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Railway infrastructure of Hungary

Submitted by Hungary

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VASÚTI HATÓSÁGI FŐOSZTÁLY

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Table of contents

1 Introduction

In Hungary, authorisation procedures for railway infrastructure and railway rolling stock fall under the competence of the Railway Authority Department of the Ministry of Construction and Transport (hereinafter: NSA HU).

The operation of the railway authority operating in Hungary (hereinafter: NSA HU) has already been described in the material prepared for the Inland Transport Committee's Working Party on Rail Transport Special Session No. ECE/TRANS/SC.2/INFO/2024/1, which can be accessed at link https://unece.org/sites/default/files/2024-06/ECE-TRANS-SC.2-INFO-2024-inf01e_0.pdf. The task of NSA HU is the technical supervision of the railway operation in Hungary and the maintenance of safe transport. Safety can only be maintained if rail transport operates under the principles of **STABILITY**. All elements of transport must be designed in such a way that any activity can be planned in advance, even on an annual basis. That is why every single activity must be directed towards tactive schedule, which can then be considered a definite basis. If a disturbance occurs, it must be clearly seen that in the event of a disturbance, the goal is to achieve a definite, secure state, i.e. to achieve STABILITY. During Hungary's presidency of the EU, the documents created under the name of NSA HU are defined by the principle of STABILITY.

2 Narrow gauge railways

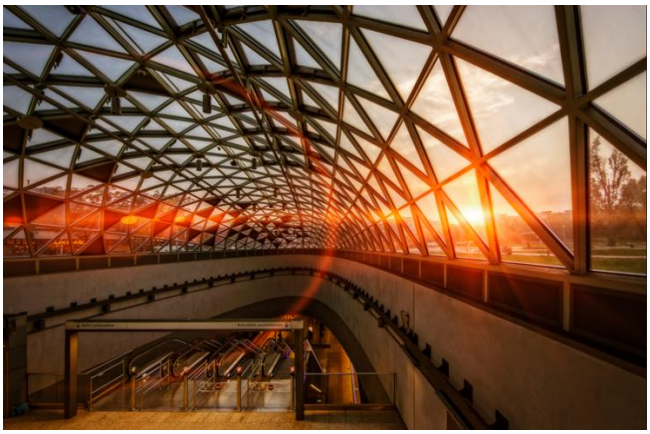
Narrow-gauge railways do not belong directly to the European core network, but they can also participate in scheduled traffic, carry out freight transport tasks, but can also fulfill functionsof tourism. Their general characteristic is lower speed and smaller capacity, but it must not be forgotten that even the operation of narrow-gauge railways can be dangerous as well. The procedures for the vehicles and related mechanical equipment of narrow-gauge railways are also an important task in the procedures of the railway traffic authorities. In Hungary, the vast majority of narrow gauge railways serve tourist purposes in terms of passenger transport, but in several countries they also perform tasks according to the exclusive timetable, practically only because of the different gauges they are separated from the national high-speed railway network.

3 Some thoughts on information and communication

Information and tools suitable for providing information were mentioned in the previous materials, however, depending on the results of the meetings, progress can be made in the direction of highlighting any area. We must never forget that the systems created by railway professionals are made for people, in any case the professionals who create the information must be aware that the information is processed differently by each person, and the response given by each passenger may differ significantly.

Picture 1. Cog railway, (source: BKV)

Picture 1 shows the cogwheel vehicles and their surroundings in Budapest. The trains run on one track, there is no alternative railway route, the replacement can only be solved by road. If an event occurs that requires the vehicle to be abandoned, this can be easily resolved due to the dense stations. Passengers can leave the railway area quickly, we can also look at it from the point of view that the railway company no longer needs to pay attention to the passenger, because the passenger has left the area affected by the contract of travel.



