26th INTERNATIONAL CONFERENCE
„CURRENT PROBLEMS IN RAIL VEHICLES -
PRORAIL 2023“
September 20 – 22, 2023, Žilina, Slovakia

https://doi.org/10.26552/spkv.Z.2023.2.25

VEHICLE INTERIORS - EFFICIENCY THROUGH CUSTOMER ORIENTATION

INTERIÉRY VOZIDIEL - EFEKTÍVNOSŤ PROSTREDNÍCTVOM ORIENTÁCIE NA ZÁKAZNÍKA

Bernhard RÜGER*)

1 INTRODUCTION

In order to be able to achieve a positive influence of the vehicle layout on the operational efficiency, the behaviour of the passengers who will ultimately use the vehicles must be placed at the centre of all considerations already during the design of rail vehicles. If the requirements and expectations of the passengers are not sufficiently taken into account, taking into account the different current realities of life and travel conditions, such as the purpose of the journey and the activities derived from it, the luggage carried, fellow passengers (e.g. children) or any mobility restrictions, the resulting poorly designed interior of the vehicles often leads to noticeable inefficiency.

2 METHOD

All of the following findings are based on more than twenty years of research in and the completion of approximately 40 research and consulting projects, in which knowledge was gathered through observations in the trains, video time measurements at the boarding points and in our own series of tests in the vehicles and interviews with passengers of more than 400,000 passengers, such as which seats are preferred, where luggage is stored and in what way, which difficulties occur when storing luggage or when boarding and moving around in the vehicle. It was possible to comprehensively collect data on the behaviour of passengers when taking and storing luggage. Based on this extensive data, which exclusively takes into account the specific behaviour of passengers in trains, the software product TrainOptimizer® was developed in cooperation with the Vienna University of Technology and netwiss, with the help of which vehicle layouts can be very easily assessed by simulation with regard to their efficiency. The findings presented in this paper are based on the application of the simulations in TrainOptimizer®. ***fig. 1*** shows the flow chart of the simulation. In a first step, layouts are created in an easy-to-use editor and then, if necessary, further settings such as deviating age distribution, special trip purpose mixes, region-specific data etc. are selected for the evaluation. Based on the extensive data available, the tool knows the volume of luggage and the behaviour of travellers when boarding and disembarking and in the context of luggage accommodation. The output is easy-to-understand graphs on passenger changeover time, luggage stowability and seat usability.

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*) **FH-Prof. Dr. Bernhard RÜGER**, TU-Wien, Track-bound Transportation Systems, Karlsplatz 13/230-2 A-1040 Wien, +43 1 58801 23212, Bernhard.rueger@tuwien.ac.at, Senior researcher.

