White Paper
The Intelligent Freight Train

From the innovative freight wagon
to the intelligent freight train

The TIS roadmap for
competitive rail freight

TIS Technical Innovation
Circle for Rail
Freight Transport

Innovative freight wagons

and the intelligent freight train are more than the sum of their parts. Together, they will give the rail freight sector an enormous boost in productivity.

Member companies of the Technical Innovation Circle for Rail Freight Transport

- BASF SE
- DB Cargo AG
- DB Systemtechnik GmbH
- ELH Waggonbau Niesky GmbH
- Ermewa SA
- GATX Rail Germany GmbH
- Knorr-Bremse Systeme für Schienenfahrzeuge GmbH
- SBB Cargo AG
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- Wascosa AG

www.innovative-freight-wagon.eu

Contents

Digitisation and automation strategies must take account of the entire train. Only this approach can pave the way for a competitive rail freight sector.

1

1.1 The TIS roadmap for the future of rail freight

Low-noise, lightweight, long-running, logistics-enabled, life-cycle-cost-oriented – the freight wagon of the future should meet all five of these basic criteria. In 2012, the white paper "Innovative Rail Freight Wagon 2030 – The '5L' Future Initiative"[1], published by the Technical Innovation Circle for Rail Freight Transport (TIS), did more than formulate ambitious goals. It also presented the sector with a new approach for developing basic innovations using the concept of a demonstrator train.

The "5L Future Initiative" has made a vital contribution to advancing basic innovations for the freight wagon

The "5L Future Initiative" is now firmly established in the rail freight sector. There is a broad consensus that innovation in accordance with the 5L criteria is a necessity for rail freight wagons. The intensification of innovation in the sector is now immediately obvious to any observer. The initiative launched by TIS has made a vital contribution to promoting the development and implementation of basic innovations in freight wagons. This has been achieved through dialogue with the supply industry, definition of functional requirements, and the testing of solutions in practical demonstrator projects. To a much greater degree than previous research ventures, the projects started by the TIS "5L Future Initiative" now focus on the cost-effectiveness of innovations. Today's developments should be economically viable when used in tomorrow's freight wagons on the track.

In its second white paper, TIS would now like to provide an interim assessment of its initiatives for the innovative freight wagon. Where are we today? Which approaches and innovations are showing promise? What are the results so far? In the following chapters, we will present the projects and activities we have undertaken so far in various fields of innovation and draw initial conclusions. However, this new white paper aims to be more than a review of the past six years. It aims to identify the challenges we are about to face and set goals for the future.

TIS is now taking this a step further – combining these innovative freight wagons into an intelligent freight train

Until now, all these activities have concentrated on the development potential of the freight wagon. But improving the competitiveness of rail freight transportation will require more than the development of isolated innovations in freight wagon design. TIS is therefore going a step further and looking at the freight train as a whole. The future will depend on our ability to combine these innovative freight wagons into intelligent freight trains.

This is reflected in the carefully chosen title of our new white paper – "IF^2". Because the innovative freight wagon and intelligent freight train are more than the sum of their parts. Together, they can trigger an enormous boost in productivity and pave the way for the digitised, automated rail freight transport of the 21st century.

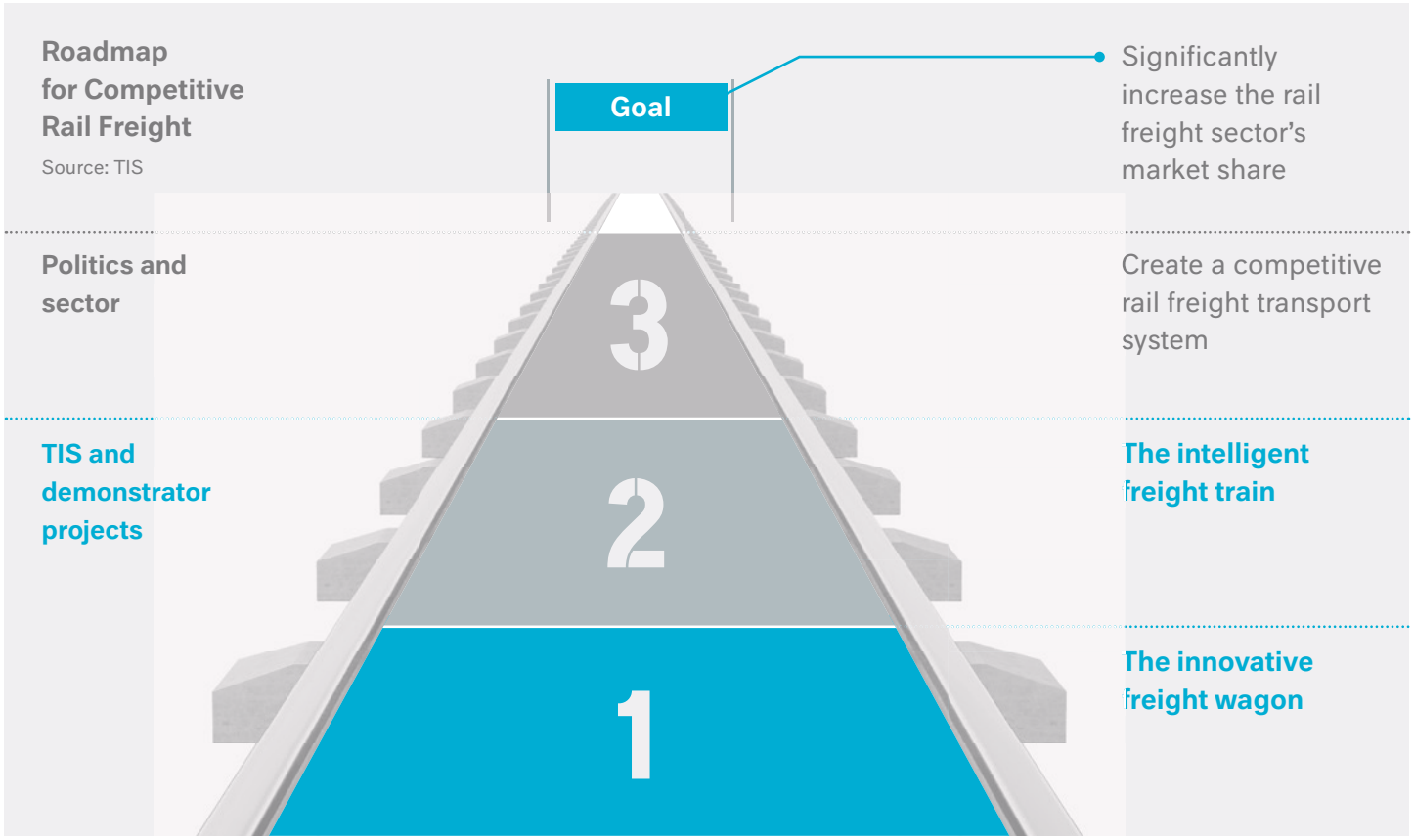
We will explain the Roadmap to the Intelligent Freight Train in the second section of this white paper. We have already taken the first steps. In November 2018, the companies involved in TIS officially acknowledged the need for the rapid introduction of the digital automatic coupling (DAC) in conjunction with an energy and data management system.

To achieve a significant increase in the proportion of total freight transported by rail, successful developments in the fields described in this document will be essential. However, it will be equally important for the rail freight sector and political authorities to initiate the necessary structural improvements. This applies, in particular, to the development of an efficient infrastructure and ensuring a level playing field for competition between the various modes of transport.

Both politicians and the sector are now pulling together to implement structural improvements.

The conditions for achieving these results are better than ever before. Politicians are promising to massively increase the market share of rail freight – the most environmentally and climate friendly mode of transport. With their Rail Freight Master Plan[2], political authorities and the sector have presented a blueprint for the future. The challenge is now to obtain the funding programmes required to implement it.

As a practice group in the sector, TIS wants to continue to play its part with initiatives for the technical, operational, and economic development of rail freight, and thus contribute to the future expansion of the industry. Consequently, we turn our gaze to the challenges of the rail freight sector which we now present to you in this second white paper.



1.2

The Technical Innovation Circle for Rail Freight Transport – Diverse and practice-oriented

The Technical Innovation Circle for Rail Freight Transport brings together the various stakeholders in the rail freight sector. As the sector's practice group, TIS has set itself the goal of initiating and implementing practical innovations for innovative freight wagons and intelligent freight trains. In doing so, it takes an integrated approach and focuses on the cost-effectiveness of innovations. Participants in TIS thus include wagon owners, railway companies and shippers, as well as companies from the wagon building industry and its suppliers.

The foundation of TIS: 13 committed member companies

Most of the companies participating in TIS operate throughout Europe and are leaders in the development and implementation of innovations for the European rail freight sector. The wagon owners in TIS are fundamentally willing to incorporate basic innovations into newbuilds and existing fleets and offer open standards. Currently, thirteen well-known companies from the rail freight sector are engaged in the various TIS working groups (see page opposite).

