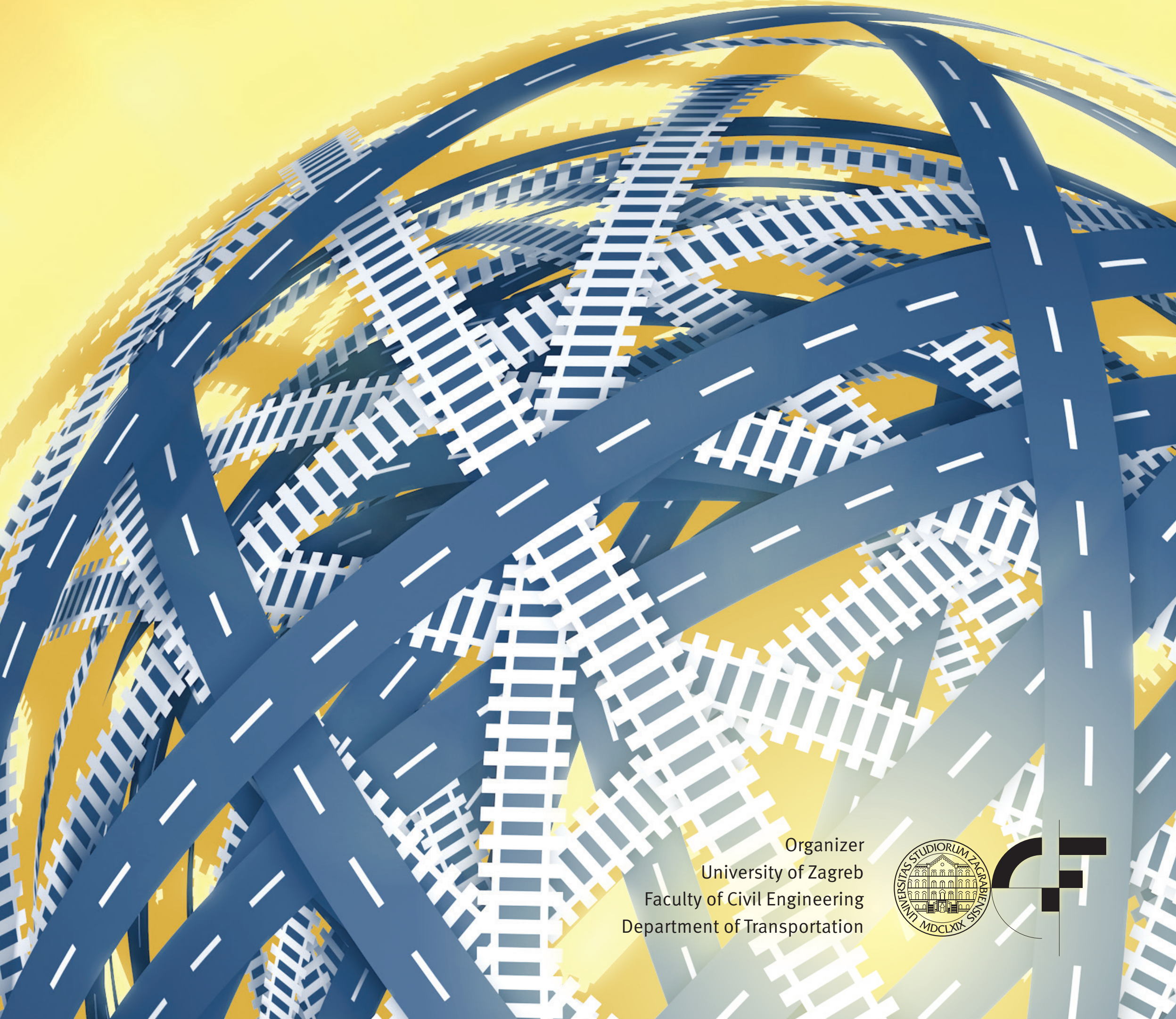
CETRA 2016

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2016]
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

TITLE
Road and Rail Infrastructure IV, Proceedings of the Conference CETRA 2016

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
"Tiskara Zelina", May 2016

COPIES
400

Zagreb, May 2016.