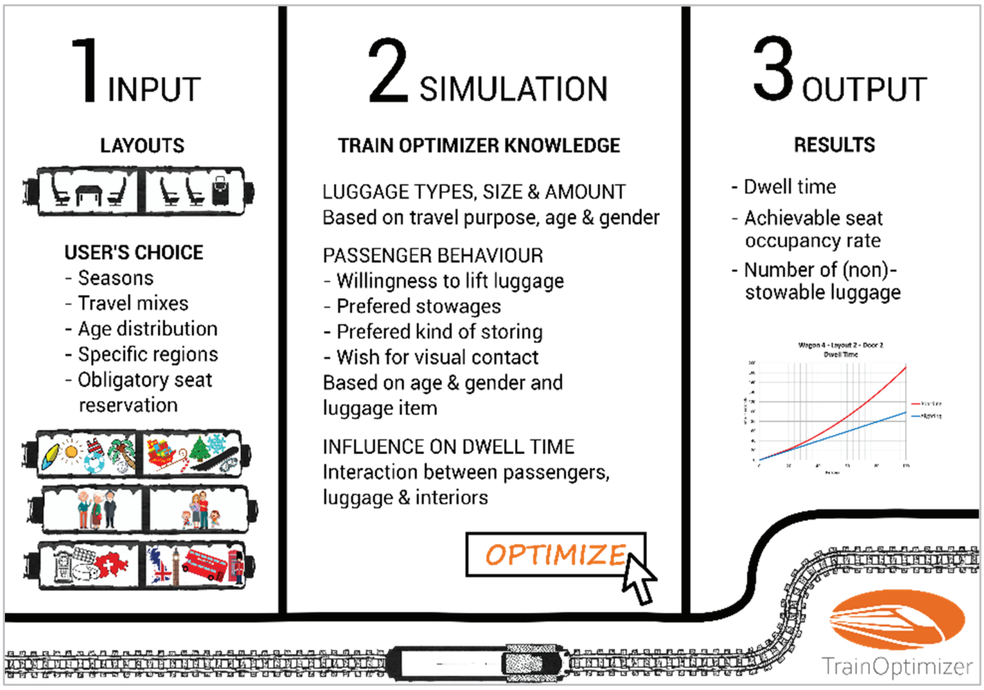

Fig. 1 *Flow chart of the simulation with TrainOptimizer® ©netwiss*

Obr. 1 *Vývojový diagram simulácie s TrainOptimizer® ©netwiss*

3 TRAVELLER BEHAVIOUR RELATED TO THE LAYOUT

Relevant behaviour patterns of passengers with a significant influence on efficiency result in particular from the carrying of luggage in long-distance transport. This influences behaviour when boarding and moving around in the vehicle, when looking for a seat and during accommodation. Adequately dimensioned luggage racks are essential and must meet the following two basic requirements of passengers:

- Travellers want to avoid lifting heavy luggage in particular
- Travellers want to have visual contact with their own luggage at all times for reasons of subjective security

The majority of vehicles currently in use hardly take these basic requirements into account and often follow the premise of seat maximisation with the expectation of a supposed increase in capacity utilisation and thus profit. Vehicles that follow these principles lead to the fact that luggage cannot be adequately stowed and that, in addition to safety risks, there is a significant loss of usable seats. In addition, deficiencies in the stowability of luggage during passenger changes lead to corresponding backlog effects and thus longer dwell time.

In local transport in particular, in addition to person-specific influences such as age or any mobility restrictions, the fact that people want to be able to reach the exit at any time and thus avoid "unpopular" areas in the vehicles from which this is supposedly not possible is also decisive. This leads to an irregular utilisation of the vehicle and thus to reductions in the de facto vehicle capacity with equally negative effects on the passenger changeover time.

In both long-distance and short-distance vehicles, the arrangement and size of the doors also has a significant influence on the passenger changeover time. If a division of the passenger flow can be achieved after boarding a vehicle, the passenger changeover time is significantly accelerated. In addition, the door width should be at least 90 cm for long-distance trains and at least 160cm for local trains in order to contribute to a further acceleration of the passenger changeover. Door widths of up to approx. 140cm usually barely allow two parallel walking lanes, doors of 160 cm and more have the full boarding capacity of two single doors.

Other noticeable influences on the passenger changeover time are the number of boarding steps and the passenger flow in the interior. A level entrance with gap bridging is the ideal situation, a gap increases the passenger changeover time in the range of 1/10sec per person. If, on the other hand, there are one or more steps, the passenger changeover time can multiply, especially in combination with luggage transport. For passenger flow in the interior, an "open" area, e.g. in the form of a small multi-purpose compartment, should be provided on both sides of the boarding area (if the door arrangement allows passenger flow in both directions). The adjoining aisles should have an aisle width of at least 60cm.

4 IMPACT ON CAPACITY AND PERFORMANCE

The most important effects of the vehicle layout on capacity in terms of seats and, in local traffic, also standing room per train and performance as a measure of the number of trains per hour and thus the number of passengers per hour are presented below:

1) Vehicle layouts that include many "unpopular" areas in local traffic and, especially in long-distance traffic, do not sufficiently take into account the basic requirements for luggage accommodation, lead to a lower possible de facto utilisation per wagon and thus per train.
2) If, as a result of the above-mentioned reasons, the dwell time is extended, this will lead to increased train following times with a corresponding reduction in performance, especially in local traffic.