TIS is supported by its scientific advisers Prof. Dr. Markus Hecht (Berlin University of Technology)[3] and Prof. Dr. Rainer König (Dresden University of Technology)[4] as well as a professional advisory board represented by Dr. Gert Fregien. The project is under the management of Mr. Stefan Hagenlocher (hwh Gesellschaft für Transport- und Unternehmensberatung mbH).[5]

Interdisciplinary work for sustainable results

Over the past few years, the various interdisciplinary working groups at TIS have developed the technical and operational requirements for basic innovations in rail freight wagons. These requirements were discussed and refined with supply industries in forums and bilateral talks.

In addition, TIS is campaigning for the automation of operational procedures in rail freight transport. Here, TIS is focusing on the introduction of a digital automatic coupling for the European rail freight sector in conjunction with an energy and data management concept for freight trains.

All project results produced by the Innovation Circle are published on the TIS homepage (http://www.innovative-freight-wagon.eu).

TIS participating companies and scientific advisory board[6]

Source: TIS

BASF SE

DB Cargo AG
DB Systemtechnik GmbH

ELH Waggonbau Niesky GmbH

Ermewa SA

GATX Rail Germany GmbH

Knorr-Bremse Systeme für Schienenfahrzeuge GmbH

SBB Cargo AG

VTG AG

J.M. Voith SE&Co.KG

Wabtec Europe

Waggonbau Graaff GmbH

Wascosa AG

Dresden University of Technology

Berlin University of Technology

The success of any innovation must be judged by whether it increases the productivity of rail freight transport. The TIS concept of the “innovative freight wagon” will guide the sector towards marketable solutions.

2.0

Component: Innovative freight wagon

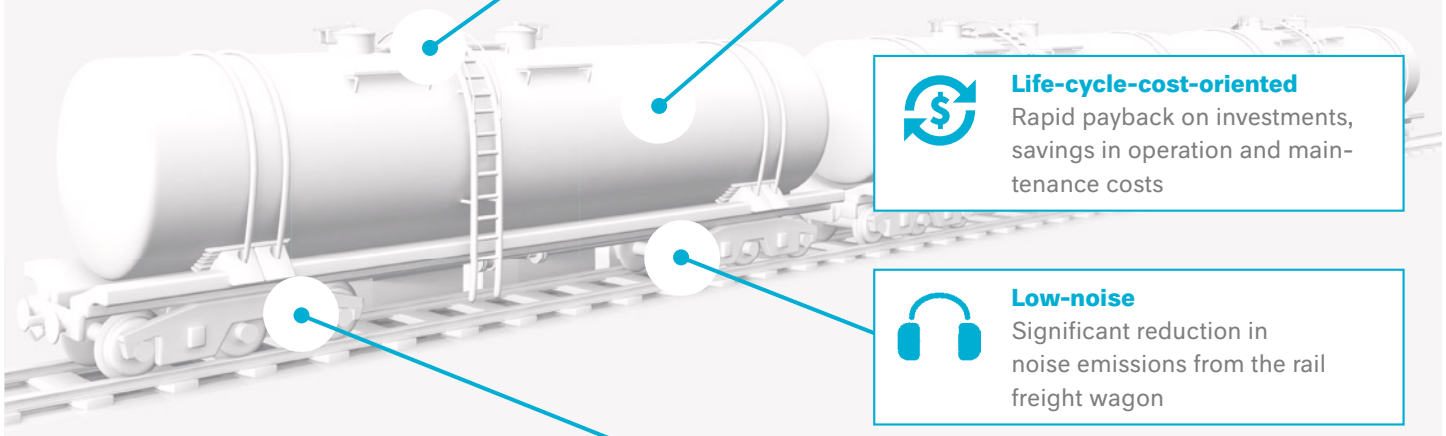
Freight wagons have long service lives: in many cases, they may be in operation on the track for 40 years or more. At first glance, this may seem to be an economic advantage, especially for wagon owners. However, the sheer longevity of freight wagons has led to an absence of basic innovations or prevented them from being implemented in practice. Without innovation, the most environmentally-friendly mode of transport is at risk of becoming irrelevant and squandering its potential.

In 2012, TIS published its first white paper "Innovative Rail Freight Wagon 2030 – The '5L' Future Initiative"[7] as a response to these challenges. In it, TIS presented a "clear strategy for the further development of one of the rail freight sector's most important resources: the rail freight wagon".[8]

Low-noise, lightweight, long-running, logistics-enabled, life-cycle-cost-oriented – these five principles were identified as key to the basic innovations that would boost the competitiveness of rail transportation.

Future initiative "5L" – The 5 factors for a competitive and successful rail freight wagon

Source: TIS



5L

Logistics-enabled
Integration into supply chains, high operational quality

Lightweight
Higher payload capacity due to reduced weight of the wagon

Life-cycle-cost-oriented
Rapid payback on investments, savings in operation and maintenance costs

Low-noise
Significant reduction in noise emissions from the rail freight wagon

Long-running
Reduction in failures and downtimes, increase in annual mileage

The rail freight sector must catch up in the area of innovation

Compared to trucks, railway freight wagons have been suffering from innovation gridlock over recent years. By way of comparison: the average road truck is in operation for no longer than eight years. This high rate of turnover enables innovations to find their way into the market much more quickly. The situation is further complicated by additional, rail-specific factors which have thwarted the innovative capacity of the sector as a whole – despite numerous research and development projects.

Five factors that make the development and adoption of innovations more difficult in rail freight sector:

- Long innovation cycle due to the longevity of freight wagons as investment goods
- International nature of transports with correspondingly high compatibility requirements for freight wagons
- Disproportionately high development and approval costs per unit due to a small and volatile market in Europe
- The lack of defined requirements for basic innovations by wagon owners vis-à-vis the supplier industry
- In many cases, innovations offer no economic benefits for the wagon owner as an investor

Road hauliers, of course, are also struggling to cope with a range of difficult issues, such as the extension of tolls from motorways to main roads, the increasing volume of road traffic, and acute driver shortages. Nevertheless, the innovations and advances achieved in the road freight sector are putting considerable pressure on the competitiveness of rail. This trend threatens European wagonload freight, in particular, but also combined transports. Long trucks, digitisation and automation, e.g. platooning or autonomous driving, are targeting significant productivity gains on the road. At the same time, commercial vehicle manufacturers are seeking to mitigate the ecological disadvantages of trucks compared to trains with trucks that use powerful, electric motors. Road freight enjoys strong support in the area of transport policy, e.g. through publicly funded pilot projects such as electrical overhead lines on motorways.

The “5L Future Initiative” shows the way

With its “5L Future Initiative”, TIS has presented a pioneering new approach for putting innovation back on track in the rail sector. The idea: to identify sustainable improvements that can be achieved using available technologies, demonstrator trains are being sent out on test runs with innovative freight wagons. Which innovations reduce energy consumption? What features improve their logistics capabilities? How can we reduce rail noise still further? What combinations of components generate tangible effects? But above all: what is economically feasible? The success of any measure must be judged in terms of whether it increases the competitiveness of freight transport. Innovation and economic viability must be considered and evaluated together. This is the philosophy of the innovative freight wagon.

To find marketable solutions, the companies participating in TIS have consciously joined forces and focused on the key aspects of the project. TIS has identified telematics and sensors, innovative running gear, and innovative wagon design as the most important fields of innovation and put them at the heart of its activities for the “5L Future Initiative”.

In addition, it has developed a model for calculating the life-cycle costs (LCC) of bogies, wheelsets, and brakes. This has been accepted by all TIS wagon owners. A valid LCC model is essential for making meaningful cost comparisons between innovative and conventional suspension components and generating acceptance in the sector.

These technical and operational requirements for basic innovations provided the theoretical framework for the three demonstrator projects with their different types of innovative freight wagon: the “5L demonstrator train” from SBB Cargo AG, the “innovative freight wagon” developed by DB Cargo AG and VTG AG, and the “innovative tank container wagon” from BASF SE. We present the specifications and evaluations of the TIS working groups in the first section of this chapter, broken down by topic according to four key themes.

TIS key themes for innovative freight wagons

Source: TIS

1. Telematics and sensors

Standardisation of interfaces for the exchange of telematics data:

- Server-server interface (Interface 1)
- Telematics unit sensor (Interface 2)
- Telematics unit/hand-held sensor (Interface 3)
- In-train communication (Interface 4)

2. Innovative running gear

- Innovative bogies
- Innovative disc brakes
- Innovative wheelsets

3. Innovative wagon design

- Lightweight design
- Innovative superstructures / modular container concepts

4. Cost-efficiency / LCC

- LCC models for freight wagon components – for analysing the cost-effectiveness of innovations in comparison to standard components
- Income approach model for freight wagons

2.1 Telematics and sensors

Rail freight transportation is going digital. Wagon owners are committed and currently upgrading their fleets with telematics devices. The devices currently available already permit a variety of applications that enhance the cost-effective use of freight wagons and the overall competitiveness of rail freight transport logistics.