Picture 2. M4 metro Bikás park station (source: BKV)

The M4 metro line was handed over as a new construction in 2014 and currently operates as an automatic system. The automatic system does not only mean that the vehicles drive without a driver, but also that the service systems operate automatically, including the operation of mechanical equipment. Several stations were built in such a way that the sky can be seen from the station or even from one of the higher levels, so the passengers can at least approximate their position and the local time from the position of the sun. It is important to mention the visibility of sky because if a tall building is visible from the station, some of the passengers can at least partially retain their ability to find their way around. Keeping the ability to find your way around is very important for a sense of security. If evacuation from the station becomes necessary, the general state of mind of the fleeing crowd can be maintained to a more favorable degree.

Picture 3. M4 metro Gellért tér station fully illuminated (source: BKV)

Picture 3 shows the Gellért tér station of the M4 metro in full light without passengers. Passengers typically do not spend a lot of time at the station after completing the boarding and disembarking function, so it is a barely noticeable psychological burden for the passengers. For workers who spend their entire working hours underground, the workload can already be significant.

Picture 4. M4 metro Gellért tér station with reduced lighting (source: BKV)

Picture 4 shows a version of the Gellért tér station with reduced lighting, if we manage to imagine ourselves at this station under such conditions, then the situation is already less favorable, especially if this change occurred from one moment to the next. Considering the above mentioned facts, let's imagine that this station is flooded with smoke and there are around 2000 people in the station area. The smoke tests of the stations were carried out using a harmless substance, but the stations can withstand the flow of air at a temperature of 400 ^{o}C temporarily, and it is also possible that the flowing smoke could be toxic. According to the above, it is very important how carefully we plan the stations, the load capacity of the stations, and the cooperation of the stations..

3.1 Information

Below is the definition of the information that may be important from the point of view of moving forward:

"In a general sense, information is any sign, symbol or signal that a person can use to influence another person in such a way that their behavior changes. The transmitter is the sender of the information, the receiver is the receiver, the information itself reaches the receiver as a message through some information transmission channel. Narrower

definition: content meaning of signs that carry new knowledge for us. From a functional point of view, its essential feature is that it always reduces uncertainty."

3.2 Communication

Communication is the process of exchanging information usually using a common signal system. The word communicatio is of Latin origin: it means publication and fulfillment, it comes from the word communio (community). The information given by the systems can raise questions in passengers, which arise because it has caused uncertainty in them. In order to reduce uncertainty, the passenger asks the system a question, if he does not get an answer to his question, then the uncertainty will increase. In this case, we are already talking about the mutual relationship and communication between the system and the passenger. Establishing communication means a new task for railway subsystems, the more complicated a railway system is, the more complicated and complex a response may be.

3.3 Panic

The concept of panic: "Panic is an emotional state in which the urge to escape overrides common sense. Panic often occurs during, for example, a disaster or situations that trigger a phobic reaction."

It is my personal experience that even the most experienced workers lose their orientation in underground workplaces, where possible operating equipment is located in smaller rooms and these rooms are connected by winding corridors. In such workplaces, it is a requirement that the workers bear the load resulting from working underground, but we cannot demand this from the passengers. More and more stations are going underground, so the escape routes must be carefully planned, the proper designation of the escape routes is of paramount importance. The throughput of the escape routes must be precisely dimensioned and strictly adhered to. In an emergency, it is not only necessary to ensure the escape of the passengers, but also to ensure the accessibility of the site by professionals entrusted with rescue. There was a case where the rescuers went to a passenger in trouble on a train in the wrong direction of the train and lost minutes, and the passenger's life depended on minutes.

4 Static and dynamic transport systems

By static traffic systems, we mean systems, whether from the vehicle or the track side, that are generally constructed in such a way that they only provide a minimal system response to disturbing factors outside the systems. Regarding the track, a general braking distance related to the maximum permitted speed is given, but the braking percentage applied to the track section is also given. In several cases, the brake percentage interpreted for the entire section is specified due to a local characteristic, but it requires unnecessary parameters from the vehicle's braking system when applied to the other sections.

