

Method for safely operating a rail traffic system and rail traffic system

The invention relates to a method for safely operating a rail traffic system. Furthermore, the invention relates to a rail traffic system.

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The European Train Control System (ETCS) is intended to advance the standardization of non-uniform train control systems within Europe. Further, it also prepares the basis for a particularly efficient use of existing rail traffic systems. However, such rail traffic systems have to meet high technical requirements. These relate in particular to the sensory monitoring of the rail traffic system, for example, by means of a measuring arrangement disclosed in WO 2020/108873 A1. In order to achieve the necessary technical expansion level, considerable investments are required, especially in existing rail traffic systems; however, their economic effect only occurs after a large part of the rail traffic system has been modernized. As a result, corresponding modernizations are often carried out too hesitantly.

WO 2021/121854 A1 describes a method for determining the position of a rail vehicle using an optical measuring system, in particular a stereo camera system, and a radio-based measuring system, with position data from both measuring systems being generated on the rail vehicle and compared with each another.

A warning system for warning people of approaching rail vehicles is known from WO 2021/121853 A1.

The object of the invention is to create an improved method for safely operating a rail traffic system, which, in particular, is particularly economical and flexible to use.

This object is achieved by way of a method with the features of claim 1. According to the invention, it has been recognized that a method for safely operating a rail traffic system can be used in a particularly economical and flexible manner if the plausibility of rail traffic information is checked using a comparison result on the basis of a first and a second rail traffic information, with the rail traffic system being controlled using the result of the plausibility check. By determining the comparison result on the basis of the first and second rail traffic information, incorrect rail traffic information can be recognized and/or compensated for particularly reliably. In particular, possible deficiencies when collecting and/or processing the rail traffic information can be compensated for by determining the result of the plausibility check. The usefulness of collected rail traffic information for controlling the rail traffic system can thus be increased. If the plausibility of the rail traffic information is confirmed, it can be assumed with a particularly high probability that this information is correct. Controlling the rail traffic system using the result of the plausibility check therefore leads to a particularly high level of operational safety. In particular, this makes it possible to overcome the reliability threshold required for a particularly efficient use of the rail network, in particular for a higher traffic density. A higher traffic capacity of the rail traffic system can be achieved with lower investments. Both the modernization of existing rail traffic systems and the construction of new rail traffic systems can thus be carried out in a particularly economical and flexible manner.

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The rail traffic system preferably comprises an infrastructure facility and at least one rail vehicle, in particular a plurality of rail vehicles. The infrastructure facility can have a rail network with a plurality of, in particular interconnected tracks, which is preferably subdivided into several rail line

sections. The infrastructure facility, in particular each of the rail line sections, can have a single or a plurality of control centres for controlling the infrastructure facility.

- 5 The at least one rail vehicle can have at least one, in particular at least two, in particular at least five, in particular at least ten, running trailers. Preferably, the at least one rail vehicle comprises at least one power wagon with a drive unit for providing the propulsive force required to move the rail vehicle along the track.

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The correlation between the state variable and the rail traffic information is understood to mean that the rail traffic information depends on the state variable, in particular that they are in a fixed, in particular a linear, relationship with each other.

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The state variable of the rail traffic system can be, for example, a position, and/or a speed, and/or a drive power, and/or a braking power, and/or a state variable which correlates with the existence of a mechanical coupling between two running trailers and/or with an object located in the area of the track, in particular an obstacle causing a point of danger.

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The second rail traffic information is preferably based on a source that is independent of the source of the first rail traffic information. In particular, the second rail traffic information is not determined by means of the first rail vehicle.

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The second rail vehicle can be designed in accordance with the first rail vehicle or have a higher or lower technical expansion level.

Controlling the rail traffic system using the result of the plausibility check may comprise continuing to operate the rail vehicle, if the plausibility of the rail traffic information is insufficient, with reduced kilometric performance, in particular reduced travelling speed, and/or stopping it, and/or carrying out a maintenance measure on the rail vehicle. Advantageously, this enables the rail traffic system to be operated in a particularly safe manner.

Determining the result of the plausibility check and/or its further processing can be done using a consensus mechanism. Thus, the result of the plausibility check can be obtained and handled in a particularly safe and reliable manner.

The different rail traffic information can be weighted uniformly or differently, in particular on the basis of the reliability of the underlying sources, in particular the sensors. For example, the rail traffic information originating from the infrastructure facility may have a higher weighting than the rail traffic information originating from the rail vehicle. Rail traffic information with lower weighting can be corrected, in particular replaced, by rail traffic information with higher weighting in case of insufficient plausibility, in particular with a difference between the two rail traffic information. This makes the method particularly reliable to execute.

Preferably, the first and/or the second rail traffic information is determined by means of at least one sensor, in particular a position detection module, in particular a GPS receiver for detecting the position of the at least one rail vehicle, in particular in the rail network; and/or an optical sensor, in particular a camera, for capturing objects on the track; and/or a completeness monitoring device for monitoring the existence of a mechanical coupling between two running trailers. Equally, the second rail traffic information

can be determined by means of the second rail vehicle. Alternatively or additionally, the second rail traffic information can be determined by means of the infrastructure facility, in particular a rail sensor.