Conversely, an increase in capacity and performance can be achieved if

1) Especially in long-distance traffic, there are sufficiently dimensioned luggage accommodations that really meet passenger requirements.
2) There are no "unpopular" areas. These are areas, especially in local transport, with a longer way to the exit, where passengers are concerned about not getting to the boarding point in time.
3) layout measures that contribute to a reduction of the stopping time and generally use vehicles with a high acceleration capacity. In this way, especially in local traffic, the train following time can be reduced and, taking into account other necessary infrastructure measures, the number of trains per hour can be increased.

In addition to the thoughts of the vehicle layout, it is important for the capacity increase to weigh the general vehicle concepts carefully. In particular, the use of double-deck trains and, ideally in combination, multiple unit trains lead to a further increase in the capacity of the train.

5 IMPACT ON RAILWAY OPERATIONS, INVESTMENT MEASURES AND ENERGY DEMAND

Dwell time has an impact on rail operations on several levels. In order to increase efficiency, measures must be sought that help to reduce the dwell time to a minimum. The vehicle layout has a significant influence on this; in addition, the technically required times for door release and door closure must be reduced and the operational handling procedure optimised.

The most important positive effects from a minimised dwell time are:

1) Punctuality: The quality of service suffers from longer dwell time, whereas minimised dwell time make a significant contribution to adherence to the timetable and thus to punctuality. By reducing the dwell time, the buffer time is increased while the total journey time remains the same.
2) Edge travel times: The edge travel times are made up of half the dwell time in the adjacent nodes and the travel time between the two nodes and represent an essential characteristic for a clockface timetable. Since the edge travel time takes a constant value (integer multiple of half the cycle time), an extended dwell time automatically requires a shorter travel time between the two nodes, which can only be achieved by a higher travel speed. Conversely, the minimised dwell time in the stations can also reduce the travel speed. This has the following effects:

a. *Energy saving:* The lower driving speed saves energy. Further potential for energy savings and a related reduction in operating costs exists in the area of structural weight. Vehicles with long car bodies and two bogies each have a higher total weight than articulated train concepts with Jacob's bogies or even single wheels. With such concepts, the total weight of the train per seat can be further reduced, which leads to a corresponding reduction in energy demand.

b. *Infrastructure upgrades:* In order to be able to achieve the required travel time to reach the edge travel times, the infrastructure is often adapted and expanded. If travel time reductions in the range of minutes are necessary to achieve the edge travel time, then these time gains can be gained through the reduction of the dwell time, whereby possibly expensive infrastructure measures can be omitted.

c. *Vehicle savings:* For various circulations, especially in the area of local transport, a reduction in dwell time, especially with many intermediate stops, can lead to a reduction in the total journey time, which means that there is potential for saving one or more vehicles in the entire circulation with the same service.

6 CONCRETE LAYOUT EXAMPLES TO ILLUSTRATE THE OPERATIONAL EFFECTS

In the following, three fictitious layouts (***Fig. 2*** to ***fig. 4)***) are used as examples to illustrate the influence of the different layouts on seating capacity and passenger changeover time. The layouts deliberately represent a maximum in terms of space for seats and do not take into account all space-reducing elements such as partitions required for technical components. Two toilets and an electrical cabinet are considered in each case.

- V1 corresponds to a classic UIC passenger coach with doors at the ends of the coach, which follows the idea of maximising seating capacity. There is overhead storage along the entire length of the carriage and a small luggage rack at one end of the carriage only.
- V2 builds on V1. Here, however, the number of seats is reduced in favour of three luggage racks.
- V3 has the same dimensions and similar luggage accommodation capacity as V2. However, the doors are shifted to the quarter points, which results in a division of the passenger flow after boarding that contributes to a significant reduction in passenger changeover time.

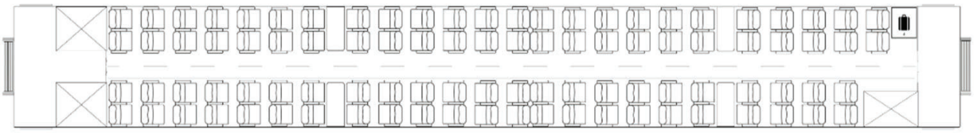

Fig. 2 *Example of layout V1 ©netwiss, created with TrainOptimizer® software*
Obr. 2 *Príklad rozloženia V1 ©netwiss, vytvoreného pomocou softvéru TrainOptimizer®*