These include track & trace, geo-fencing, mileage recording, and impact detection functions. Temperature, pressure, and humidity information data also allow operators to estimate the current condition of the cargo.

5L check
Telematics and sensors

- Low-noise
- Lightweight
- Long-running
- **Logistics-enabled**
- **LCC-oriented**

Compatibility of telematics devices – crucial for successful digitisation

In 2014, the TIS working group for telematics and sensor technology defined the key requirements for telematics solutions. From the outset, it was clear that these requirements would have to reflect the needs of all participants in the rail freight sector. Successful digitisation would have to take account of the process chain between shippers, wagon owners, and railway companies. To find practical solutions, TIS developed and evaluated use cases.[9]

The lack of compatibility between devices from different manufacturers proved a major obstacle to the introduction of telematics devices at this point. A common European standard, at the very least, was clearly going to be essential to allow different telematics and sensor interfaces from different suppliers to communicate with each other. Standards are also important because they create investment security for wagon owners and enable rail transport operators to automate operational processes.

TIS in dialogue with telematics providers

To standardise telematics interfaces, TIS invited all the well-known telematics suppliers to a forum for the first time in October 2014. Here they were able to exchange their ideas. The meeting was starting shot for the founding of the industry platform for telematics and sensors (ITSS). A total of 16 telematics providers from various countries are currently active in the ITSS.

Companies participating in the industry platform for telematics and sensors (ITSS)

Source: Industry platform for telematics and sensors

Amsted Digital Solutions

asto Telematics GmbH

Bosch Engineering GmbH

Bosch Engineering

BOSCH
Invented for life

CargoMon Systems GmbH

Cognid Telematik GmbH

DOT Telematik und Systemtechnik GmbH

Dresden Elektronik Ingenieurtechnik GmbH

dresden elektronik

EPHY MESS GmbH

EPHY MESS
Gesellschaft für Elektro-Physikalische Meßgeräte mbH

Franz Kaminski Waggonbau GmbH

ibes AG

Intermodal Telematics BV

Nexiot AG

Savvy Telematic Systems AG

SAVVY
Telematic Systems AG

Siemens AG

SIEMENS
Ingenuity for life

Traxens

TRAXENS

ubidata SA/NV

ubidata
TRACK-ANALYSE-OPTIMISE

First, the ITSS identified the four telematics interfaces which are relevant for standardisation.

Interface 1: Standardisation of server-server communication

The telematics devices in the freight wagons send information via a mobile communications network to a server operated by the telematics provider. There, the data are processed, e.g. translation of GPS coordinates into location/track information. Next, the telematics provider sends the information via the Internet to the user's server where it is imported into the user's ERP systems.

The ITSS group has standardised this interface and updates it regularly with new releases.[10] Without the standardised Web interface, customers would have to operate telematics systems from various providers and modify multiple interfaces. The result: more time-consuming processes, more opportunities for errors, and thus higher costs.

Interface 2: Specifications for data exchange between sensors and telematics units in the freight wagon

Sensors in the freight wagons collect information, such as impact, temperature, and pressure data. They send this data to the telematics unit in the freight wagon using either a wired or wireless solution. Since there is currently no standard for this data exchange, not every sensor can communicate with every telematics device. In practice, this means that sensors from another manufacturer cannot usually be integrated into an existing system. Wagon owners must therefore select a single manufacturer to equip their fleet with telematics devices and sensors at a very early stage. This limits the range of sensors they can use and their ability to adapt to future requirements. To eliminate this obstacle and allow greater competition, TIS and ITSS agreed that the frequency 2.4 GHz 802.15.4 should be used as the standard for wireless communication between sensors and telematics devices. This was an important first step.

By the end of 2018, the specifications for Interface 2 had been produced and agreed with all ITSS telematics providers and TIS wagon owners. Currently, a reference implementation of the specifications is being conducted by members of ITSS.

Interface 3: Facilitate data exchange between the telematics unit in the freight wagon and hand-held devices

Operating personnel on the track and in the workshop often depend on receiving fast and direct information about the status of a freight wagon or its individual components. A hand-held device can quickly and accurately transmit values recorded on-site by a telematics unit. Here, too, a common data exchange standard is an essential prerequisite. It allows even mixed trains to be processed efficiently.

Interface 4: Establish data exchange between the freight wagon and the locomotive

"Locomotive to wagon" or even "wagon to locomotive" – data must be able to flow back and forth between the locomotive and freight wagon in order to reflect and automate operational processes. This applies equally to the train integrity test, automatic brake test, determination of the wagon order, and many other applications. Two different transmission paths are available for intra-train communication.

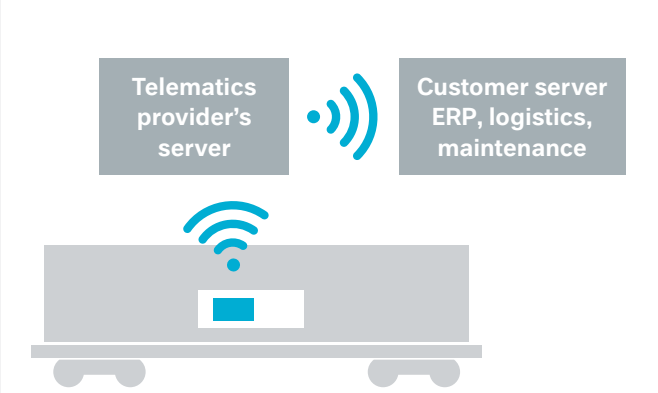
Firstly, information can be transferred from the telematics unit in the freight wagon to a server via a mobile communications network. From there, it can be accessed by the driver using a hand-held device. This method is suitable for non-time-critical information. However, for time-critical and safety-relevant information the second option should be used – direct data transmission from the telematics units in the freight wagons to the locomotive. This can be implemented via a wired or a wireless solution.

Impact detection: Development of a framework for further application options is in progress

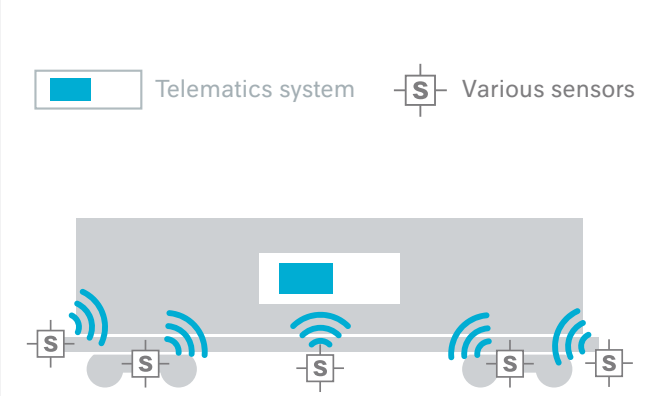
The standardisation of interfaces is one of the main challenges to be overcome if we are to realise the full potential of digitisation. However, there are other fields in the area of telematics in which agreements on generally accepted procedures would benefit the sector as a whole. Here, too, TIS and ITSS are working on solutions together.

Definition of ITSS telematics interfaces 1 to 4

Source: TIS

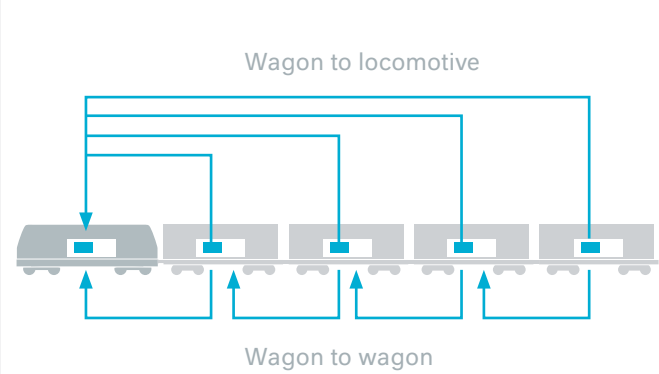


Interface 1
Telematics provider's server to (customer) server



Interface 2
Sensors to telematics system

Interface 3
Telematics system to handheld



Interface 4
Intra-train communication wagon to wagon to locomotive

For example, sensors are already being used to record impacts to freight wagons. This offers an interesting use case: any damage to freight wagons or cargo could be recorded with a time and location stamp and assigned to the responsible party who caused the damage. Studies have shown that impact sensors from various suppliers now calculate reliable and comparable physical measurement values. However, no empirical values are currently available that could be used to define the threshold force from which it can be assumed that an impact actually causes damage to the wagon – in other words, the direction, duration, and position of the impact as well as the type of freight wagon. The sector must join forces to develop a generally accepted method with a standard assessment procedure.