- 5 The transmission of the second rail traffic information can be wired or wireless. Preferably, the second rail traffic information is transmitted via a wireless signal connection, in particular between a vehicle radio module of the first rail vehicle and a control-centre radio module of a control centre of the infrastructure facility and/or a vehicle radio module of the second rail
10 vehicle. The wireless signal connection may comprise a WiFi signal connection and/or a 5G signal connection. The signal connection is preferably designed as a peer-to-peer connection.

- Preferably, the transmission of data via the wireless signal connection is
15 encrypted. This makes the method particularly safe in operation.

- According to a further aspect of the invention, at least one rail traffic information comprises, in particular the first and the second rail traffic information comprise, in particular the rail traffic information underlying the
20 comparison result, information on whether objects, in particular people, are located in the area of the track. To warn people of approaching rail vehicles, a signal-box controlled crew warning system can be provided. Such a warning system is disclosed, for example, in WO 2021/121853 A1, the disclosure content of which is incorporated herein by reference. This
25 rail traffic information can be detected by means of the optical sensor, for example. The optical sensor may be a component of the infrastructure facility and/or the at least one rail vehicle.

The first and/or the second rail traffic information may comprise the position of the at least one rail vehicle, in particular along a track. Preferably, the position of the rail vehicle is determined by means of a lateration method, in particular by radio trilateration, in particular by WiFi trilateration. For this purpose, the rail vehicle can have a tracking module, in particular a radio tracking module, in particular for determining the position by means of radio trilateration. The tracking module can also be referred to as the anchor module. The tracking module can be designed to detect signals from stationary and/or movable tracking markers, in particular transponders. Stationary tracking markers can be attached to infrastructure elements. By means of stationary tracking markers, which are arranged in particular at fixed points with a known position, it is possible to determine the position of the rail vehicle, in particular along the track. Movable tracking markers can, for example, be carried by people, in particular track maintenance workers. This allows the position of the person to be determined relative to the rail vehicle and/or in the track and/or along the track. With respect to the method for determining the position of the rail vehicle and/or person, reference is made to WO2021/121854 A1, the disclosure content of which is incorporated herein by reference.

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A method according to claim 2 ensures the operation of the rail traffic system in a particularly economical and flexible manner. The second rail traffic information is preferably collected by means of the second rail vehicle and/or the infrastructure facility, in particular by sensors. The comparison result and/or the result of the plausibility check can be determined by means of the first rail vehicle, in particular a vehicle control unit. By having the first and second rail traffic information available on the first rail vehicle, the comparison result and/or the result of the plausibility check can be determined by means of the first rail vehicle. The rail traffic information

available on the first rail vehicle, in particular on a vehicle control unit of the rail vehicle, can thus be determined with a particularly high degree of reliability. A threshold for a technical expansion level of a rail vehicle, which is required for operating the rail traffic system with a particularly high traffic capacity, can thus be achieved particularly easily. The reliability of the measuring values that can be detected with the existing sensor system of a rail vehicle can be increased using the comparison result. For example, the safety integrity level (SIL) required to achieve a correspondingly high traffic capacity can be achieved by determining the result of the plausibility check. Accordingly, the effort required to implement the corresponding sensor system can be reduced, making the method particularly flexible to use and economical to operate.

A method according to claim 3 enables the operation of the rail traffic system in a particularly safe and economical manner. The second rail traffic information is preferably collected by means of the first rail vehicle. The comparison result and/or the result of the plausibility check can be determined by means of the infrastructure facility, in particular a control-centre control unit. The rail traffic information received by the first rail vehicle can thus be regarded as accurate with particularly high probability. The rail traffic information received by the rail vehicle can be used to determine the plausibility of the rail traffic information collected by the infrastructure facility. In this way, an infrastructure facility of a given technical expansion level can be operated particularly safely and economically. In particular, controlling the rail traffic system using the result of the plausibility check can enable a threshold value to be overcome for operating the rail traffic system with a higher traffic capacity.

A method according to claim 4 ensures the operation of the rail traffic system in a particularly safe and economical manner. For sensory detection of the at least one measuring value, the at least one rail vehicle may have the optical sensor, and/or the position detection module, and/or the completeness monitoring device. For sensory detection of the at least one measuring value, the infrastructure facility may have a rail sensor for detecting a passing rail vehicle, in particular for determining the number of running trailers of the rail vehicle, and/or the position, and/or the speed of the rail vehicle. The at least one rail sensor may comprise a point-shaped rail sensor, such as an axle counter, and/or a line-shaped rail sensor, such as a light guide sensor, in particular a glass fibre sensor. Such a rail sensor can be part of a balise or be designed in the form of a sensor coupled to a rail or an overhead line. Such a light guide sensor is disclosed, for example, in WO 2020/108873 A1, the disclosure content of which is incorporated by reference herein. By determining the result of the plausibility check, a higher safety integrity level can be easily achieved for the corresponding sensors.