Proceedings of the
4th International Conference on Road and Rail Infrastructures – CETRA 2016
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA[2016]
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

ORGANISATION

CHAIRMEN

Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering
Prof. emer. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. emer. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Assist. Prof. Ivica Stančerić
Assist. Prof. Saša Ahac

Assist. Prof. Maja Ahac
Ivo Haladin, PhD
Josipa Domitrović, PhD
Tamara Džambas
Viktorija Grgić
Šime Bezina

All members of CETRA 2016 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Davor Brčić, University of Zagreb
Dražen Cvitanić, University of Split
Sanja Dimter, Josip Juraj Strossmayer University of Osijek
Aleksandra Deluka Tibljaš, University of Rijeka
Vesna Dragčević, University of Zagreb
Rudolf Eger, RheinMain University
Makoto Fujiu, Kanazawa University
Laszlo Gaspar, Institute for Transport Sciences (KTI)
Kenneth Gavin, University College Dublin
Nenad Gucunski, Rutgers University
Libor Izvolt, University of Zilina
Lajos Kisgyörgy, Budapest University of Technology and Economics
Stasa Jovanovic, University of Novi Sad
Željko Korlaet, University of Zagreb
Meho Saša Kovačević, University of Zagreb
Zoran Krakutovski, Ss. Cyril and Methodius University in Skopje
Stjepan Lakušić, University of Zagreb
Dirk Lauwers, Ghent University
Dragana Macura, University of Belgrade
Janusz Madejski, Silesian University of Technology
Goran Mladenović, University of Belgrade
Tomislav Josip Mlinarić, University of Zagreb
Nencho Nenov, University of Transport in Sofia
Mladen Nikšić, University of Zagreb
Dunja Perić, Kansas State University
Otto Plašek, Brno University of Technology
Carmen Racanel, Technological University of Civil Engineering Bucharest
Tatjana Rukavina, University of Zagreb
Andreas Schoebel, Vienna University of Technology
Adam Szeląg, Warsaw University of Technology
Francesca La Torre, University of Florence
Audrius Vaitkus, Vilnius Gediminas Technical University

EFFICIENT RAILWAY INTERIORS – EXPERIENCES

Bernhard Rüger
Vienna University of Technology, Austria

Abstract

In order to be "competitive" as a railway, operating efficiency counts as an important imperative. In the context of railway carriage interior planning this is often made subordinate to other substantial aspects such as for example, expediency. This leads in practice to the opposite wished for result. Misunderstood operating efficiency concepts such as a maximal utilization of space for seating can in reality lead to a decline in operating efficiency, operational problems and in incidents to serious safety risks.

1 Introduction

The railway finds itself, especially in long-distance travel, in an area of tension between both of its competitors, road travel and air travel. People who travel by air have or at least see no alternative to air travel. This leads to an acceptance by air travellers of comfort constraints which arise due to economic pressures on the airlines. Airlines can afford to arrange the seats in the passenger cabin to achieve a maximum of seating. Since in airline travel reservations as well as the check-in of luggage are compulsory, all seats can therefore actually be used and sold. For the railway such restrictions or drastic loss of comfort are not common and are therefore seldom implemented. Depending on travel duration and distance at least half of railway passengers could use the alternative of auto or air travel. Over 50% of travellers on ÖBB long-distance trains say that they have a driving license and have an auto available at any time. Also, because airline tickets are to some extent inexpensive, the cost argument regarding this mode of transportation is often eliminated. This in turn makes air travel more attractive. The railway cannot afford to (and should not) ignore the demands and needs of travellers. In order to achieve the high proportion of railway travellers wished for in transport policy, which as a rule also actually contains economic benefits, the railway must bring into play the advantages which it has over other modes of transportation.
However, the tendency in recent years to equip vehicle interiors with the highest possible number of seats contradicts these considerations. This leads not only to a loss of comfort, which approximates the comfort level of air travel, but also in a number of ways constitutes serious operational problems. These problems are often not considered especially in the purchase of vehicles. The often applied evaluation criterion of the highest possible number of seats and thereby expected lower purchase- and operating costs per passenger is one-dimensional and therefore inadequate since it clearly contradicts reality in more ways than one. The consequences are elucidated in this paper.
Especially in long-distance train travel but also on many local routes particularly in the service of cruise ship ports and airports the volume of luggage is often underestimated and not taken seriously in sufficient measure as an influence factor on the criteria of station dwell time, achievable seat occupancy rate, comfort, customer satisfaction and ultimately safety.