The VPI telematics guidelines aim to ensure the continuing development of standards

TIS is now working closely with representatives of ITSS to establish initial standards for the standardisation of telematics interfaces. The challenge going forward will be to continue the development of these and other standards which are currently in the pipeline. To do this, the ITSS group is cooperating with Verband der Güterwagenhalter in Deutschland e.V. (VPI). VPI European Rail Service GmbH (VERS), which is supported by the association, is currently producing telematics guidelines – analogous to the established maintenance guidelines. Current interface releases, standards, etc. will be published in the telematics guidelines.
In parallel, TIS is engaged in close discussions with the UIP (the European umbrella organisation of wagon owners), UIC, and the project Shift²Rail (www.shift2rail.org) to promote the Europe-wide introduction of interface standards for telematics and sensors.

2.2 Innovative running gear

A freight wagon's running gear consists of springs and shock absorbers, wheelsets and the brake system. They are also the key to regulating two important factors: the freight wagon's maintenance costs and noise emissions. The running gear components are subjected to the highest mechanical loads and thus wear faster – so they are a major cost factor. At the same time, the running gear's wheel-rail contact generates most of the noise produced by the freight wagon.

The running gear plays a significant role in terms of maintenance costs and noise

TIS has taken the initiative and is promoting projects for the development and testing of innovative running gear, wheelsets, and braking systems. If successful, such components will have an excellent chance of being adopted quickly in real-world operations.

2.2.1 Innovative bogies

Type Y25 standard bogies have been among the most commonly used components in four-axle freight wagons since the 1960s. The Y25 bogie has a simple design and is manufactured in relatively high quantities – so it is available at a reasonable cost. However, one major disadvantage of this design is that in a Y25 bogie the wheelsets cannot be adjusted radially. This can lead to a high level of friction between the wheelset and the rails, particularly in bends.

5L check
Innovative bogies

- **Low-noise**
- Lightweight
- Long-running
- Logistics-enabled
- **LCC-oriented**

The result: "screeching" in the curves and thus higher noise levels and maintenance costs caused by wear to both wheelsets and infrastructure.

Various suppliers have already taken up the challenge over the past few years and are working on innovative bogies with radially adjustable wheelsets. Nevertheless, no innovations in the area of bogies have yet been truly adopted by the market and there is no sign of a universal replacement for Y25 bogie technology, especially in new freight wagons. Innovative bogies are still significantly more expensive to purchase than conventional Y25 bogies.

Definition of requirements for innovative bogies through dialogue with the manufacturers

As a first step, TIS developed requirements for innovative bogies[11] and then invited manufacturers of bogies to bilateral talks as well as a joint discussion forum. During the evaluation of current developments, it quickly became evident that the different bogies are difficult to compare. Claims by manufacturers relating to reductions in noise and energy consumption, as well as wear on wheelsets and rails, were generally based on subjective estimates or non-standardised tests.

First results: less noise, lower energy consumption

To assess the impact of innovative bogies on noise emissions, energy consumption and wear more effectively, TIS produced a testing concept for innovative bogies. Based on this, SBB Cargo AG commissioned four different innovative bogies[12] for its "5L" demonstrator project. These are currently being tested over a total distance of 400,000 kilometres. (see chapter 2.5.1).

The research project "Construction and testing of innovative freight wagons" under the management of the consortium of DB Cargo AG and VTG AG[13] is also running practical tests on two innovative bogie designs[14] over a distance 150,000 km (see chapter 2.5.2).

In terms of noise emissions and energy consumption, the innovative bogies in all three demonstrator projects are already yielding positive results – especially on winding routes.

2.2.2 Innovative wheelsets

Wheel-rail contact is one of the key sources of noise emissions in rail freight transport. Here, the introduction of "whispering brakes" has already been a major step forward. Wheelsets fitted with modern LL or composite brake blocks reduce noise by 10 dB in comparison to the old brake blocks made of grey cast iron.

However, wheelsets are not only important because of their potential for noise reduction. They also play a major role in defining maintenance costs. Extending maintenance intervals significantly improves the cost-efficiency of freight wagons. Here, too, products using various approaches are available on the market and being tested in demonstrator trains.

5L check
Innovative wheelsets

- **Low-noise**
- Lightweight
- **Long-running**
- Logistics-enabled
- **LCC-oriented**

TIS is primarily pursuing two main objectives in the area of wheelsets: the development of durable, low-maintenance wheelsets, and the reduction of noise emissions due to wheel-rail contact. If possible, these goals should be achieved simultaneously.

A stronger wheelset axle reduces costs

Increasing the service life of wheelsets is a key factor in improving cost-efficiency. This is why TIS actively supported the project "European Standard Freight Axle" (EFSA)[15] which developed a catalogue of requirements for a new and far stronger wheelset axle. The new wheelset axle extends the maintenance interval for wheelset axles between non-destructive tests (NDT) and thus reduces maintenance costs.

New technologies promise further noise reductions

Several manufacturers have developed wheelsets with technologies, such as absorbers or ring elements, designed to provide further noise reductions. Although their noise-reducing effects have been demonstrated by the respective manufacturers in their own tests, there is currently no way to objectively compare the results for these quiet wheelsets from the various manufacturers. Moreover, it is unclear how successfully these noise-reducing wheelset technologies will perform in real-world operations.

Demonstrator trains confirm that significant reductions in noise emissions are possible but with higher costs

In order to produce valid and comparable data for the mitigation of noise emissions, TIS developed a testing concept which was implemented in the "5L" demonstrator project run by SBB Cargo AG (see chapter 2.5.1). This uses four different wheelsets with the new absorber systems and/or ring elements.[16] The research project "Construction and testing of innovative freight wagons" run by DB Cargo AG and VTG AG has also tested the noise reducing effects of various innovative wheelsets. The innovative freight wagons are being used with disc- and block-braked wheels on a test track as well as in real operations under comparable conditions (see chapter 2.5.2).[17]

Both demonstrator projects have shown that the innovative wheelsets offer a clear reduction in noise levels. The measured values were approximately 4 to 7 dB(A) below the currently valid TSI noise limit of 83 dB(A). However, the test runs showed that although the absorber systems blocked noise, they also blocked the view of the wheel disc during inspections. This limits their potential for use in real-world operations. Wheelsets with ring elements also achieved a significant reduction in noise levels.

Further noise reduction will increase costs

It is already clear that innovative wheelsets reduce noise but only with higher costs. The higher procurement costs for these wheels will not be offset by reduced life-cycle costs. On the contrary. None of the noise reducing components contributes to minimising the wear on the wheel and thus a reduction in maintenance costs. However, it is still too early for TIS to provide a definitive answer to the central questions of innovative wheelsets. Further studies with funding to support operational testing, or a continuation of ongoing projects, will be required to provide reliable estimates of the trends for future maintenance costs and the sustainability of noise reduction effects.

2.2.3 Innovative disc brakes

The use of innovative disc brakes can make sense in certain types of rail freight wagons. For wagons with high mileage, the reduced wear of a disc brake already offers economic benefits today – despite the higher investment costs compared to a system with K or LL brake blocks. However, at present, high procurement costs make them uneconomic in wagons with medium or low mileage.

5L check
Innovative disc brakes

- Low-noise
- Lightweight
- **Long-running**
- Logistics-enabled
- LCC-oriented

The heavy brake discs are a fundamental disadvantage as they reduce the capacity available for the payload. Consequently, disc brakes are primarily used in freight wagons which do not use their full payload capacity most of the time. Particularly for fast freight trains operating at speeds of more than 100 km/h, disc brakes can already be a cost-effective solution. A major market segment for disc brakes is in freight wagons with high annual mileage, especially in seaport to hinterland transports.

TIS objective: a lighter disc brake

TIS has defined the requirements for innovative disc brakes[18] and discussed them with disc brake manufacturers. The central question is that of weight. Several manufacturers have now developed new discs which offer significant weight advantages, either due to their smaller disc diameter or as a result of new materials and manufacturing processes. The new disc brakes are currently undergoing testing in the “5L demonstrator” and “Innovative Freight Wagon” projects. The use of new materials and manufacturing processes has enabled manufacturers to reduce the weight of disc brakes significantly. The new disc brakes are around 50 kg lighter – a reduction of appr. 35 percent. For a four-axle freight wagon, this liberates capacity for a remarkable 400 kg of additional payload.

Review of the existing regulations is required

TIS believes that the potential for further reductions in the weight of the disc brake is not yet exhausted. One promising option, which has the support of TIS, is the “single disc solution” – a disc brake with just one rather than two brake discs per axle. However, there are safety considerations here which must be taken into account, e.g. regarding the transportation of hazardous goods.

Identifying ways to reduce the still comparatively high procurement costs remains a major challenge. In addition, it is important to consider the processing costs for vehicles with disc brakes compared to those with conventional block brakes.

2.3 Innovative wagon design

2.3.1 Lightweight design

"Lightweight" is one of the "5L" criteria for innovative freight wagons. A reduction of the wagon weight offers many economic advantages – shippers benefit from increased payload capacity, railway companies from lower energy consumption for empty runs.

5L check
Lightweight design

- Low-noise
- **Lightweight**
- Long-running
- Logistics-enabled
- **LCC-oriented**

Even the intelligent selection of conventional materials provides scope for weight reductions. The use of innovative materials creates further opportunities. Here, however, basic research is required.