A method according to claim 5 enables the operation of the rail traffic system in a particularly safe manner. Preferably, the determination of the result of the plausibility check is carried out repeatedly, in particular at a time interval in the range from 0.01 s to 300 s, in particular from 0.1 s to 60 s, in particular from 0.5 s to 30 s, in particular from 1 s to 10 s. For this purpose, the transmission of the second rail traffic information can take place with a time interval in the same range, in particular with the same time interval.

According to a further aspect of the invention, it is monitored whether the transmission of the second rail traffic information takes place within a predetermined time range, in particular within the range described above. If

transmission is delayed or fails to occur, safety measures may be taken. The safety measures may comprise, for example, reducing the travelling speed, and/or stopping the rail vehicle, and/or prohibiting it from entering another rail line section. This makes the method particularly safe in operation.

A method according to claim 6 ensures the operation of the rail traffic system in a particularly safe manner. In the case of divergent rail traffic information, the rail traffic information whose origin has a lower safety integrity level, in particular which is based on a measuring value from a sensor with a lower safety integrity level, can be corrected, in particular using the rail traffic information whose origin has a higher safety integrity level, in particular which is based on a measuring value from a sensor with a higher safety integrity level. Alternatively, both pieces of rail traffic information can be modified and/or discarded, in particular replaced by other rail traffic information, in particular information determined in advance. Preferably, correction data for changing divergent rail traffic information is transmitted between the first rail vehicle and the infrastructure facility and/or the second rail vehicle, in particular it is transmitted wirelessly.

For example, the travelling speed of the first rail vehicle is determined based on a measuring value, which correlates with the speed of a rail wheel, and based on the diameter of the rail wheel. As the diameter of the rail wheel decreases with increasing wear, the measured travelling speed deviates from the actual travelling speed. By means of rail sensors, which are arranged at spaced positions along the track, the travelling speed can be determined precisely. The travelling speed detected by the rail vehicle can be transmitted to the infrastructure facility. By means of the infrastructure facility, the comparison result can be determined as the difference between

this travelling speed and the actual travelling speed. The infrastructure facility can transmit correction data to the rail vehicle, in particular a corrected diameter of the rail wheel, which enables the actual travelling speed to be determined by means of the rail vehicle.

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A method according to claim 7 ensures the operation of the rail traffic system in a particularly safe manner. Calibration can be performed using locally determined and/or transmitted comparison results and/or correction data. Calibration can be carried out automatically at regular time intervals
10 or manually.

A method according to claim 8 ensures the operation of the rail traffic system in a particularly flexible manner. The control capacity class of the rail vehicle is understood to be a measure of its technical equipment. For example, the control capacity class may correlate with an ETCS classification, in particular corresponding to a specific ETCS level. The technical
15 equipment of a rail vehicle and correspondingly the control capacity class can be decisive for a train control system as to which methods the control of the rail vehicle is based on, in particular which traffic capacity can be achieved, in particular to what degree the rail vehicle can move autonomously through the rail network. The control capacity class functions according to the safety integrity level. By controlling rail vehicles of different control capacity classes in different manners, traffic capacity can be increased. Rail vehicles with a high control capacity class, in particular a
20 high technical expansion level, can travel on a rail network, in particular a rail line section, at a higher density than rail vehicles with a lower control capacity class. For example, high control capacity class rail vehicles can be controlled on the basis of moving spatial distances. Rail vehicles with a low control capacity class can be controlled on the basis of fixed spatial
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distances. A higher control capacity class is preferably achieved through higher sensory and/or processor performance. Processor performance is understood to mean the ability to process data, in particular the processing speed and/or the performance of the functions underlying data processing.

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A method according to claim 9 ensures the operation of the rail traffic system in a particularly economical and flexible manner. Controlling the rail traffic system using the result of the plausibility check enables the rail traffic system to be controlled on the basis of a particularly reliable information base. If the validity of the rail traffic information is confirmed by the result of the plausibility check, the at least one rail vehicle can be classified in a higher control capacity class. In the event of a result of the plausibility check which speaks against the validity of the rail traffic information, the control capacity class of the at least one rail vehicle can be downgraded, in particular if the result of the plausibility check speaks against the validity of the rail traffic information several times, in particular several times in succession.

20 A method according to claim 10 ensures the operation of the rail traffic system in a particularly safe and economical manner. By continuously receiving and processing the rail traffic information, the comparison result and/or the result of the plausibility check can be determined continuously. This can ensure a particularly high reliability of the rail traffic information, allowing the rail vehicle to be classified in a higher control capacity class.

25 Alternatively or additionally, the infrastructure facility may be classified in a higher control capacity class due to the continuous receipt of the rail traffic information from the rail vehicle.

A method according to claim 11 ensures the operation of the rail traffic system in a particularly safe manner. If the result of the plausibility check is positive, the control capacity class can be upgraded or remains at an unchanged high level. If the result of the plausibility check is negative, the control capacity class can be downgraded or remains at an unchanged low level. In the event of a poor result of the plausibility check, the rail vehicle can continue to be operated at reduced maximum speed, or be stopped, and/or maintenance measures can be carried out on the rail vehicle.