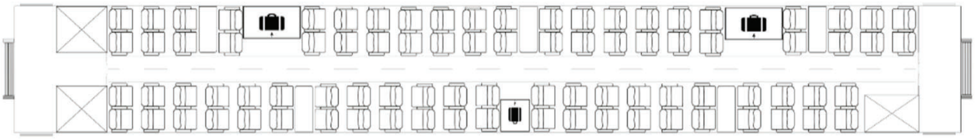

Fig. 3 *Example layout V2 ©netwiss, created with TrainOptimizer® software*
Obr. 3 *Príklad rozloženia V2 ©netwiss, vytvoreného pomocou softvéru TrainOptimizer®*

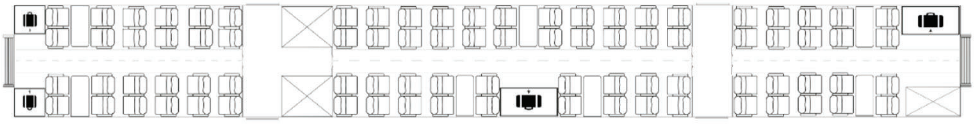

Fig. 4 *Example layout V3 ©netwiss, created with TrainOptimizer® software*
Obr. 4 *Príklad rozloženia V3 ©netwiss, vytvoreného pomocou softvéru TrainOptimizer®*

7 SEAT OCCUPANCY AND LUGGAGE STOWAGE CAPACITY

The actual availability of seats and the number of stowable pieces of luggage per layout variant for classic travel days are shown in ***fig. 5*** and ***fig. 6*** are shown.

A comparison of the three layouts shows that with theoretical full occupancy (the same number of people in the wagon as seats), only 77 of the 94 seats can be used on a travel day with variant V1, as approx. half of the luggage cannot be stowed.

Despite the reduction in the number of seats to 86, the V2 variant has more seats available (79) than the V1 variant. 77% of the luggage can be properly stowed in this variant.

The V3 variant has 84 seats; here, too, an average of 79 seats are available on travel days, and approx. 85% of the luggage can be stowed.

This comparison shows that a higher number of available seats does not necessarily lead to a higher proportion of seated passengers. In most cases, the actual seat availability is even lower than variants with a lower number of seats but more capacity for luggage accommodation. If trains are used on routes with highly variable trip purpose mixes, variants such as V2 or V3 may make sense, as they have a higher seating percentage with lower luggage volumes. If trains are used on long runs with more luggage-intensive trip purpose mixes, then it seems sensible to reduce the number of seats further, in the upper cases to 80 seats, as more seats are not usable anyway, but then in fact all the luggage can be properly stowed.

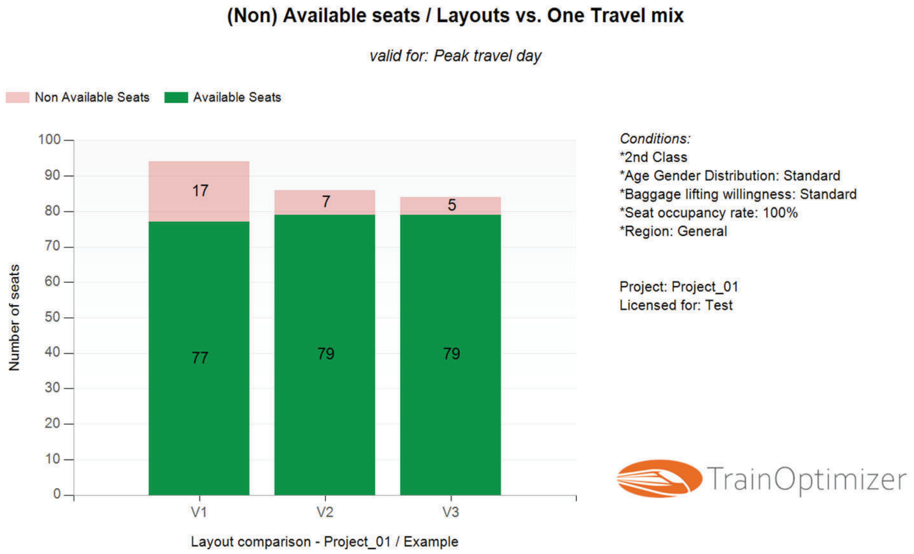

Fig. 5 *Proportion of available seats per variant ©netwiss, created with TrainOptimizer® software*