2 Luggage volume

Type, size, weight and number of particular pieces of luggage depend substantially on the parameters of travel purpose in combination with travel duration, age, gender and present group size of the travellers.
More than ten years of intensive observation shows that the volumes of individual pieces of luggage tend to be larger. This is due to an increase in comfort during transport particularly attributable to the fitting of luggage with rollers. For example, pieces of luggage which weigh 14 kilos and are meant to be carried feel as though they are the same weight as pieces of luggage which weigh 21 kilos but are equipped with two rollers. Fifteen years ago 50% of suitcases taken along on rail travel were not equipped with rollers and therefore had to be carried. Five years ago this percentage amounted to about 5%. In the meantime, nearly 100% of suitcases, so-called trolleys, are equipped with rollers.
In accordance with the comfort enhancement provided by rollers increasingly larger pieces of luggage are being manufactured and used by travellers. This has led not only to an increase in the size of individual pieces of luggage but also to an increase in weight. Meanwhile, the tendency can be seen in luggage manufacturers to equip more and more trolleys with four wheels. As a result, in many transport situations an additional increase in comfort has been achieved. The assumption is that these pieces of luggage will be felt to be even more comfortable and in weight comparison even lighter; therefore, in the near future a further increase in luggage volume and pack weight is to be expected.
Both the increase in weight as well as in size present the rail operator with corresponding challenges. Namely, in the case of boarding the train over steps as well as the frequently necessary lifting of luggage in stowing, the rollers provide no support and accordingly increase the difficulties for travellers.
In order to construct adequate and efficient luggage storage areas, as a first step, knowledge of luggage volume in terms of type, size, weight and number of pieces per person is important. With regard to an efficient overall interior design statements on this cannot and must not be generalized. It appears that there can also be a regionally specific difference in the accompanying luggage. In particular the total volume to be reckoned with for each carriage is highly dependent on respective routes and their passenger or travel purpose mix. However, due to the existing amount of data very specific remarks can be made about this.
For example, in holiday travel on statistical average 50% of travel luggage pieces are medium and large trolleys. At the same time it can be said that on average one piece of luggage per person is taken on holiday. On short trips on statistical average each traveller takes 0.8 pieces of luggage which are 35% medium and 10% large trolleys (see Figure 1). Relevant to necessary luggage accommodation is the most exact knowledge possible of the travel purpose mix which particular vehicles in their area of operation can expect. From this the actual expected average luggage volume per person and thus the corresponding total volume per vehicle can be determined.
For air travellers who use the train for arrival an approx. 20% higher luggage volume is shown than for plain holiday train travel. This fact should be taken into account especially for all trains which eventually serve airports.
As an example of luggage volume, the average travel purpose distribution in Germany was used in a fictional carriage with 84 seats and a 100% occupancy, which led to the luggage volume represented in table 1.
On average travel days an average of 36 medium and large trolleys and 38 medium and large rucksacks or travel bags were stowed. With regard to luggage accommodation the total volume of luggage must subsequently be superimposed on the wished for or actual passenger behaviour concerning the accommodation. For example, to believe that the luggage volume can be accommodated in overhead racks is a fatal mistake. Even if the calculated luggage volume could be stored in overhead racks the majority of travellers would not use the overhead racks. This means in practice much of the luggage would be stowed disruptively (see below).