10 A method according to claim 12 ensures the operation of the rail traffic system in a particularly economical manner. Preferably, rail vehicles of a high control capacity class are transferred to areas of the rail network, in particular to rail line sections that are heavily utilized. Rail vehicles of a low control capacity class can be moved out of these areas. This is advantageous in that heavily utilized areas of the rail network can be travelled particularly densely. The traffic capacity of the rail traffic system can thus be increased in these areas. In areas of the rail network in which only rail vehicles of a high control capacity class are arranged, these can, for example, be operated on the basis of moving spatial distances and/or autonomously controlling themselves, in particular without control commands from the infrastructure facility.

A method according to claim 13 ensures the operation of the rail traffic system in a particularly safe manner. For example, travel parameter ranges such as the maximum traction drive power, and/or the maximum travelling speed, and/or the maximum braking power can be controlled, in particular limited, based on the result of the plausibility check. Rail line sections can be opened or closed using the result of the plausibility check. For example, heavily utilized rail line sections can be closed for a rail vehicle that deliv-

ers a negative result of the plausibility check, in particular does not generate valid rail traffic information.

A method according to claim 14 is particularly economical to execute.

- 5 Travelling in moving spatial distances ensures a particularly high traffic capacity. Preferably, the control of the rail traffic system takes place depending on the result of the plausibility check and/or the control capacity class either in moving spatial distances or fixed spatial distances. In the rail traffic system, in particular in different rail line sections, the control of the
- 10 rail traffic system can be carried out uniformly or non-uniformly, in particular in moving and/or fixed spatial distances.

- A method according to claim 15 ensures the operation of the rail traffic system in a particularly safe and economical manner. Preferably, the at
- 15 least one rail vehicle can travel on the infrastructure facility, in particular the rail network, completely autonomously, in particular without a control command from the infrastructure facility. For this purpose, the rail vehicle can control the infrastructure facility, in particular rail signals and/or turnouts, in particular rail adjusting means and/or rail supply means, in particular the electric power provided via an overhead line. For this purpose,
- 20 the rail vehicle can receive sensor data collected by the infrastructure facility or be controlled exclusively by means of sensor data collected by the rail vehicle itself.

- 25 A further object of the invention is to create an improved rail traffic system which is particularly safe, economical, and flexible in operation.

This object is achieved by way of a rail traffic system with the features of claim 16. The advantages of the rail traffic system according to the inven-

tion correspond to the advantages of the method described above. Preferably, the rail traffic system is further developed with at least one of the features described above in connection with the method. The infrastructure facility and/or the at least one rail vehicle may have at least one control unit, in particular a vehicle control unit, and/or a control-centre control unit for carrying out the method described above.

The invention also relates to a computer program product for carrying out the method described above. The advantages of the computer program product correspond to the advantages of the method described above. Preferably, the computer program product is further developed with at least one of the features described above in connection with the method. The computer program product can be stored on a storage unit of the at least one control unit and/or on a portable storage unit.

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Further features, details, and advantages of the invention result from the following description of an embodiment based on the figures. The following figures show:

20 Fig. 1 a schematic representation of a rail traffic system, comprising an infrastructure facility with a first rail line section, a first rail vehicle entering the first rail line section, and a second rail vehicle leaving the first rail line section,

25 Fig. 2 a side view of the first rail vehicle in Fig. 1,

Fig. 3 a schematic representation of the rail traffic system in Fig. 1, with means for collecting and transmitting rail traffic information being shown in further detail, and

Fig. 4 a block diagram of the rail traffic information exchanged in the rail traffic system in Fig. 1 between the respective rail vehicle and the infrastructure facility.

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Figs. 1 to 4 describe an embodiment of a rail traffic system 1. The rail traffic system 1 comprises an infrastructure facility 2 and a plurality of rail vehicles 3, 4, in particular a first rail vehicle 3 and a second rail vehicle 4.

- 10 The infrastructure facility 2 has a rail network 5. The rail network 5 is divided into a plurality of rail line sections 6, 7, 8. The rail line sections 6, 7, 8 overlap each other. In such an overlapping area 9, 10, there are tracks 11 assigned to a plurality of rail line sections 6, 7, 8. Alternatively, at least individual, in particular all of the rail line sections 6, 7, 8 can be designed
15 without overlapping, in particular directly adjacent to each other.

The infrastructure facility 2 has rail sensors 12a, 12b, rail adjusting means 13, rail signals 14a, and rail supply means 15 along the tracks 11. The rail sensors 12a, 12b can be designed to detect a measuring value correlating
20 with a passing rail vehicle 3, 4. The detection of a measuring value is also understood to mean the measurement of the measuring value. The rail sensors 12a, 12b can be designed as point-shaped rail sensors 12a or as line-shaped rail sensors 12b. Point-shaped rail sensors 12a are understood to be, for example, axle counters. Line-shaped rail sensors 12b are under-
25 stood to be rail sensors 12b based in particular on light being conducted in a fibre, in particular in an optical fibre. The rail adjusting means 13 can be designed as a switch drive. The rail signal 14a can be a switchable light signal or a movable, in particular switchable, semaphore signal. An optical marking 14b, also referred to as a fixed point marker, is attached near the

track 11. Further, a person 14c, in particular a track worker, is near the track 11. Preferably, the optical marking 14b is in the form of a QR code. The rail supply means 15 can be an overhead line for supplying the rail vehicles 3, 4 with electric power.