Obr. 5 *Podiel dostupných miest na variant ©netwiss, vytvorený pomocou softvéru TrainOptimizer®*

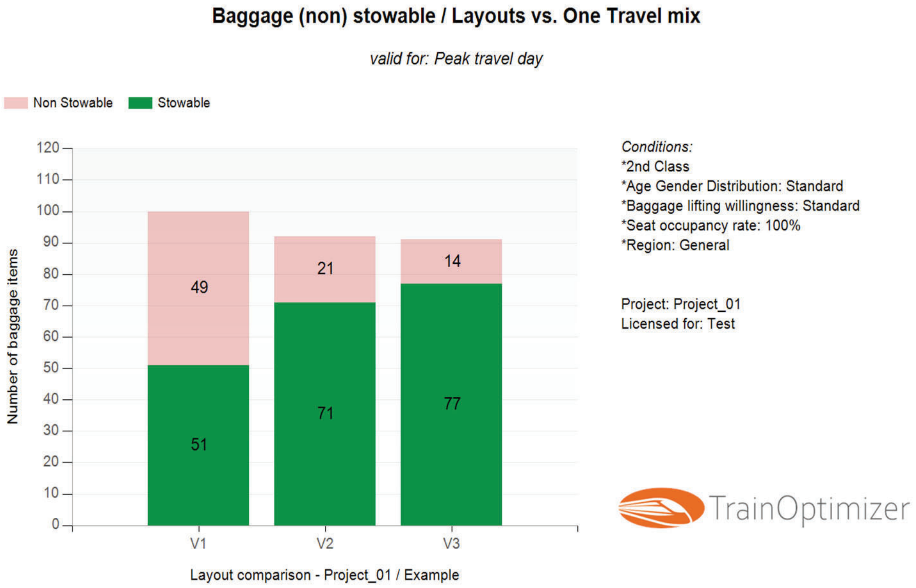

Fig. 6 *Stowable versus non-stowable luggage per variant ©netwiss, created with software TrainOptimizer®*

Obr. 6 *Skladná verzus neskladiteľná batožina podľa variantu ©netwiss, vytvorený pomocou softvéru TrainOptimizer®*

8 PASSENGER CHANGEOVER TIME

There are even greater differences between the three variants in terms of passenger changeover time. The effects with regard to the passenger changeover time are characterised by the following influencing parameters:

- Variant with high number of seats and low baggage stowage capacity - V1
- Variants with lower number of seats (but higher defacto capacity) and higher baggage stowage capacity - V2 and V3
- Variants with the doors at the ends of the carriages - V1 and V2
- Variant with the doors approximately at the quarter points, allowing the passenger flow to be divided - V3
- In all versions, the door width is 90cm and the aisle width 55cm.
- Variants with three entry steps (V1, V2, V3), with one entry step (V1, V2, V3) and with level entry including gap bridging (V3)

The right-hand pair of doors was selected for the display of the passenger changeover time. ***fig. 7*** shows the time required for a 60% passenger changeover. This means that 60% of the passengers, in relation to the available number of seats, get off and another 60% get back on***. fig. 8*** shows the progression of the passenger changeover time over the number of people who can mathematically board each door. The values on the abscissa refer to passengers getting on and off the train; for example, the value 30 shows the total time required for 30 passengers getting on and off the train.