The demonstrator trains show that weight savings amounting to several tonnes are possible

The "Innovative Freight Wagon" project run by DB Cargo AG and VTG AG, and "Innovative Tank Container" project run by BASF SE, focused on freight wagons made from conventional materials which are "trimmed for lightweight design". In some cases, the resulting innovative freight wagons were several tonnes lighter than the reference vehicles. Further weight savings should be possible through the use of innovative materials.

The rules must clear the way for lighter wagons

Current regulations are likely to be an obstacle to further weight reductions. They stipulate a high unladen weight for freight wagons: at least 20 tonnes for four-axle wagons with disc brakes and at least 16 tonnes for those with block brakes. TIS therefore considers it necessary to review and adapt the existing regulations to enable freight wagons to exploit the potential of lightweight design more fully.

In principle, TIS is open to the use of innovative materials such as carbon fibre composites. However, more basic research and extensive testing will be required before they can be used in normal railway operations. Naturally, safety requirements are paramount – in particular measures to prevent derailment. Economic requirements are also an important part of the bigger picture. These include, for example, the requirement that repairs and maintenance should be as easy to perform with innovative materials as they are today.

2.3.2 Modular design and innovative container concepts

Today's freight wagons have a technical life span of several decades. While this is generally positive, it also leads to long replacement and innovation cycles. Moreover, the majority of the wagons are very specific to the type of goods they transport and their respective requirements.

Because freight wagons are designed for a specific type of freight, their capacity utilisation is often low. A major disadvantage of this specialisation is that only small quantities of a type of wagon can be ordered. This results in higher costs – both for procurement and maintenance.

Persuasive advantages: better capacity utilisation in operation, lower procurement and maintenance costs

TIS believes that a modular flat wagon design in conjunction with innovative container concepts could offer a solution to this problem. Container concepts are nothing new in the rail freight sector, as the growth of intermodal transport clearly demonstrates. However, innovative container solutions are now also being adopted more widely for bulk goods.

The separation of the freight wagon and its superstructure offers several advantages: the wagon base can be standardised and produced cost-effectively in large quantities – in a variety of lengths. This could and should continue to have a long technical service life. In contrast, the superstructure/container can be designed for the specific type of freight and, if necessary, manufactured for a shorter technical service life. This would be an advantageous way to shorten innovation cycles.

5L check
Modular design and innovative container

- Low-noise
- Lightweight
- **Long-running**
- **Logistics-enabled**
- **LCC-oriented**

The modular design also offers greater investment security for wagon owners. While special freight wagons designed for long-term use in changing markets present a particular risk, a modular concept allows one container solution to be replaced with another. Maintenance requirements, such as materials, technical know-how, and measuring and testing equipment, could also be minimised with a corresponding reduction in costs and throughput times.

A modular approach of this type is currently being tested in practice, as part of BASF's innovative mobile tank concept. A modular concept of this type has been in operational use since 2017. The BASF class tank container weighing up to 75 tonnes is used in combination with an exceptionally lightweight innovative wagon. It convincingly demonstrates how separating the flat wagon from the superstructure opens new horizons for optimised logistics concepts and increases the operating mileage of freight wagons (see also chapter 2.5.3).

However, it is also clear that for long-term customer transports and the transportation of goods that are not or only partly suitable for shipment in containers, a freight wagon designed specifically for the requirements of these cargos will continue to be an economic advantage.

2.4 Life-cycle cost analysis

Technical innovations for rail freight wagons must not be an end in themselves. Technical feasibility must be tempered by economic viability.

Life-cycle costs determine the value of innovations

Procurement costs for technical innovations, initially, are often higher than those for conventional components. Development and approval costs usually have to be covered by a small production run for the market launch. However, economic viability is determined by a consideration of the life-cycle costs (LCC). How do the costs alter throughout the life-cycle?

Until now, the industry has not had a generally accepted basic model for LCC – especially for calculating the life-cycle costs of freight wagons. Customers perceived the LCC models developed by individual manufacturers primarily as sales promotion tools.

The LCC model from TIS: an industry-wide initiative

In a hitherto unprecedented cooperation within the sector, the companies involved in TIS have developed a joint LCC model for bogies, wheelsets, and brake systems. A neutral, third party consulting firm gathered data on the real-world procurement and maintenance costs required for the project. It then used these data as the basis for algorithms to calculate the life-cycle costs based on the operating mileage. The data provided by TIS wagon owners were anonymised and used to calculate average values.

Expand the LCC model and make it useful for the entire sector

Models for the determination of life-cycle costs are fundamental for making investment decisions – especially when innovations are set to replace conventional or familiar technologies. This is why TIS is promoting the integration of further components into the LCC model alongside the existing LCC model for the freight wagon running gear. In addition, future LCC models should consider the revenue side from the viewpoint of railway companies as well as wagon owners. This would provide the whole sector with a comprehensive and coordinated tool for optimisation and, ultimately, for proving the economic viability of innovations.

2.5 Practical track testing

It is not enough to assess the impact of innovations on the "5L" criteria exclusively from a theoretical standpoint. Their practical viability must certainly be demonstrated before they go into series production. For this reason, TIS developed a concept for the operational testing of innovative components in a demonstrator train as early as 2015. This concept is currently being implemented in three projects.

Three demonstrator projects provide important insights into basic innovations

In 2016, SBB Cargo AG – a participant company in TIS – stated for the first time that it was prepared to construct a train incorporating a wide range of innovative solutions and test it on the tracks. The "5L" demonstrator project is supported by the Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Office of Transport (FOT).

In Germany, the Federal Ministry of Transport and Digital Infrastructure commissioned a research project of its own – "Construction and testing of innovative freight wagons" – in 2016. The contract was awarded to the joint venture between DB Cargo AG and VTG AG – both are members of TIS.

Finally, BASF SE initiated its "Innovative mobile tank concept" project. This project developed, tested and implemented new designs for innovative and exceptionally lightweight container wagons and the world's largest BASF class tank container in practical applications.

All three innovation projects investigated the impact of innovations on the economic viability of freight wagons, lowering energy consumption and reducing noise emissions. Although some of the projects are not yet complete, they have delivered some promising and valuable initial insights.

2.5.1 "5L" demonstrator – SBB Cargo

In May 2017, SBB Cargo presented its "5L" demonstrator train to the public at the transport logistic trade fair in Munich for the first time.[19] The pioneering project combines a total of 16 freight wagons – all container wagons equipped with a wide range of innovations. The company has set itself the goal of putting the "5L" philosophy into practice: an innovative freight wagon that is low-noise, lightweight, long-running, logistics-enabled, and life-cycle-cost-oriented.

400,000 km covered in four years

The "5L" demonstrator train has been in operation since May 2018. Over four years, it will cover a total distance of not less than 400,000 km. The focus is on gaining insights into wear behaviour, noise reduction effects and automation applications, such as the automatic brake test. The first

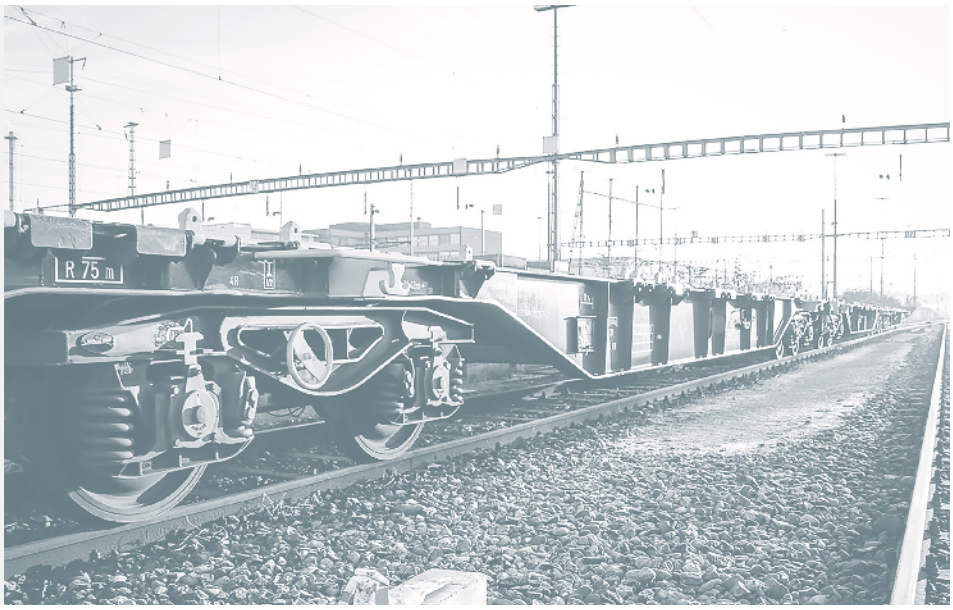
results in the area of noise emissions have been released. The noise level measurements taken so far show a reduction of approximately 5 decibels compared to freight wagons already refurbished with composite brake blocks.