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Further, the infrastructure facility 2 comprises a control centre 16, 17, 18 for each rail line section 6, 7, 8. The respective control centre 16, 17, 18 controls the rail traffic within the assigned rail line section 6, 7, 8. For this purpose, the respective control centre 16, 17, 18 is connected in a signal-
10 transmitting manner with the rail sensors 12a, 12b, the adjusting means 13, the rail signals 14a and the rail supply means 15, which are assigned to the respective rail section 6, 7, 8. In particular, these can be controlled and/or read out by means of the respective control centre 16, 17, 18.

15 Fig. 2 shows the rail line section 8 of the rail traffic system 1 in further detail. The first rail vehicle 3 is arranged on the track 11. The first rail vehicle 3 is supplied with electric power via the overhead line 15. The first rail vehicle 3 has a vehicle radio module 19 in the form of a 5G radio module, a tracking module 19a, in particular a radio tracking module for radio trilat-
20 eration, a position detection module 20, and a first optical sensor 21a in the form of a camera. Further, the first rail vehicle 3 comprises a vehicle control unit 22 for processing digital data. The vehicle control unit 22 is connected in a signal-transmitting manner, in particular wired connection, with the vehicle radio module 19, the tracking module 19a, the position detec-
25 tion module 20, and the first optical sensor 21a. The position detection module 20 is preferably designed as a GPS module and serves to detect the position of the second rail vehicle 4. The first optical sensor 21a is designed, in particular together with the vehicle control unit 22, to automatically recognize rail signals 14a and/or objects in the area of the track, in par-

tical people 14c in the track and/or fixed point markers 14b. The second optical sensor 21b may be designed according to the first optical sensor for detecting objects in the track and/or optical markings 14b.

5 The control centre 18 comprises a control-centre radio module 23, which is designed as a 5G radio module. Further, the control centre 18 comprises a control-centre control unit 24 for processing digital data. The control centre 18, in particular the control-centre control unit 24, is connected in a signal-transmitting, in particular wired, manner with the rail sensors 12a, 12b, the
10 rail adjusting means 13, the rail signals 14a, and the rail supply means 15. With regard to the mode of operation of the rail sensor 12b, which is based on light being conducted in an optical fibre, reference is made to WO 2020/108873 A1. The control-centre control unit 24 is further connected with the control-centre radio module 23 in a signal-transmitting manner.

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The first rail vehicle 3 is connected with the third control centre 18 via the vehicle radio module 19 and the control-centre radio module 23 in a signal-transmitting, in particular wireless, manner. Wireless signal connections 25 are shown as dash-dot lines in the figures. Wired signal connections 26 are
20 shown as dashed lines in the figures.

The second rail vehicle 4 leaving the first rail line section 6 is connected with the first control centre 16, in particular via a vehicle radio module 19, in a wireless, signal-transmitting manner. Rail vehicles 3, 4 arranged in the
25 overlapping areas 9, 10 can be in signal connection with the control centres 16, 17, 18 of several of the rail line sections 6, 7, 8 at the same time.

In Fig. 3, the rail traffic system 1 is shown in further detail with the two rail vehicles 3, 4, which are arranged in the first rail line section 6.

In addition to the sensors 20, 21a described above, the first rail vehicle 3 further comprises a second optical sensor 21b, in particular a front camera, a completeness monitoring device 27 for monitoring the completeness of
5 the first rail vehicle 3, in particular the existence of a mechanical connection between two running trailers 28a, 28b mechanically coupled to each other. Further, the first rail vehicle 3 comprises a drive unit 29 and a brake unit 30. The completeness monitoring device 27, the drive unit 29 and the brake unit 30 are connected with the vehicle control unit 22 via the wired
10 signal connection 26.

The second rail vehicle 4 has a vehicle radio module 19, a drive unit 29, a brake unit 30, and a vehicle control unit 22. The second rail vehicle 4 does not have any sensors to determine the existence of an existing mechanical
15 coupling between its running trailers 28a, 28b, 28c, or to detect the position, or to detect objects in the track. The first rail vehicle 3 is accordingly grouped in a higher control capacity class than the second rail vehicle 4.

The infrastructure facility 2 comprises the first rail sensor 12a, which is designed to detect a passing rail vehicle 3, 4, in particular to detect the number of running trailers 28a, 28b, 28c coupled to each other. The second rail
20 sensor 12b, which is designed in the form of the optical fibre sensor, also enables the detection of a rail vehicle 3, 4 that is transferred over the track 11 equipped therewith.

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The mode of operation of the rail traffic system 1, in particular the control units 22, 24, is as follows:

The first rail vehicle 3 is located in the third rail line section 8. The second rail vehicle 4 is located in the first rail line section 6. The wireless signal connection 25 exists between the first rail vehicle 3 and the third control centre 18. There is also a wireless signal connection 25 between the first control centre 16 and the second rail vehicle 4.