4.1 Static transport systems

The general characteristic of static traffic systems is that a specific process takes place in response to the input signal of another process according to a specific characteristic curve, however, the parameters of the actual process rarely change when the input parameters change. The subsystems of the systems can also work as islands, some parameters of the islands mostly change as a result of human intervention. Some subsystems of a system may be suitable for dynamic system operation, but the operation of the entire system will still remain static. The description of the above was important because the information provided by the system will also be static. More and more elements of current transportation systems are becoming dynamic, but until each subsystem of the system becomes dynamic, the entire system will give a static response. The description of the above was important because the information provided by the system will also be static.

4.2 Dynamic transport systems

Dynamic systems provide a dynamic system response to changes in the parameters of the external environment, there is a more complicated relationship between the individual subsystems, and many more parameters must be monitored. The dynamic system is capable of performing many more functions, which is why its maintenance requires much more knowledge and experience. The information provided by the dynamic system can provide information regarding several parameters, but creating and managing the information is a much bigger task.

5 Stability of railway lines

Hungary, as the successive president of the EU, considers increasing the stability of public transport an important task. Hungary's railway network can be said to be dense by European standards, and the situation is less favorable in terms of the number of trains running on a single line section. Traffic can be difficult on routes that are located in a radius of the network, centered in Budapest, and do not touch Budapest. One of the busiest railway lines is located between Budapest and Debrecen, approximately 200 trains run daily.

Trains from Szeged and Békéscsaba connect to this railway line, so they can play a significant role in the filling and emptying processes of the Budapest-Debrecen line, which is why it is very important how the traffic processes are organized. The Szeged and Debrecen arrow pointing to the Budapest-Debrecen line is bidirectional because these lines can participate in filling as well as emptying.

Parameter stable state	Budapest-Nyugati	Line Nr. 100	Debrecen
Number of passengers at a moment	StNumPassBud	StNumPass100	StNumPassDeb
Number of trains at a given moment	StNumTrainsBud	StNumTrain100	StNumTrainsDeb

Parameter unstable state	Budapest-Nyugati	Line Nr. 100	Debrecen
Number of passengers at a moment	InstNumPassBud	InstNumPass100	InstNumPassDeb
Number of trains at a moment	InstNumTrainsBud	InstNumTrain100	InstNumTrainsDeb

The operation of the railway line is stable if passengers do not accumulate at the stations marking the beginning and end of the line, and the trains do not get congested between the two stations. In the event of irregularities, the railway line may have parameters different from usual, but everything must be done to bring the system from an unstable state to a stable state. If an abnormality occurs, there is a deviation compared to the parameters of the stable state, the question is under what parameters the system of the Budapest-Debrecen railway line is restored so that the restoration process can be planned in the future as well. Mentioning the above is important because, based on experiences gained in Europe, in several cases when an abnormal situation occurs, passengers received incorrect or ambiguous information, which could even lead to an outbreak of panic.

When dimensioning railway systems, it is important to know the limits of the theoretical load capacities, which means that you must be aware of the values that represent the load capacity of a line or station when the comfort of passengers does not decrease, but differs from the normal load. It is necessary to know the load capacity of the station and line when the comfort of the passengers is already seriously damaged, but we cannot avoid this state in view of force majeure cases. It is necessary to determine how many passengers are in the stations and on the trains, precisely so that this situation can be overcome as soon as possible. It is very important that this shift is conscious, within the framework of which we are aware of what further events are triggered by performing a specific action. When each event occurs, you must be aware that rail transport can play a significant role in reducing disruptions in air and road transport, but air transport cannot significantly alleviate disruptions in rail transport.