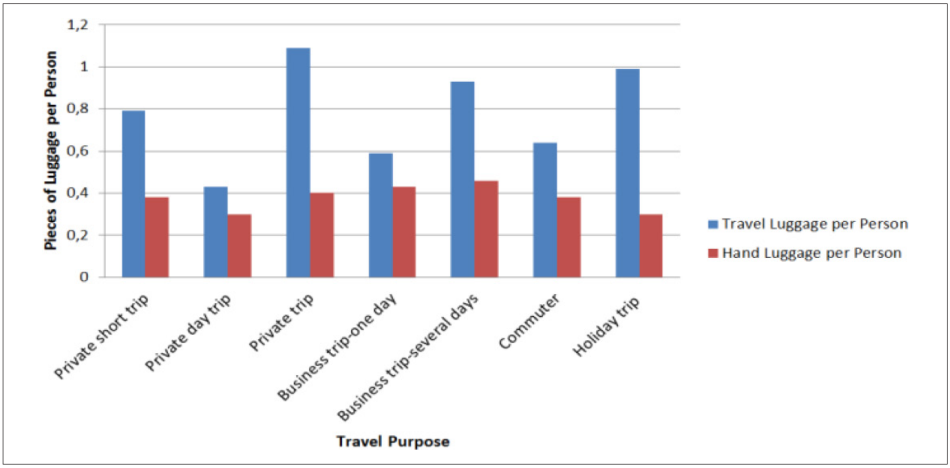


Figure 1 Average Luggage Volume per Person per Travel Purpose (Source: Plank)

Table 1 Fictional Example: Luggage volume for an average travel purpose distribution in Germany with 84 people per carriage (Source: Rüger)

Luggage type	Dimensions [cm]	Number with 84 People
Trolley large	approx. 80x50x35	13
Trolley medium	up to 70x50x30	23
Travel bag/Rucksack large	approx. 90x40x35	9
Travel bag/Rucksack medium	up to 70x35x35	29
Hand luggage	up to 55x40x25	32

3 Luggage accommodation

3.1 Passenger behaviour

Regarding luggage accommodation there are two fundamental principles. Travellers do not want to have to lift their luggage; and for security reasons they want to have visual contact with their luggage at all times. If these two criteria are not sufficiently taken into account from the very beginning of planning, inefficient and in an "incident" quite dangerous conditions in the vehicles can be expected.

For 88% of passengers visual contact to their luggage is important or very important. This means that luggage must be able to be stowed in close proximity to the traveller. If there is no adequate possibility for this, and the luggage must be stowed at a greater distance, such as in luggage racks near the entrance, for most travellers this results in a corresponding uneasiness and loss of comfort. However, from an operational viewpoint the risk is even greater from luggage which due to a lack of visual contact has been stowed disruptively. Seventy-five percent of travellers indicate explicitly that they are prepared to stow their luggage disruptively in order to meet the need for visual contact.

As a result, luggage is placed on or in front of seats or in aisle areas. This leads to an increase in unusable seats and obstructions to passenger flow.

The second important criterion with regard to planning appropriate luggage racks is the willingness to lift luggage. For example, only 20% of travellers are prepared to lift heavy luggage into the overhead rack; over 50% are under no circumstances ready to do such lifting. With medium sized luggage at least 50% are prepared to lift it into the overhead rack. With regard to luggage racks, at least 50% of travellers are prepared to lift heavy luggage up to waist level (see Figure 2). These specific values make it clear that it is pointless to provide overhead racks with no exception or alternative. Also, the existing number of luggage racks must be adequately dimensioned!