By means of the respective vehicle control unit 22 of the rail vehicles 3, 4 and the sensors 20, 21a, 21b, 27 connected thereto, rail traffic information is collected, in particular continuously. By means of the infrastructure facility 2, in particular the first control centre 16, in particular the control-centre control unit 24, and the sensors 12a, 12b connected thereto, further rail traffic information is determined. The rail traffic information describes a current state of the rail traffic system 1, in particular of the infrastructure facility 2, in particular the state of the rail signals 14a as well as of the rail adjusting means 13 and the state of the rail vehicles 3, 4, in particular their position, speed, brake curve, completeness, and/or their drive and braking power.

The two rail vehicles 3, 4 are classified in different control capacity classes. The decisive factor for this classification is the ability of the rail vehicle 3, 4 to move safely through the rail network 5 to a certain extent, in particular completely, independently of the infrastructure facility 2. In particular, it is decisive whether the respective rail vehicle 3, 4 has the sensory and/or processor capacity required for this. The first rail vehicle 3 is classified in a higher control capacity class because it can collect and process a larger volume of rail traffic information compared to the second rail vehicle 4. Further, the safety integrity level (SIL) of the respective rail vehicle 3, 4, in particular of the sensors 20, 21a, 21b, 27, is decisive. The safety integrity level of a sensor is higher the more precise and robust the

measuring values it detects are, in particular the lower its probability of failure is.

Fig. 4 shows the exchange of rail traffic information 31, 32 between the first rail vehicle 3 and the first control centre 16. When the second rail vehicle 4 enters the first rail line section 6, in particular the first overlapping area 10, a connection 33a is established between the first rail vehicle 3 and the first control centre 16.

By means of the first rail vehicle 3, the first rail traffic information 31 is determined, in particular continuously. By means of the position detection module 20, the position of the first rail vehicle 3 along the track 11, in particular in the rail network 5, is determined. By means of the optical sensor 21a, 21b, it is determined whether objects that could potentially interfere with the rail traffic are located in the area of the track 11. Further, rail signals 14a are automatically recognized by means of the optical sensors 21a, 21b and the vehicle control unit 22. By means of the at least one optical sensor 21a, 21b, optical markings 14b can further be detected, in particular for determining the position of the rail vehicle 3, in particular along the track 11. The position of the rail vehicle 3 can be determined on the basis of the fixed point markers 14b and by means of the optical sensors 21a, 21b. A signal from the completeness monitoring device 27 is used to detect whether all running trailers 28a, 28b are connected to each other. This data detected in a sensory manner by means of the rail vehicle 3 is referred to as vehicle sensor data 34. Further, the vehicle control unit 22 determines travel parameters 35 that describe the travelling state of the first rail vehicle 3. The travel parameters 35 comprise the drive power provided by the drive unit 29 and the braking power generated by the brake unit 30. The first rail

traffic information 31 may further comprise adjusting commands 36 and vehicle correction information 37.

By means of the tracking module 19a, which may be designed in particular
5 in the form of an anchor module, the position of the rail vehicle 3, in particular along the track 11, is determined. The tracking module 19b may be designed identically to the vehicle radio module 19 or as a separate component. By means of the tracking module 19a, tracking markers 19b, 19c can be detected, which can be designed to be stationary, as part of the infrastructure facility 2, or movable. Stationary tracking markers 19b can, for
10 example, be attached to infrastructure elements, in particular near the track 11. Movable tracking markers 19c may be carried, for example, by people 14c such as track construction workers. With regard to the mode of operation of a monitoring system for determining the position of the rail vehicle
15 3 and/or people 14c by means of the tracking module 19a, reference is made to WO2021/121854 A1. The position of the rail vehicle 3 and/or people 14c is determined by means of a trilateration method, in particular by means of radio trilateration, in particular by means of WiFi trilateration. A warning signal is preferably transmitted to the person 14c who is in a
20 danger zone, in particular via a radio connection 25, and/or an optical signal, and/or an acoustic signal, in particular by means of the rail vehicle 3.

The second rail traffic information 32 is determined by the infrastructure facility 2, in particular the first control centre 16, in particular the control-
25 centre control unit 24. The second rail traffic information 32 comprises control centre sensor data 38, which are determined on the basis of the rail sensors 12a, 12b, and adjusting parameters 39, which have information about the adjusting state of the rail adjusting means 13, the rail signals 14a, and the rail supply means 15. Further, the second rail traffic information 32

may comprise travel commands 40 and control centre correction information 41.

5 Via the wireless signal connection 25, the rail traffic information 31, 32 is exchanged between the first rail vehicle 3 and the infrastructure facility 2. To determine the comparison result, a comparison 33b of the first rail traffic information 31 and the second rail traffic information 32 takes place, in particular the information portions of the rail traffic information 31, 32 correlating with the same state variable of the rail traffic system 1 are compared with each other. For example, it is compared whether the rail sensors 10 12a, 12b detect the same position and speed of the rail vehicle 4 as the position detection means 20. Further, it can be compared whether the number of mechanically connected running trailers 28a, 28b detected by the completeness monitoring device 27 matches the number of mechanically connected running trailers 28a, 28b detected by the rail sensors 12a, 12b. Additionally, it is possible to compare whether the rail signals 14a automatically detected by the optical sensors 21a, 21b match the rail signals 14a actually predefined by the infrastructure facility 2, in particular to the adjusting parameters 39.