Parameter comfort state	Budapest-Nyugati	Line Nr. 100	Debrecen
Number of passengers at a moment	KomNumPassBud	KomNumPass100	KomtNumPassDeb
Number of trains at a moment	KomNumTrainsBud	KomNumTrain100	KomNumTrainsDeb

Parameter extreme state	Budapest-Nyugati	Line Nr. 100	Debrecen
Number of passengers at a moment	ExtNumPassBud	ExtNumPass100	ExtNumPassDeb
Number of trains at a moment	ExtNumTrainsBud	ExtNumTrain100	ExtNumTrainsDeb

The parameters are explained as follows:

Stable state: the network has normal operating conditions, trains run punctually, and the planned number of passengers is present at the station.

Unstable condition: the operation of the network has been affected by some kind of disturbance, more and more trains are late, passengers are not spending their time in the place according to the normal operation. The question is whether this condition continues to deteriorate, or whether measures have been taken to return the unstable condition to normal.

StNumPassCity: The number of passengers simultaneously present at the station at a given moment in the range for which the station is sized under normal operating conditions and passengers can comfortably fulfill their possible needs.

StNumTrainsCity: The range of the number of trains present at the station at a given moment, under normal operating conditions the trains can run according to the schedule. Since there are freight trains running at several stations, the number of these trains must also be taken into account, regardless of whether the train is passing through the station at the given moment, occupying the track, or stopped for traffic reasons.

StNumPassLine: The range of the number of passengers simultaneously present on the line at a given moment in the range for which the line was sized under normal operating conditions and passengers can comfortably fulfill their possible needs on the trains. In this state, the number of seats on passenger trains and the number of passengers must be related to each other in such a way that every passenger can occupy a seat, but this number of seats does not include the number of seats in the dining car.

StNumTrainLine: The range of the number of trains on the line at a given moment, under normal operating conditions the trains can run according to the schedule. Since there are freight trains running on several lines, the number of these trains must also be taken into account, regardless of whether the train is traveling on the line at the given moment, occupying the track, or stopped for traffic reasons.

InstNumPassCity: The number of passengers simultaneously staying at the station at a given moment in the range, under abnormal operating conditions, which may differ from the number of passengers for which the station was designed. In this operating state, it is no longer certain that the passengers' comfort criteria will be met. There may be few passengers at the station because several trains have not yet arrived at the station due to delays.

InstNumTrainsCity: The number of trains present at the station at a given moment, under abnormal operating conditions. Since there are freight trains running at several stations, the number of these trains must also be taken into account, regardless of whether the train is passing through the station at the given moment, occupying the track, or stopped for traffic reasons. In this case, there may already be a danger that the trains may obstruct each other's traffic, the consequence of which is that, unlike normal operation, unusual decisions have to be made under a heavy mental burden. In such circumstances, delays are regular and usually just accumulate.

InstNumPassLine: The number of passengers on the line at a given moment in the range, under abnormal operating conditions, which may differ from the number of passengers for which the station was designed. In this operating state, it is no longer certain that the passengers' comfort criteria will be met.

IstNumTrainLine: The number of trains on the line at a given moment, under abnormal operating conditions. Since there are freight trains running on several lines, the number of these trains must also be taken into account, regardless of whether the train is passing through the station at the given moment, occupying the track, or has stopped for traffic reasons. In this case, there may already be a danger that the trains may obstruct each other's traffic, the consequence of which is that, unlike normal operation, unusual decisions have to be made under a heavy mental burden.

KomNumPassCity: The upper limit of the number of passengers simultaneously staying at the station at a given moment, for which the station has been sized under normal operating conditions and passengers can comfortably fulfill their possible needs.

KomNumTrainsCity: The upper limit of the number of trains present at the station at the same time, under normal operating conditions the trains can run according to the schedule. Since there are freight trains running at several stations, the number of these trains must also be taken into account, regardless of whether the train is passing through the station at the given moment, occupying the track, or stopped for traffic reasons.

KomNumPassLine: The upper limit of the number of passengers on the line at a given moment, for which the line has been designed under normal operating conditions, and passengers can fulfill their possible needs comfortably on the trains.