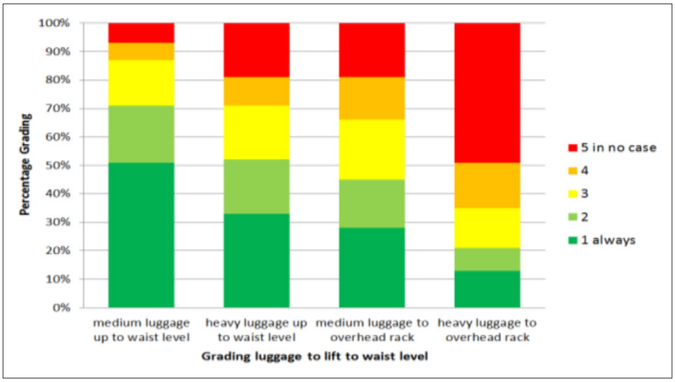


Figure 2 Readiness to Lift Luggage (Source: Plank)

The sampled readiness regarding luggage accommodation has been confirmed by extensive objective observations. Although in some cases up to 50% of the overhead racks are not used, a variety of pieces of luggage are placed on the floor, in front of seats, in the aisle or on seats. At lower occupancy rates of up to 35%, thirty percent of medium and large trolleys are placed on or in front of seats or in the aisle. Even at high occupancy rates of over 70%, by which making seats free can be expected, up to 20% of large and medium sized trolleys are placed in these positions. With rucksacks and travel bags nearly the same behaviour has been observed.

3.2 Possibilities for accommodation

The basic possibilities for luggage accommodation are: overhead racks, luggage racks and spaces between the seat backrests. In part, areas under the seats can also be used. However, as a rule these areas can be used only for those pieces of luggage which fall under the category of hand luggage. In order to design luggage storage space so that even with a very high occupancy rate all luggage can be properly accommodated, the following principles must be observed:
- Above mentioned principles “not lifting” and “visual contact”
- Determination of the actual luggage volume
- Reliable knowledge of the shape of the luggage

In order to efficiently design the most popular storage spaces between the seats and in the luggage racks, knowledge of the shape, size and volume of the luggage is by all means essential. Experience shows that luggage racks which are only a few centimetres, often only 5 cm to 10 cm too narrowly dimensioned, or whose shelf heights are too high or too low, can hold up to 50% less luggage than suitably dimensioned shelves!
The same applies to the space behind or between the seat backrests. Here 10 cm to 15 cm of too little usable space can lead to 70% less storage space.
In addition to the appropriate sizing of luggage racks and seat spacing, it is also important to ensure a well considered distribution of luggage storage possibilities in the vehicle. These must be distributed as evenly as possible over the vehicle to allow good visual contact to luggage from each seat and not impair the flow of passengers.

4 Consequences of unsuitable luggage accommodation

If the important basic principles of luggage storage space design are not respected, two serious operational consequences can be expected. The passenger boarding and deboarding time in stations will be prolonged and the actual available occupancy rate will decline up to 80%.

4.1 Passenger boarding and deboarding time

There are many factors which affect passenger boarding and deboarding time. These include passenger related factors which manufacturers and operators have no control over. These factors include age, gender, accompanying luggage and any kind of mobility limitation.
However, the vehicle-side factors are important. On one hand, by correct planning the passenger-side factors can be correspondingly reduced; on the other hand, by improper planning these can be exacerbated. These factors include for example, the entry height and door width, potentially any existing level entrances, location and number of entrances, the suitability of entrance spaces as collection areas, any restrictions to passenger flow and the overall design of the vehicle interior.
From the perspective of passenger boarding and deboarding time the difference between the best and the worst vehicles currently in use is at a ratio of 1:4. This means in concrete terms that with an assumed passenger boarding and deboarding time of one minute in the best case, the time for the same number of passengers in the worst case can be up to four minutes! It should be noted here that with some exceptions younger generation vehicles which are currently in operation tend to produce higher values.