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Using this comparison result, a result of the plausibility check is determined as a value for the validity of the first rail traffic information 31. The first rail traffic information 31 is considered plausible and therefore correct if it matches the second rail traffic information 32. For example, the position of the first rail vehicle 3 determined by means of the position detection module 20 is considered plausible if it matches the position determined by means of the rail sensors 12a, 12b.

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The rail traffic system 1 is preferably controlled using the result of the plausibility check. The travel command 40 may comprise position information if the position detection by means of the position detection module 20 provides plausible vehicle sensor data 34, in particular data matching position information of the infrastructure facility 2. In particular, the travel command 40 may comprise a relative position, in particular a distance, to the first rail vehicle 3 travelling ahead. Based on the plausibility of the position information, the rail vehicles 3, 4 can be safely controlled by means of the travel command 40, in particular moved at a certain safety distance from each other in the rail network 5.

There may be deviations between the first rail traffic information 31 and the second rail traffic information 32, in particular with regard to at least one state variable of the rail traffic system 1. Such deviations are recognized when determining the result of the plausibility check using a comparison result on the basis of the rail traffic information 31, 32. Using the comparison result, the first rail traffic information 31 can be modified. In particular, the rail traffic system 1 can be controlled on the basis of the modified first rail traffic information 31. For example, the position determined by the second rail vehicle 4 can be corrected to match the position of the rail vehicle 4 determined by one of the rail sensors 12a, 12b.

Preferably, the collection of the first rail traffic information 31 is calibrated using the comparison result, in particular the sensors 20, 21a, 21b, 27 can be calibrated using the comparison result. For example, the speed of the rail vehicle 4 detected by the position detection module 20 and the vehicle control unit 22 can be calibrated according to the time period determined by rail sensors 12a, 12b, which elapses between the passing of two successive rail sensors 12a, 12b whose distance along the track is known.

Determining the result of the plausibility check is preferably done at regular time intervals, for example at intervals of 1 s.

- 5 Determining the comparison result, in particular the result of the plausibility check, creates the possibility of checking the reliability of rail traffic information 31 determined by means of the respective rail vehicle 3, 4, in particular continuously, and increasing it with regard to its validity. This enables sensors 20, 21a, 21b, 27 of the respective rail vehicle 3, 4 to be
10 classified in a higher safety integrity level. Further, the rail vehicle 3, 4 can be classified in a higher control capacity class. Appropriate use of the comparison result ensures that measurement inaccuracies can be reliably recognized, in particular compensated for.
- 15 Determining corresponding correction information can be carried out to compensate for measurement inaccuracies on the part of the rail vehicle 3, 4 by means of the control centres 16, 17, 18. Corresponding control centre correction information 41 can be transmitted to the rail vehicle 3, 4 for correcting the vehicle sensor data 34.
- 20 In the case of a particularly high control capacity class, in particular in the case of a high safety integrity level of the rail vehicle 3, 4, the second rail traffic information 32 can alternatively or additionally be corrected by means of the first rail traffic information 31 using the comparison result. In
25 particular, the second rail traffic information 32 can be corrected using the comparison result, in particular on the basis of a vehicle correction information 37.

Further rail traffic information 42 is preferably transmitted from the second rail vehicle 4, in particular via the wireless signal connection 25 directly or via the first control centre 16, to the first rail vehicle 3. The comparison result can be determined on the basis of the first rail traffic information 31 and the second and/or the further rail traffic information 32, 42. Advantageously, this means that further rail traffic information 42 is available for assessing the validity of the first rail traffic information 31 and can be used for an even more reliable result of the plausibility check. Alternatively, the further rail traffic information 42 of the second rail vehicle 4 can replace the second rail traffic information 32, in particular for determining the comparison result.

The control of the rail vehicles 3, 4 is preferably carried out on the basis of their control capacity classes. Rail vehicles 3, 4 of different control capacity classes can be controlled in the same rail traffic system 1 in different manners. For example, the first rail vehicle 3 with the higher control capacity class can itself provide the travel commands 40 required to travel on the rail network 5 and/or provide adjusting commands 36 to control the infrastructure facility 2, in particular the control centre 16, 17, 18, in particular to control the rail supply means 15, the rail signals 14a, and the rail adjusting means 13. The second rail vehicle 4 can be controlled exclusively by means of travel commands 40 of the infrastructure facility 2.

Preferably, the control of the first rail vehicle 3 in the rail network 5 is carried out according to the principle of travelling in moving spatial distances, and/or the control of the second rail vehicle 4 is carried out according to the principle of travelling in fixed spatial distances.