Six innovative systems in practical testing on the container wagon

The “5L” demonstrator train is testing the functions and properties of six innovative systems in practical applications:

- Innovative bogies from four different manufacturers
- Innovative wheelsets from four different manufacturers
- Innovative disc brakes from three different manufacturers
- Automatic couplings from two different manufacturers
- Separation of the flat wagon and superstructure through the use of an innovative 60‘ sliding wall construction
- Telematics applications.

“5L” demonstrator train from SBB Cargo



2.5.2 BMVI project “Innovative freight wagon” – DB Cargo / VTG

In the spring of 2016, the German Federal Ministry of Transport and Digital Infrastructure (BMVI) issued an invitation to tender for a research project “Construction and testing of innovative freight wagons”. BMVI provided a clear objective – the development of a quiet, energy-efficient, and economically viable freight wagon. Using existing components and technologies, the research project was to design and test new, innovative freight wagons and test them in demonstrator trains. The contract for the 2.5-year project was awarded to the consortium of DB Cargo AG and VTG AG[20] in September 2016.

Twelve prototypes of four wagon types in test drives

To complete its mission, the consortium has built a demonstrator train with innovative freight wagons (IFW) and has tested them in practical operations. The train incorporates a total of twelve IFW prototypes, specifically three wagons of the four following types:

- Flat wagons – for the transportation of steel products
- Car transport wagons – for the transportation of finished vehicles
- Tank wagons – for the transportation of liquid chemical products
- Container wagons – for the transportation of containers

The twelve prototypes are fitted with a variety of innovative components, such as bogies with radially adjustable wheels, disc brakes, quiet wheelsets with noise reducing technologies, telematics equipment, digital brake monitoring systems, power and data cables and electro-pneumatic brakes. For the purposes of comparison, the demonstrator train includes a further eight reference vehicles with conventional components. Two different types of automatic coupling were tested using three existing freight wagons.

150,000 km across Europe

In March 2018, the demonstrator train began its test run through Germany and Europe. At the end of the project, in March 2019, it had completed the target mileage of 150,000 km. In January, February and October 2018, the IFW was also subjected to extensive testing in the area of noise emissions and energy consumption at the Siemens AG test and validation centre in Wegberg-Wildenrath. The results were compared with those for the reference freight wagons. The first results of the noise emission tests are now available: With a measured reduction of four to seven decibels compared to the current TSI noise limit value of 83 decibels, the project not only achieved its targets but exceeded them. However, it remains to be seen whether the noise reducing effect of the innovative wheelsets with sound absorbers or ring elements is sustainable.

It is still too early to make a final evaluation of the project. Nevertheless, it is already clear that this validation of the effectiveness of various measures for reducing noise levels and energy consumption in freight wagons – conducted by a neutral testing institute commissioned by the BMVI – offers important insights for the entire sector.

Innovative freight wagon from DB Cargo AG and VTG AG

2.5.3 Innovative mobile tank concept – BASF

BASF has more than one thousand railway tank wagons in operation on its premises. They transport liquid or gaseous chemicals from the station to the plants. Optimising the use of these tanks is the central objective of the BASF project “Innovative mobile tank concept”.[21] It aims to reduce high pre- and post-carriage costs of rail freight transport in the BASF plants. The essential idea is to automate the future transportation of goods on the factory premises. At the same time, the new freight wagon should be quieter in order to increase the public acceptance of rail transports.

The “Innovative mobile tank concept” consists of the following modules:

- Innovative BASF class tank containers (75 tonnes gross vehicle weight)
- Innovative container wagon
- Automated (e-mobile) vehicles for pre- and post-carriage
- Fully automated tank container storage

To this end, BASF railway logistics specialists developed a new type of tank container with a high payload volume in partnership with Van Hool, the Belgian commercial vehicle manufacturer. This enables it to be integrated into modern logistics chains on the factory premises. Industry professionals refer to this new class of tank containers as the B-TC (BASF class tank container). To transport the innovative tank container, BASF developed an innovative 45’ container wagon in collaboration with project partners. With its innovative bogies and quiet wheelsets, the freight wagon’s noise emissions are approx. 5 dB lower than the TSI noise limit value. The weight of the container wagon has been optimised and is only 16.5 tons despite the use of disc brakes. In mid-2018, in the north of its plant in Ludwigshafen, BASF commissioned a terminal where the new tank containers could now be loaded fully automatically. The transportation from the tank container terminal to the plant is performed by an automated guided vehicle (AGV).

Innovative tank container concept from BASF SE

2.6 Outlook: Innovative freight wagon

Over the past few years, the companies involved in TIS, as well as other market participants, have designed, developed, and tested many innovations which aim to significantly improve the technical and economic performance of freight wagons. Today, there is widespread agreement in the rail freight sector regarding the innovative freight wagons of the future.

The freight wagons of the future will incorporate the following features:

Innovative running gear, bogies, wheelsets, and braking systems. Lighter, quieter, lower wearing components will contribute to the economic viability and acceptance of modern freight wagons.

Telematics devices. Freight wagons will be equipped with sensors for the implementation of a wide range of use cases in the specific area of application, e.g. impact detection, weighing, temperature or pressure measurements in the tank. Telematics data will be transmitted using standardised interfaces to ensure compatibility between all freight wagons equipped with telematics devices.

Innovative wagon design with modular design and lightweight construction concepts. The flat wagon will have a modular design in order to ensure it can be used flexibly throughout its service life. Both the flat wagon and the superstructure will take advantage of lightweight design principles. In the future, however, there will still be many areas where freight wagons with conventional designs offer specific advantages, e.g. due to their higher payload.

The innovations described above will ensure that the freight wagons of the future are low-noise, lightweight, long-running, and logistics-enabled. However, the fifth “L” is of central importance: Life-cycle-cost-oriented. Innovations will only be adopted by the market if they are economically viable. To evaluate the cost-effectiveness and other effects of these innovations, various parties involved in TIS have launched demonstrator projects. The interim results of the demonstrator projects initiated and supervised by TIS are a positive signal for the future – as is the welcoming attitude to innovation that is now widespread in the sector.

The intelligent freight train puts efficiency back on track. The heart of the system: the digital automatic coupling with continuous power and data lines.

3.0 Target: The intelligent freight train

If the sector wants to increase the competitiveness of rail freight transport significantly, the “innovative freight wagon” can only be the first step. The real value of the many basic innovations only becomes apparent when we focus on the freight train as a whole.

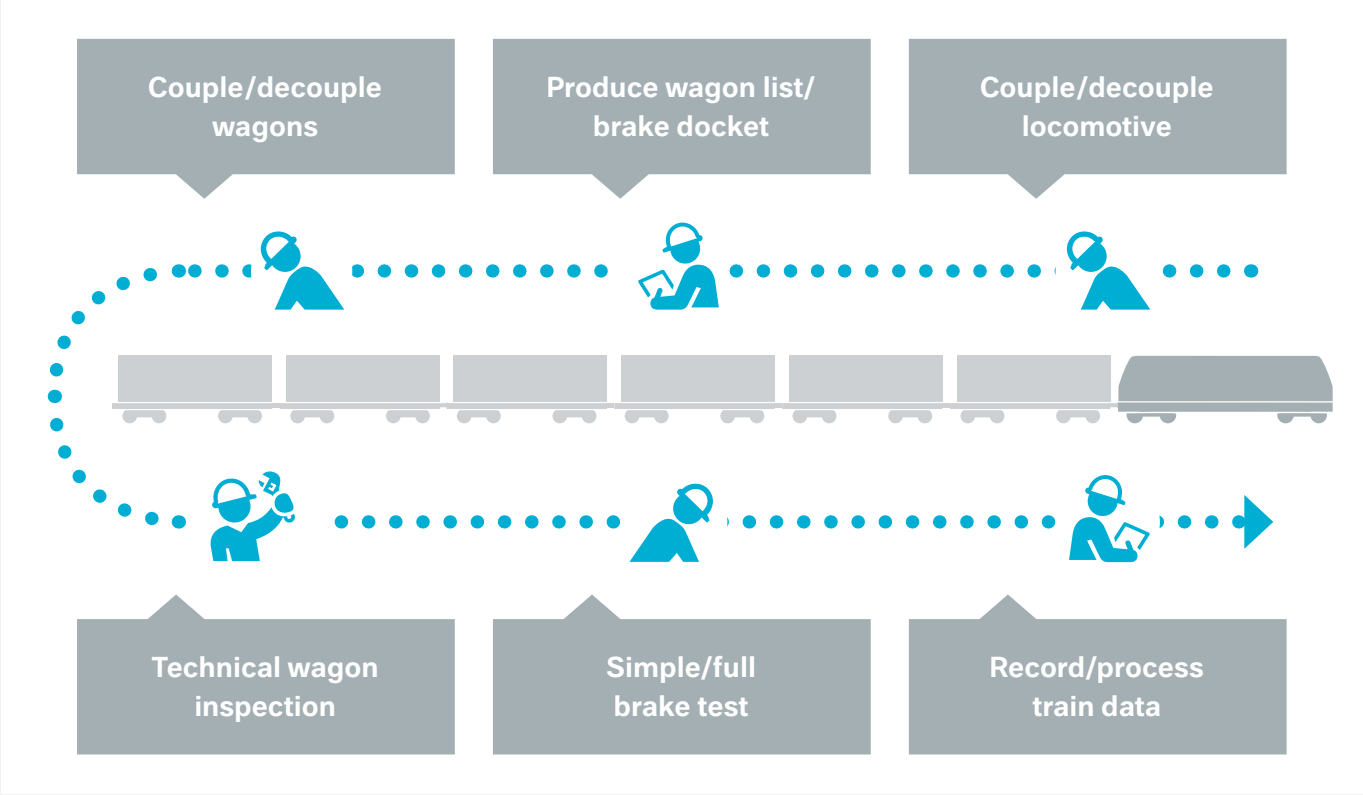
This is especially true in the digitisation and automation of operational procedures. TIS is therefore taking the next logical step: combining innovative freight wagons into intelligent freight trains. This offers enormous potential for increasing the efficiency and cost-effectiveness of rail freight transportation.