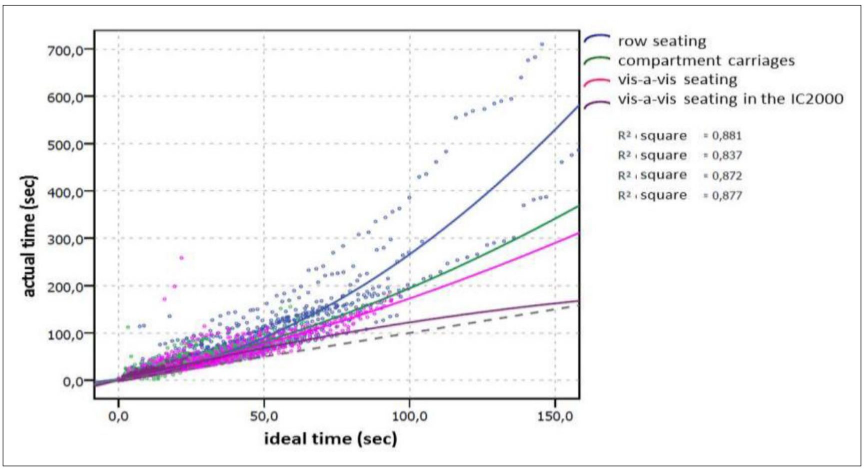


Figure 3 Time required for the boarding and deboarding process in different interior designs (Source: Tuna)

The influence of interior design between the best and worst case already produces an affect with a ratio of 1:2 (see Figure 3). This means for example, in the best case at a high rate of passenger exchange in conventional vehicle constructions, a passenger boarding and deboarding time of two minutes can be achieved. Whereas, in the worst case it requires four minutes. In Figure 3 fundamental concepts are presented; in such a way whereby in this example in row seating practically only overhead racks are available and in vis-a-vis seating luggage can be well stowed between the seat backrests. There is similar data from approximately ten basic vehicle interior categories. All findings show the clear correlation between time demand and luggage storage. The more suitable the design of luggage storage areas, the less time is needed for boarding and deboarding.

4.2 Occupancy rate

From an operational point of view, the second relevant effect of well planned or vice versa insufficiently thought out luggage storage areas, is the actual occupancy rate.
In long-distance traffic the only significant occupancy rate is the seat occupancy rate. With unsuitable and insufficiently designed luggage storage possibilities, even this can decline noticeably. In conventional passenger carriages with a length over buffers of 26.4 meters, a maximum of 80 seats for standard days and 78 seats for travel days are provided (see Figure 4). This number is achieved if the remaining areas are used in suitable form for luggage storage. If this is the case, up to 100% of the seats can be occupied. If there are more seats over these limits, it is at the expense of customer-oriented luggage accommodation; and the actual number of available seats as well as the occupancy rate sink drastically. Previous studies by the Research Centre for Railway Engineering at the Technical University of Vienna show that the average achievable occupancy rate in comparable vehicles with 88 seats is only about 80%. This means that on average only 70 of the 88 installed seats can be used (see Figure 4)! The reason for the sharp decline in occupancy is that there is not enough luggage accommodation capacity available and the existing areas are frequently unsuitably designed. This leads to the fact that part of the luggage is stored not only in the aisle but also on and in front of the seats.

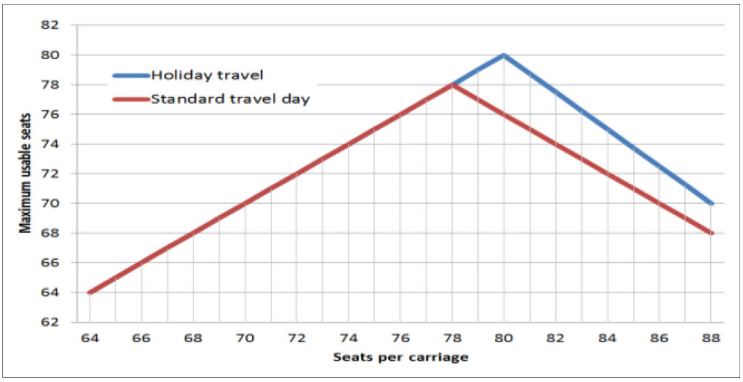


Figure 4 Maximum possible number of seats in passenger carriages with a length of 26.4 meters over buffers