- Using the result of the plausibility check and/or on the basis of the control capacity class, it can be determined which travel parameter ranges, in particular which travelling speed and/or which travel distance to a preceding rail vehicle 3 must be maintained, and/or which maximum drive power
- 5 must be maintained by the rail vehicle 3, 4, and/or which rail line sections 6, 7, 8 may be travelled on. For example, the maximum permissible travelling speed of a rail vehicle 3, 4 can be reduced due to a lack of plausibility with regard to the determined rail traffic information 31.
- 10 The traffic capacity, in particular the density of rail vehicles 3, 4, with which a rail line section 6, 7, 8 may be travelled on, depends on how large the travel distances between two successive rail vehicles 3, 4 must be in order to reliably ensure safe operation of the rail traffic system 1. The mandatory minimum travel distance decreases with increasing control capacity
- 15 class of the respective rail vehicle 3, 4. To increase the traffic capacity of heavily utilized rail line sections 6, 7, 8, rail vehicles 3, 4 can be transferred to heavily utilized rail line sections 6, 7, 8, in particular from less heavily utilized rail line sections 6, 7, 8, on the basis of their control capacity classes. Rail vehicles 3, 4 of lower control capacity classes can be trans-
- 20 ferred from heavily utilized rail line sections 6, 7, 8 to less heavily utilized rail line sections 6, 7, 8.

By controlling the rail traffic system 1 using the result of the plausibility check, it is advantageously achieved that the operation of the rail traffic

25 system 1 can be carried out particularly safely. Comparing 33b different traffic information 31, 32 increases the reliability of the information base for controlling the rail vehicles 3, 4 and the infrastructure facility 2. The control capacity class of a rail vehicle 3, 4 can be increased due to the higher reliability of this rail traffic information 31, 32. The traffic capacity

of the rail network 5 can be increased. In particular, the traffic capacity of certain heavily utilized rail line sections 6, 7, 8 can be increased. The method is suitable for safely operating a rail traffic system 1 with rail vehicles 3, 4 that are equipped with the same or different sensors and processors. In particular, the rail traffic system 1 can be used for mixed operations, with rail vehicles of different control capacity classes. The method enables the operation of a rail traffic system 1 in a particularly safe, economical, and flexible manner.

Claims

1. A method for safely operating a rail traffic system (1), having the steps:
 - 5 1.1. Collecting first rail traffic information (31) correlating with a state variable of the rail traffic system (1),
 - 1.2. Transmitting second rail traffic information (32, 42) correlating with the state variable of the rail traffic system (1) between a first rail vehicle (3) and an infrastructure facility (2) and/or a second rail
10 vehicle (4),
 - 1.3. Determining a comparison result on the basis of the first rail traffic information (31) and the second rail traffic information (32, 42),
 - 1.4. Checking the plausibility of the first rail traffic information (31) and/or the second rail traffic information (32, 42) using the com-
15 parison result, and
 - 1.5. Controlling the rail traffic system (1) using the result of the plausibility check.
2. A method according to claim 1, **characterized in that** the first rail
20 traffic information (31) is collected by means of the first rail vehicle (3), and that the second rail traffic information (32, 42) is transmitted to the first rail vehicle (3).
3. A method according to claim 1 or 2, **characterized in that** the first rail
25 traffic information (31) is collected by means of the infrastructure facility (2), and that the second rail traffic information (32, 42) is transmitted to the infrastructure facility (2).

4. A method according to one of the preceding claims, **characterized in that** the first rail traffic information (31) and/or the second rail traffic information (32, 42) is based on a measuring value detected in a sensory manner.
5. A method according to one of the preceding claims, **characterized in that** checking the plausibility is done at regular time intervals.
6. A method according to one of the preceding claims, **characterized by** controlling the rail traffic system (1) by means of at least one piece of rail traffic information (31, 32) modified using the comparison result.
7. A method according to one of the preceding claims, **characterized by** calibrating the collection of the first rail traffic information (31) and/or the second rail traffic information (32, 42) using the comparison result.
8. A method according to one of the preceding claims, **characterized by** controlling rail vehicles (3, 4) of different control capacity classes in the same rail traffic system (1) in different manners.
9. A method according to one of the preceding claims, **characterized by** classifying the at least one rail vehicle (3, 4) in a higher control capacity class due to controlling the rail traffic system (1) using the result of the plausibility check.
10. A method according to one of the preceding claims, **characterized by** classifying the at least one rail vehicle (3, 4) in a higher control capacity class due to continuous transmission of the second rail traffic information (31, 32).

11. A method according to one of the preceding claims, **characterized by** classifying the at least one rail vehicle (3, 4) depending on the result of the plausibility check.
- 5
12. A method according to one of the preceding claims, **characterized by** transferring at least one rail vehicle (3, 4) on the basis of its control capacity class to a highly utilized rail line section (6, 7, 8) to increase the traffic capacity.
- 10
13. A method according to one of the preceding claims, **characterized in that** controlling the rail traffic system (1) using the result of the plausibility check comprises the determination of travel parameter ranges to be complied with and/or rail line sections (6, 7, 8) that can be travelled on.
- 15
14. A method according to one of the preceding claims, **characterized in that** controlling the rail traffic system (1) is based at least in part on travelling in moving spatial distances.
- 20
15. A method according to one of the preceding claims, **characterized by** controlling the infrastructure facility (2) due to a control command of the at least one rail vehicle (3, 4).
- 25
16. A rail traffic system (1), having
- 16.1. an infrastructure facility (2) and/or
- 16.2. at least one rail vehicle (3, 4),

16.3. with the infrastructure facility (2) and/or the at least one rail vehicle (3, 4) having at least one control unit (22, 24) for carrying out a method according to one of the claims 1 to 15.