Train marshalling in 2019 – still a manual job

A glance at the train marshalling process clearly shows that little progress has been made in the area of automation for decades. The preparation of a train prior to departure is still a largely manual process. The locomotive and freight wagons must be coupled mechanically, the brake and air hoses connected. The wagon order is checked, the brakes tested. The train’s braking weight is determined and a braking calculation performed.

Manual handling during train preparation

Source: TIS



The technical condition of the freight wagons is inspected by operating staff as part of a technical wagon inspection. Finally, even the sign at the end of the train has to be attached manually.

Automation is the key to more efficient operations

Obviously, something has to change. TIS has set itself the goal of automating manual tasks in every area of train preparation and handling. However, achieving the necessary results will require more than the automation of individual steps.

We need solutions that minimise the need for railway staff in preparing the freight train as a whole. The following example makes this clear: even if the brake test or technical wagon inspection could be automated successfully, freight wagons would still have to be coupled manually. Although operational staff on the track would have less to do, they would still be required.

TIS thus considers the introduction of an automatic coupling to be essential. It is key to delivering a leap in efficiency that will benefit the entire railway system. For the automation of railway operations, an adequate

TIS key themes for intelligent freight trains

Source: TIS

1. Automated operations

- Automatic brake test / Braking weight calculation
- Train setup and train integrity test
- Registration of wagon order
- Digitisation of technical wagon inspections
- Sensor-based monitoring of components and condition-oriented maintenance

2. Digital automatic coupling (DAC)

- Use of a DAC with additional automatic coupling of air, power and data bus lines
- Definition of functional requirements and selection of coupling head
- Development of use cases and economic viability considerations
- Production of migration and financing concepts

3. Energy and data management

- Development of a standard for the future energy supply on board of freight wagons (battery, power line) Identification of future energy and voltage requirements for power supply
- Development of a future data communication standard for freight trains, wireless and wired, incl. selection of a technology

4. Electro-pneumatic brake

- Use of power line in freight wagons (also) for the control of EP brake valves
- Development and testing of a cost-effective solution for an EP brake

energy supply and secure data communication within the train are also important. Combining these components into a digital automatic coupling (DAC) with integrated power and data bus lines will open up considerable opportunities for rail operators. The position of TIS is therefore clear: the Europe-wide introduction of a digital automatic coupling must be made a top priority.

Since the concept of a DAC also includes the use of a power line, it is clear that, in this context, the introduction of an electro-pneumatic brake should also be considered in rail freight transport.

The Roadmap to the Intelligent Freight Train

The TIS Roadmap to the Intelligent Freight Train comprises four key themes. These focus on the following fields of innovation: automated operations, the digital automatic coupling, power and data management, and the electro-pneumatic brake.

3.1 Automation of operations

TIS is convinced that the automation of operations has a key role to play in boosting the competitiveness of the rail freight sector. Telematics applications offer a wide range of options for automating manual tasks with freight wagons/trains. The key will be to find solutions that completely replace all the manual steps and visual inspections – not just simplify or shorten these individual operations.

Secure competitiveness, counteract the shortage of skilled workers

The objective is not just to improve cost-effectiveness – automation also offers a response to the growing shortage of skilled professionals. Staff shortages, especially in professions such as train drivers or vehicle inspectors, is an urgent problem in the industry that looks set to intensify over the coming years. Automation will relieve the burden of less attractive manual tasks – which have to be performed at all hours and in all weather conditions. It will not only focus on the time required for each activity but also the waiting and transfer times to bring the necessary actors to the respective locations.

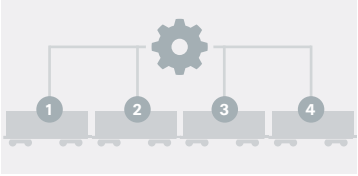
The contribution that automation of operations can make to the rail freight sector becomes clear when we study the following seven relevant fields of application:

Brake test

The automatic brake test offers significant leverage for increasing efficiency. Currently, the brakes of every train have to be tested prior to departure to ensure they are functioning correctly. These time-consuming manual brake tests are usually performed by the driver or vehicle inspector. Not only does this task create costs, it is also becoming increasingly difficult to manage due to the aforementioned shortages of qualified staff.

Braking calculation

Before each departure, the braking weight of the train must be calculated and from this the braking capacity – or “brake mass percentage”. It is conceivable that, in the future, an intelligent freight train could perform this braking calculation itself and display the result via a screen in the driver’s cab. This would save staff time and money.

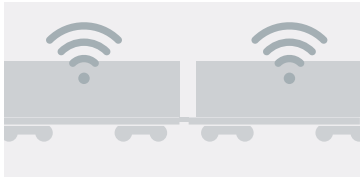


Registration of wagon order

In future, the intelligent freight train should incorporate automated wagon registration. This would involve a “train setup” prior to departure which registers the respective freight wagons in the train network and transmits the wagon order. The wagon order would thus be known at all times. The system could actively notify the operator if it were to deviate from the planned order.

Train integrity test

At the latest, the introduction of ETCS Level 3 should eliminate the need for expensive axle counters and clear track signalling systems in railway infrastructure. However, there is still a barrier to this happening today – in contrast to passenger trains, there is currently no train integrity test for freight trains. The development and introduction of a train integrity test is an essential condition for the introduction of ETCS Level 3 in rail transport. A train integrity test regularly checks whether all the freight wagons are still in the train and that no part of the train has become separated.



Digitisation of the technical wagon inspection

Train preparation is currently a very labour- and time-intensive process. Among other things, it requires a technical wagon inspection to be performed. For infrastructure operators, wagon owners, and railway companies, telematics now offer a wide range of options for the automated and predictive monitoring of the condition of components.

TIS commissioned a study on this topic that analysed the potential for the digitisation of the technical wagon technical inspection and provided a roadmap for the digitisation process.[22] Quantitatively, it concluded that only a relatively small number of technologies are required to make progress in digitising the technical wagon inspection. The authors identify four key technologies:

- Automatic brake test
- Digital wagon identity or wagon addresses
- Sensor-based recording and evaluation of accelerations in the wagon chassis or wagon body
- Camera-based systems with feature recognition.

In addition to optimising train preparation, the digitised technical wagon inspection offers further advantages. Firstly, it supports learning processes that involve all stakeholders. As in the aviation industry, this could provide a systematic pathway for eliminating errors. Secondly, more detailed status information about the wagon would permit a reorganisation of maintenance procedures as a whole. Overhauls and fixed maintenance intervals could be replaced by condition-based maintenance.

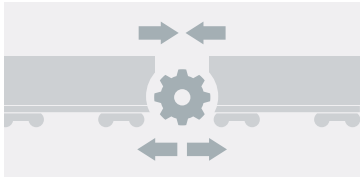
Depending on their perspective, companies are investing in the development of fixed location technologies alongside the track (way-side) or mobile diagnostic equipment in the wagon (on-board) for the detection of component states. TIS believes it is important that existing way-side and on-board technologies should be used to identify an optimum and economic approach for all parties and be tested in other pilot projects. The networking of all diagnostic data is of particular importance.

Condition-based maintenance

Today, freight wagon maintenance schedules are essentially based on time and mileage. One important reason for this is that continuous status data are not available for the wagons. The drawback is obvious: components are replaced or overhauled as a preventive measure regardless of their condition – prematurely, if necessary. Digital wear sensors offer

a solution. They can be used to analyse the status of wagon components at any time. The results can be transmitted from the freight wagon to the back office via a mobile communications network in real-time. This could significantly reduce maintenance costs while simultaneously increasing freight wagon availability. Both these factors would significantly reduce the costs of operating freight wagons.

Importantly, in future, companies will be able to use big data analysis to predict how components will wear and adjust their maintenance cycles accordingly.