4.3 Operating efficiency

The consequences of falsely planned luggage storage possibilities presented so far ultimately have significant operating efficiency impacts. The hope or goal to also be more efficient through a greater number of seats is transformed as a general rule into the opposite. Under the premise that the goal is to want to take advantage of the highest number of available seats, the following circumstances always prevail:
Delays: Vehicle interiors following the idea of seat maximization inevitably lead to long station stop times. With a high passenger exchange, four to six minutes per station are the result. Whereas, ideally designed vehicles require only one to one and a half minutes. This fact in the case of a close sequence of stations leads to corresponding delays.
Declining operating quality: When they cannot be made up for, the aforementioned delays lead to a decline in operating quality. This is especially important if delays are carried over to connecting or opposite trains, or if the results are missed connections.
Higher energy consumption: If it is at all possible to make up for the delays, it is only possible by constant use of maximum line speed, which means a significant additional energy consumption especially at a high rate of speed.

Lower occupancy rate: There are seats installed which in practice are not available. At the same time the achievable seat occupancy rate declines for 20%
Declining passenger satisfaction: The declining seat occupancy rate causes a correspondingly high number of standing passengers, which accordingly reduces passenger satisfaction. Comfort is significantly reduced by the in part “chaotic” conditions in “overcrowded” vehicles. For nearly 18% of travellers high occupancy together with the already mentioned associated effects means a high stress factor!

4.4 Safety

The most important criterion which is often overlooked in insufficiently estimated operating efficiency considerations is safety. If in an emergency a train has to be evacuated, a large number of seats at a high occupancy rate in combination with the aforementioned effects presents a high safety risk. In air transportation a maximum evacuation time of 90 seconds must be proven before the certification of an aircraft. In railway transportation there are no such known provisions. However, it is understood that in most vehicles this time cannot be met. In a fully occupied carriage with 88 seats, the absolute exit time of all passengers under ideal conditions (no luggage during the exiting process, no backup because of crowding at the entrance door, only two steps) with the best carriage designs approx. 120 sec. is required and with the worst constructions, approx. 160 sec.
In an incident, rising panic must be considered in which case an orderly exiting process cannot be expected. Above all, in this case improperly stowed luggage would lead to a corresponding safety risk! For this reason alone it must be ensured that for every installed seat there is also a suitable luggage storage space.

5 Fundamental planning errors

From past experience, both on the part of the purchaser as well as on the part of the manufacturer, fundamental errors which lead to the inefficient conditions described above can be identified in the planning and ordering process.
Error 1: Volume calculation: Every cuboid-like object has a volume and also three definite dimensions. As a rule In tender documents there is only information on the total volume required for luggage accommodation. For cuboids the volume is known as the product of width, length and height. This means that an often called for volume of approx. 0.125m³ per passenger can either correspond to the dimensions of a midsized trolley with dimensions of 50x70x35 cm, or at the same time, a trolley with dimensions of 1x4160x30 cm! Accordingly, it is also common practice to multiply every small cross-sectional area by the available depth and to sum the resulting volumes to a total volume! As a rule, in practice a maximum of 50% of the calculated volumes are available. It is therefore necessary to have precise knowledge of the statistical distribution, shape and dimensions of the luggage!
Error 2: Disregard of passenger behaviour: If the principles of “not lifting” and “visual contact” with regard to luggage storage construction are disregarded, the planned storage areas will be only in part accepted by the passengers. In practice this leads to the condition that up to 50% of all storage areas remain unused and yet a larger amount of luggage is stored disruptively.
Error 3: False awareness of luggage volume: The actual luggage volume has to be calculated for each route and expected passenger or travel purpose mix. Frequently blanket assumptions are made, or days are taken as a basis for calculation on which only a below average luggage volume can be expected.
Error 4: False dimensioning: Meanwhile, luggage accommodation is increasingly being taken into account in vehicles with regard to the installation of luggage racks and the space between the seat backrests. However, here it must be noted that the dimensions of luggage racks are