KomNumTrainLine: The upper limit of the number of trains simultaneously present on the line at a given moment, when it is still possible to run the trains according to the schedule under normal operating conditions. Since there are freight trains running on several lines, the number of these trains must also be taken into account, regardless of whether the train is traveling on the line at the given moment, occupying the track, or stopped for traffic reasons.

ExtNumPassCity: State created as a result of elemental damage. The number of passengers staying at the station at a given moment, under abnormal operating conditions, which may differ from the number of passengers for which the station was designed. In this operating state, the comfort aspects of the passengers are probably met. There may be few passengers at the station because several trains have not yet arrived at the station due to delays, or simply have not started and will not start.

ExtNumTrainsCity: State created as a result of elemental damage. The number of trains present at the station at a given moment, under abnormal operating conditions. Since there are freight trains running at several stations, the number of these trains must also be taken into account, regardless of whether the train is passing through the station at the given moment, occupying the track, or stopped for traffic reasons. In more serious cases, trains may not run and will not run.

ExtNumPassLine: Status created as a result of elemental damage. The number of passengers on the line at a given moment in that range, under abnormal operating conditions, which may differ from the number of passengers for which the line was designed. In this state, trains are delayed or wasted on the line, so passengers are forced to spend their time on the train.

ExtNumTrainLine: State created as a result of elemental damage. The number of trains on the line at a given moment, under abnormal operating conditions. Since there are freight trains running on several lines, the number of these trains must also be taken into account, regardless of whether the train is traveling on the line at the given moment, occupying the track, or stopped for traffic reasons. In an extreme situation, it may even happen that the line is empty, but the station may be inaccessible.

The relationship between the variables StNumPassLine and StNumTrainLine reveals whether all the passengers have been given a seat on each train, or whether it can be considered a stable state that a significant number of passengers are standing. This condition can still be tolerated in suburban traffic, but during international journeys lasting several hours, all systems must be designed so that passengers spend the entire duration of the journey sitting. If the passenger travels on the train sitting on the floor or on the stairs, it means discomfort for him, the former are also not lucky in the event of an accident. The braking percentages of overloaded trains can also change significantly, it may happen that the train is only able to stop beyond the planned braking distance due to the overload.

6 Stability of railway systems

The table below contains the railway stations with the largest traffic in Europe, it can be assumed that in addition to the huge local traffic, significant international traffic also takes place between the following railway stations. Thus, it is advisable to design the running trains in the future in such a way that any of the following stations can be reached at least once a day by a direct train. Studying the map, we can see that there are several other high-traffic train stations on the lines that touch the cities below, so it is likely that a significant number of passengers only use these trains on one section.

	City	Station	Passengers (million / year)
1	Paris	Gare du Nord	292.2
2	Hamburg	Hamburg Hbf	196
3	Frankfurt am Main	Frankfurt(Main) Hbf	179.9
4	Zürich	Zürich HB	154.6
5	München	München Hbf	150.7
6	Paris	Gare de Lyon	150.2
7	Rome	Roma Termini	150
8	Berlin	Berlin Hbf	120.1
9	Milan	Milano Centrale	120
10	Berlin	Berlin Friedrichstraße	95,6

If the above relationships are characterized by the variables described above, the load capacity and reserve of each relationship can be established. If appropriate functions are defined, it can be determined how long it takes for a given abnormal or extreme state to recover. In several cases, it happens that certain destinations are approached with regional or national tickets. Several passengers leave the validity area of their passes, but in some form continue to travel with or without a ticket within or outside the limits of tolerance. Since there are no other general passes in Europe apart from the Interrail ticket, many passengers remain unaccounted for, so several transport routes may falsely appear unused. Therefore, it is important to develop appropriate pass systems, as a result of which it is possible to determine exactly how many passengers are staying in the station and line system of a route.