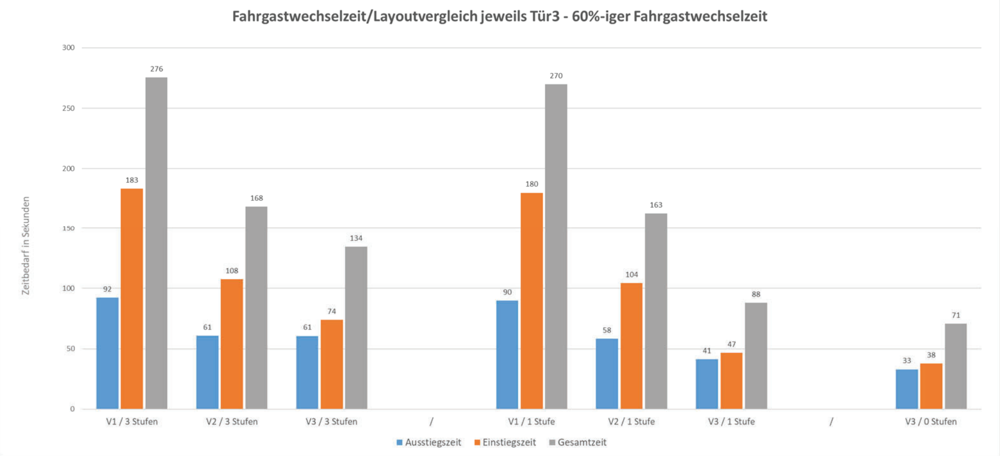

Fig. 7 *Passenger changeover time for a 60% passenger changeover ©netwiss, created from softwre TrainOptimizer®*

Obr. 7 *Čas výmeny cestujúcich pre 60 % výmenu cestujúcich ©netwiss, vytvorený zo softvéru TrainOptimizer®*

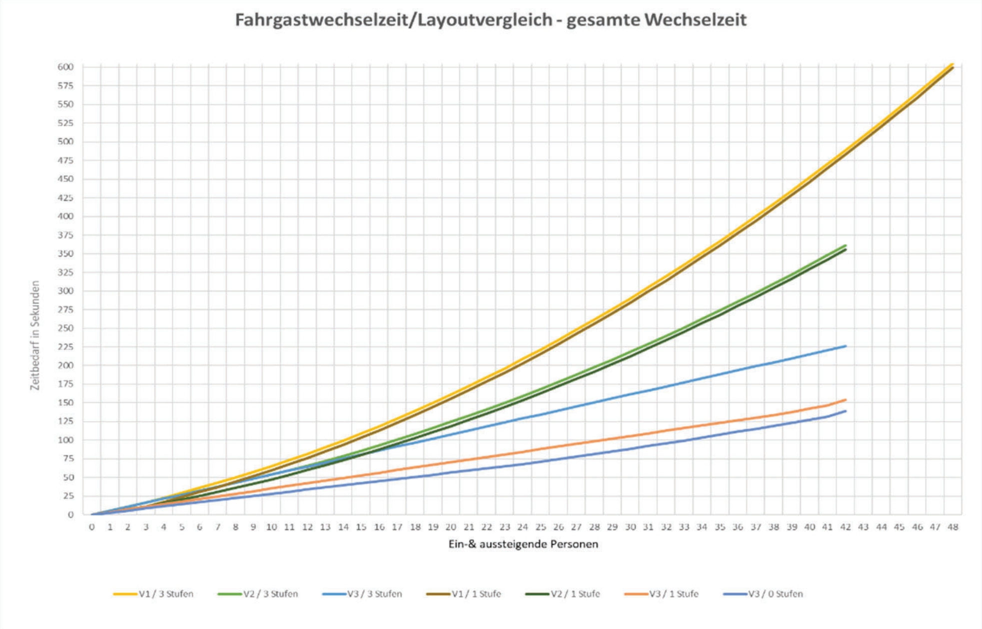

***Fig. 8** Passenger changeover time (boarding and alighting time) - progression over all passengers ©netwiss, created from software TrainOptimizer®*

***Obr. 8** Čas prestupu pasažierov (čas nástupu a výstupu) - priebeh cez všetkých cestujúcich ©netwiss, vytvorený zo softvéru TrainOptimizer®*

The following findings can be read with regard to the passenger changeover time:

Influence of luggage storage and door arrangement

When comparing the variants V1 and V2 with three steps, it can be seen that the 60% passenger changeover in the seat-maximised variant V1 with an average of 276sec takes 65% longer than in the variant V2 with adapted luggage accommodation capacity. Compared to variant V3 with the doors in the quarter points and also with three steps, the passenger changeover even takes slightly more than twice as long. Even if the number of passengers is normalised to a certain value in

Fig. the corresponding differences can be seen.