often oriented to seat spacing resulting in very inefficient dimensions. The same can be observed in the spaces between the seat backrests. When dimensioning the respective storage areas it is advantageous to take into account the forms and dimensions of the luggage as well as the storage behaviour of passengers. Seat spacing and luggage racks are often dimensioned a few centimetres to small, which can lead to an actual storage loss of 50% or more.
Error 5: False evaluation criteria for orders: In vehicle orders it can often be observed that evaluation criteria are applied which are not logically understandable. A popular evaluation criterion in tenders is to define the minimum number of seats. Usually this involves specifications which can be classified as a psychological perception; and thus, they often jump to increments of 100. If for example in the tender as a fictitious number it is predetermined that a train must have 500 seats, then the hands of the manufacturer are already bound in the tender phase; and from the outset actually efficient solutions are not possible. These figures are usually based on a previously calculated maximum number per vehicle and thereby disregard reality. With the fictitious example mentioned it can be expected that a maximum number of 450 seats will actually be available in the train. Thus, it would be much more efficient to make no such requirement, but rather to allow the manufacturers to search for efficient overall solutions. With appropriate solutions it can be expected that vehicle design concepts can be found which in the example mentioned offer approx. 470 seats. Seats, which in the end can actually be used!

6 Conclusion

Fifteen years of research and development as well as participation in numerous vehicle plans make it clear that at all times with vehicle development and orders an overall optimum for vehicle interiors should be sought. Many negative examples make clear that the exclusive pursuit of a maximum number of seats can in practice lead to inefficient and dangerous situations. In particular, luggage storage possibilities must be precisely and thoughtfully planned in order to contribute to efficient overall systems. Experience further shows that it is very critical to lay aside blanket assumptions about design. Each vehicle must be assessed individually in terms of attainable overall efficiency which ultimately leads to an actual maximum seating occupancy. Requirements for luggage storage must be thoughtfully formulated in the tender. Furthermore, in order achieve the greatest possible degree of efficiency, where and which luggage storage areas can be installed must be precisely considered in the beginning phase of vehicle planning. Later changes are usually achieved only with great difficulty or with little effect.
Fortunately, in recent times one can discern an awareness regarding these problems. Numerous recent projects confirm that both on the part of the operators as well as the manufacturers, interest in and willingness to develop efficient overall systems have emerged; and that some efficient overall solutions can be developed with negligible additional cost.

References

[1] Tuna, D.: Passenger Exchange in Passenger Transportation; TU-Vienna, Institute for Railway Engineering, Transport Economics and Cable Railways, 2008

[2] Cis, P.: Occupancy Rate of Railway Carriages Depending on Individual Passenger Behaviour; Diploma Thesis, TU-Vienna, Institute for Railway Engineering, Transport Economics and Cable Railways, 2009

[3] Plank, V.: Dimensioning of Luggage Storage Areas in Passenger Trains; Diploma Thesis, TU-Vienna, Institute for Railway Engineering, Transport Economics and Cable Railways, 2008

[4] Rüger, B., Tauschitz, P., Petutschnig, B.: Boarding Assistance System Evaluation Criteria Report; Report for European Commission; Report-No. Deliverable D2.1, 2010

[5] FLEXICOACH-AP2-Report, 2012, FFG-Tender ways2go, 4.Tender

[6] http://de.wikipedia.org/wiki/Evakuierungssimulation