no more than 89 seats can ever be used. A reduction in the number of seats therefore not only leads to a noticeable gain in comfort for the travellers, but on the majority of the time even to a higher proportion of available seats.

5.2 Passenger changeover time

The figure 6 shows that the time required for boarding increases more than linearly as the number of passengers boarding increases. The calculations are based on a travel purpose mix with a higher proportion of holidaymakers. Furthermore, it can be seen that the time required for layout 2 with improved baggage accommodation (higher capacity, better distribution in the vehicle) and better siding possibilities increases less strongly. For example, 40 boarding passengers need on average 210 sec for layout 2, whereas the time required for 40 persons for layout 1 is already 50% higher with an average of 310 sec.

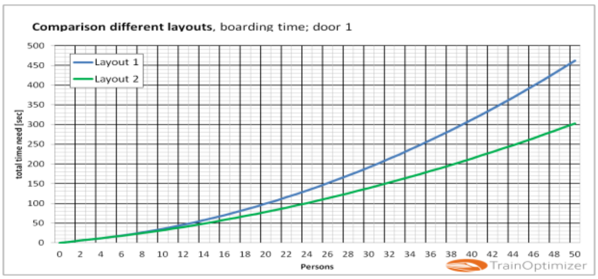

Figure 5. Time required for boarding passengers during layout comparison: *netwiss - Evaluation with Beta - TrainOptimizer*

The**Fehler! Verweisquelle konnte nicht gefunden werden.** 7 shows the time required for a so-called 60% passenger exchange. This includes both boarding and alighting passengers. A 60% passenger change is a frequently requested comparative value for calculations which states that 60% of the passengers of a fully occupied wagon get out and the same number of passengers get back in. With layout 2, the lower number of seats per door also results in a three person lower number of passengers.

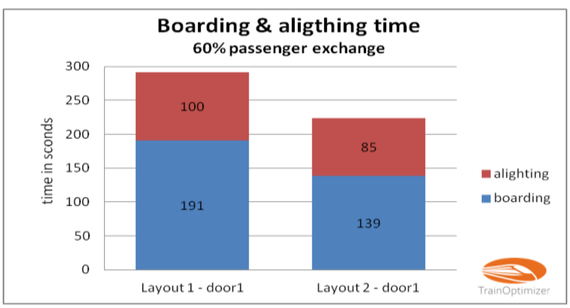

Figure 6. Time required for a 60% passenger exchange in the layout comparison: *netwiss - Evaluation with Beta - TrainOptimizer*

The boarding time for the 60% passenger exchange is just over three minutes, which is about 30% higher than for layout 2, and the total passenger changeover time, including passengers getting off, still differs by 25%!

6 Conclusion

The vehicle layout and the associated interior design have an influence on the operating quality in many ways. The correct and sufficient dimensioning of luggage racks has a significant influence. Baggage racks that do not meet passengers' basic needs, such as the desired visual contact with luggage or avoiding the lifting and manipulation of larger items of luggage, result in many items of luggage being stored in a disturbing manner. This leads to a decreasing seat occupancy rate and significantly longer passenger changeover times. A lower number of seats, if properly planned, leads to more seats being available in total, even in absolute terms, and to reduced dwell times.

The differences shown in this essay between the two **TrainOptimizer®** simulated variants, which differ from each other essentially only in the area of improved luggage accommodation, make it clear that with 12% fewer seats, the proportion of usable seats remains at least the same or is even higher than in the seat-maximized variant with 100 seats. At the same time, the passenger changeover time is approx. 25% less with a 60% passenger exchange! If, in addition to the improvement of the baggage systems, further principles for optimisation are taken into account, such as shorter car bodies with the resulting wider aisles or the arrangement of the entrance doors with short car bodies in the middle, further significant improvements are possible, especially in the passenger exchange.

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