This comparison shows that with practically the same defacto seating capacity, the passenger changeover time can be significantly reduced by taking into account suitable and customer/interior-friendly luggage racks; if the door position is also taken into account, this time can even be halved.

Influence of the number of steps and the door arrangement

The number of steps generally has a noticeable influence on the passenger changeover time, as people need longer to negotiate several steps, especially in combination with luggage, than with level entrances or only one step. Nevertheless, it can be seen in ***fig. 7*** and in ***fig. 8***

Fig. that the influence of the number of steps has to be put into perspective, especially in long-distance traffic with a high share of luggage. With the V1 and V2 variants, it can be seen that despite a difference in the number of steps, with one and three steps respectively, there is hardly any difference in terms of passenger changeover time. At the exit, the difference is generally less noticeable; at the entrance, the influence of the adjacent passenger compartment is clearly evident in both variants. In both variants, even in the "faster" variant V2 with higher luggage stowage capacity, the backlog from the interior already has an effect after a few passengers. Thus, after a few passengers, the bottleneck is no longer at the boarding door but in the interior of the vehicle. The time difference is therefore only a few seconds. Nevertheless, for reasons of passenger comfort and accessibility, the number of steps should always be kept as low as possible and, ideally, level access should be provided.

When considering variant V3, in which there is a splitting of the passenger flow after boarding the vehicle and thus the backlog effects from the interior spaces are significantly reduced, the difference in passenger changeover time between the presence of three steps, one step and a level boarding with gap bridging can be clearly seen. Due to the good passenger flow inside the vehicle, the boarding door now becomes the bottleneck again. With three steps, the passenger changeover time takes about 50% longer than with one step. With a level entrance with gap bridging, the passenger change takes only half as long as with three steps. Despite the passenger flow distribution, with a higher proportion of passengers at level boarding, a backlog effect from the interior becomes noticeable again, albeit to a lesser extent.

9 CONCLUSION

Dwell time is an important lever for increasing operational efficiency. Shorter dwell times in a clockface timetable mean lower required travel speeds with corresponding potential energy savings, higher travel time reserves and thus improved punctuality and, conversely, offer the possibility of reducing the travel time to achieve required edge travel times and help to avoid possibly expensive infrastructure expansions.

In order to be able to reduce the holding time accordingly to generate the above-mentioned benefits, the following factors are decisive and must be taken into account:

1) Sufficient and properly designed luggage racks
2) Avoiding unpopular areas, especially in local transport vehicles
3) Door arrangements shall be such that a division of passenger flow can be achieved after boarding.
4) As few entry steps as possible, ideally a level boarding with gap bridging, should be provided.
5) Door widths of at least 90 cm for long-distance traffic and at least 160 cm for short-distance traffic shall be provided.
6) After the boarding space, good passenger flow shall be provided, with aisle widths of at least 60cm and open areas such as multi-purpose compartments at the beginning of the aisle.
7) Vehicle concepts such as double-decker trains, multiple unit trains and trains with shorter car bodies and Jacob's bogies or single wheels lead to a reduction in structural weight per passenger with corresponding energy efficiency. Likewise, such vehicles also largely increase capacity.

If the above-mentioned design rules for rail vehicles are fully taken into account from the outset, the efficiency in the rail system can be significantly increased without additional expenditure, as an increase in capacity, a lower energy requirement, higher punctuality and, if necessary, the avoidance of more expensive route extensions can be achieved.

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J., Turk M., Schöbel A.; Energy efficiency by optimizing passenger-changeover in the station, Third UIC Energy Efficiency Conference, Portoroz, 2007. **[4]** Application of the TrainOptimizer® simulation tool

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Summary

The vehicle design has a significant influence on the possible capacity and thus the performance of a route as well as on operational requirements such as punctuality, the achievement of edge running times and turnaround times, but also on economic and environmental criteria such as energy consumption.

Resumé

Konštrukcia vozidla má významný vplyv na možnú kapacitu, a tým aj výkonnosť trasy, ako aj na prevádzkové požiadavky, ako je presnosť, dosahovanie okrajových dôb a dôb obratu, ale aj na ekonomické a environmentálne kritériá, ako je spotreba energie.