It is not necessarily true that in every case we look for the description of the filling and emptying processes for railway lines and stations in this form, different formulas and values must be used in each case. Functions describing the saturation process of a station can be described below.

$\mathrm{StNumPassCity}(t) = \mathrm{StNumPassCity}_0 * \left(\frac{e - e^{\frac{(T-t)}{T}}}{e}\right)$, where T is the time constant, t is the time instant, $\mathrm{StNumPassCity}_0$ is the number of passengers to be reached.

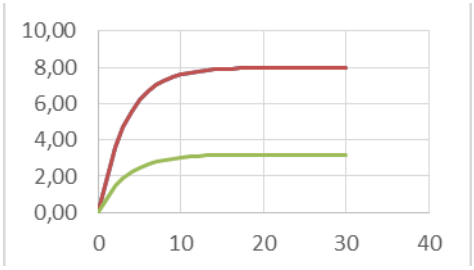


Diagram 1: Increase in the number of passengers

With appropriate applications, alternative routes can be selected at the system level in the event of an elemental damage, that is, the system immediately offers an alternative solution in the event that someone wants to travel on a section of a section that touches two cities that is not operating due to elemental damage. Let's look at the following example:

Planned route: Zurich-Frankfurt-Hamburg.

Non-operating station: Frankfurt

Alternative route: Zurich-Berlin-Hamburg.

The current ticketing system is not suitable for dealing with this problem, it leaves passengers to spend the entire duration of their journey in doubt, even though by offering an alternative route, it takes the burden off the damaged station and makes it possible to plan the transport of passengers.

7 Conclusions

Based on the above, it can be concluded that the European railway systems can be considered sensitive based on the traffic density, because the disruption of the high-traffic railway stations listed above can have an effect over a distance of up to a thousand kilometers. Above, only the railway stations with very high traffic have been indicated, but interruptions in a section with a relatively lower load can also cause serious problems in the operation of larger railway stations.

7.1 Parameters by line

From the above, the load of a given line section can also be measured, so it even becomes clear whether it is necessary to expand the given line section, or whether the construction of an independent high-speed railway track is justified.

7.2 Parameters by country

Some countries in Europe can be characterized by the above parameters, or new parameters can be created, which can reveal how loaded a country's railway network is, whether it is suitable to take over the traffic of other countries in the event of a disruption.

7.3 Case of long-distance trains

On behalf of Hungary, the representative of NSA HU took over the railway strategic tasks from Belgium within the framework of the EU presidency, a short-term overview of several aspects was also carried out. According to the position of the EPF (European Passenger Transport Association), which is handing over the tasks, it is advisable to include longer downtimes, as this can reduce schedule delays. According to the representative of Hungary who appeared on the scene, it is advisable to run the trains over as long a distance as possible, because this will reduce the number of transfers. This reduces the idle time of the vehicles, which is a very important aspect in terms of the purchase and maintenance costs of the vehicles. According to the above, we are faced with an optimization task, because in reality the optimum is roughly halfway. If a new tunnel is opened, with the help of which the travel time between two cities can be reduced by even hours, the equilibrium state prior to the tunnel's completion will already change, and the resulting new network system will shift to a new state.

7.4 Case of catastrophes

In all life cycle cost (LCC) analysis, events whose probability of occurrence is close to zero even if projected in 30 years, but damages can occur to such an extent that significant unexpected costs can occur even when multiplied by the probability. The main ventilation system of the subway is one of the best examples of this: with the current design parameters, the occurrence of a serious fire in 30 years means a single digit in percentage terms, but very serious investments were made to maintain this value, the purpose of which was to protect the lives of hundreds of passengers. While the removal of damaged vehicles in an accident on an open line is a relatively minor problem, approaching damaged vehicles in a tunnel of several kilometers can also be a serious organizational task. That is why it is very important that, at least in theory,

measures are defined as soon as possible for an interruption caused by an elemental damage, so that the damaged area can be cleared as soon as possible.