Coupling and decoupling

Probably the most physically strenuous – and also dangerous – manual task is the coupling and decoupling of freight wagons with a screw coupling. Automation of the coupling process by using an automatic central buffer coupling will make a crucial contribution to reducing the workload on operating personnel during shunting operations. At the same time, it will make the organisation of operational processes much more efficient. It will open the gateway for modern logistics concepts. In many cases, it will pave the way for a host of digital applications.

The list of automation challenges described here is not intended to be exhaustive. Train preparation often involves further manual activities, such as checking the brake lever position or the hand brake. These tasks must be considered during the automation process as well. One crucial factor in the implementation of automated operations will be the future safety requirements for automated solutions. These will be extremely relevant for the economic viability of the solutions.

However, the automatic coupling will play a key role in many other aspects of the automation of operations. The following section will provide a detailed examination of the road ahead for the development of the automatic coupling.

3.2 Digital automatic coupling

The introduction of an automatic coupling will be the central component in the extensive automation of the rail freight sector. It will not only provide the power supply but also data communication in the train. Combining these functions in a digital automatic coupling with integrated power and data bus lines will open up considerable opportunities for rail operators. It is the key to delivering leaps in efficiency that will benefit the entire rail system.

The position of TIS is clear: the Europe-wide introduction of a digital automatic coupling (DAC) must be made a top priority.

Digitisation opens new horizons for the automatic coupling

All previous attempts to introduce an automatic coupling (AC) for European rail freight transportation have failed. The companies participating in TIS are all aware of this fact. In the meantime, however, the underlying conditions for the introduction of an AC have changed radically: technological advances mean the focus is no longer solely on improving the occupational health and safety of shunting staff or increasing the productivity of shunting operations. On the contrary, the introduction of a DAC for freight trains could now generate a variety of additional benefits which considerably increase the competitiveness of rail freight transportation.

Simply automating the process of mechanical coupling – standard practice in America and Russia for many years – is no longer enough. To achieve significant increases in productivity, the AC must also automatically couple the air, power, and data bus lines. This will enable operators to automate many other processes which are currently performed manually. In the future, it may even be possible to develop a DAC that can decouple by remote control.

Migration strategy for the introduction of the automatic coupling

The sector must develop a migration strategy for the aforementioned innovations and implement it in the medium term. This includes the agreement of a uniform, Europe-wide DAC as well as an energy and data management standard for freight trains.

TIS has agreed on five essential technical principles that provide the framework for the definition of a DAC:

Definition of various types of automatic coupling
Types 1 to 5 – beginning with an AC that creates only a mechanical connection; progressing through a design that integrates automatic connection of the air line; and concluding with a digital, fully automated AC that not only provides the mechanical connection but also automatically couples the air, power, and data bus lines and can be coupled/decoupled by remote control.

Integrated coupling of air, power, and data bus lines as the minimum standard for the migration of the DAC into the market. The corresponding DAC Type 4 should aim to achieve maximum impact on the digitisation and automation of rail freight transportation. Important: the digital automatic coupling must be upgradeable and upwardly compatible with a DAC Type 5.

No compatibility with the traditional screw coupling (SC). This should allow the DAC to be adopted quickly and completely throughout Europe. Although a temporary mixed operation using both DAC and SC could simplify the transition period, the benefits of rapid migration are more significant.

Standardised power and data management via a continuous power and data bus line to ensure reliable telematics applications and automation. The power supply should be sufficient for these functionalities to be expanded in future and also provide enough energy to charge a battery. TIS has begun to standardise the data interfaces for today‘s and tomorrow‘s telematics applications along the entire transmission chain – from the telematics units on the freight wagons to the train, the locomotive and all the way to the control unit.

A technically robust design that takes into account the tensile and compressive forces to which the DAC will be subjected by the heavier and longer trains of the future. At the same time, the coupling should remain as light as possible in order to avoid losing payload capacity.

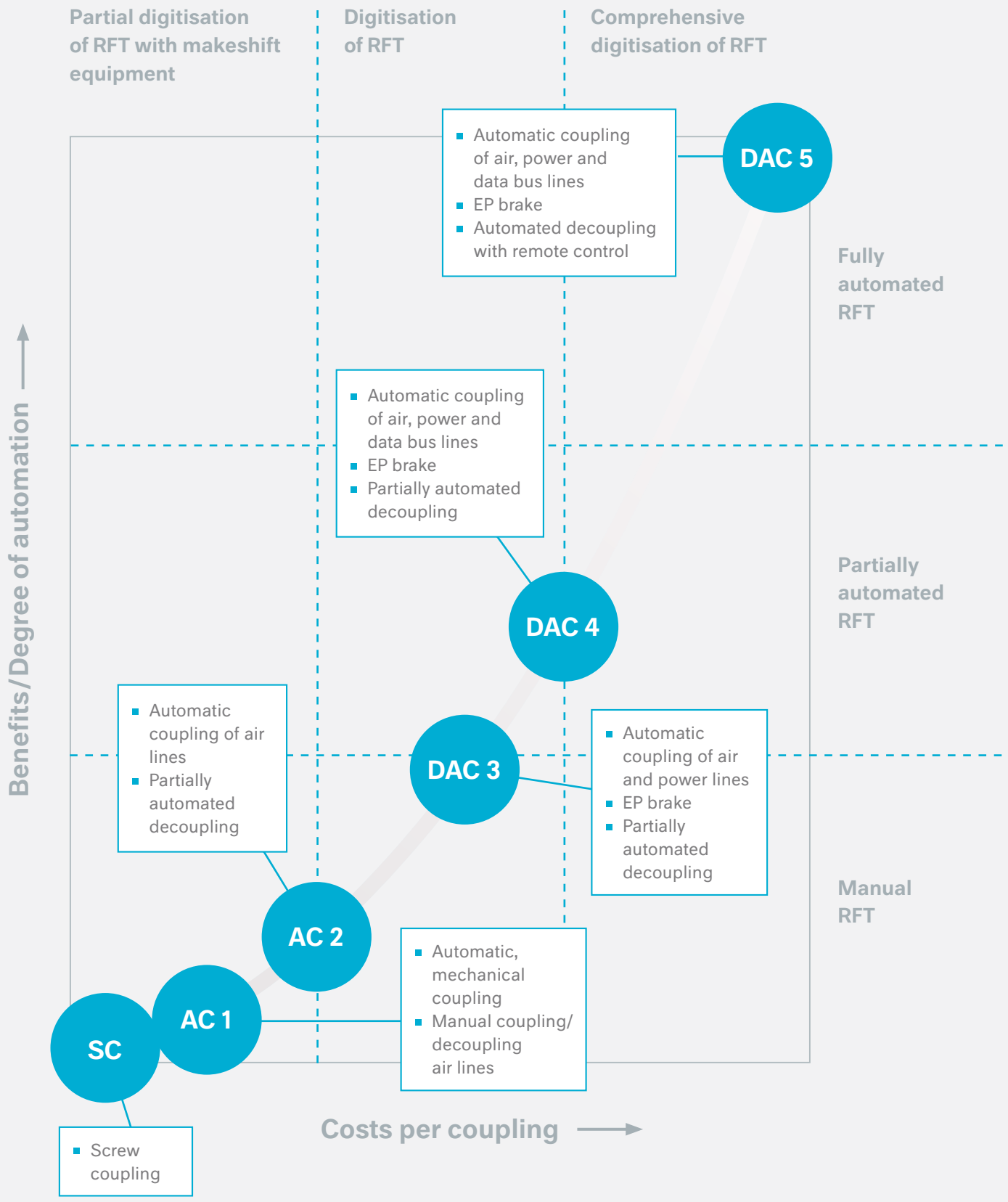
The first automatic couplings with integrated air line connections are currently being used in demonstrator trains operated by companies participating in TIS. These Type 2 couplings are a good entry-level solution and already generate added value for operators. However, the introduction of the fully digitised automatic coupling must remain the ultimate goal. Only a DAC Type 5 will enable companies to take full advantage of the potential offered by digitisation and automation. When companies take the first step of investing in an AC Type 2, manufacturers and users should ensure these couplings will be compatible with future upgrades.

A sectoral challenge in need of political support

The process of introducing a digital automatic coupling seamlessly across a continent is both complex and financially challenging. Without broad political support at the national and European levels, it will be difficult to accomplish. The high procurement and conversion costs make financial support an absolute necessity.

Automation potential of various types of digital automatic coupling in rail freight transportation (RFT)

Source: TIS



The introduction of a DAC offers benefits for many stakeholders in the rail freight transportation system – for rail transport and infrastructure companies as well as shippers and wagon owners. However, most of the economic added value will be felt by the rail transportation companies. They stand to increase their productivity significantly by automating operations. By contrast, the burden of investment lies exclusively with the wagon owners. For the migration of a DAC to be successful, it will therefore be crucial to create a financial incentive for wagon owners.

The investment in upgrading freight wagons with a DAC must be made economically viable for them. Political leaders and the sector must create a pragmatic and fair model for sharing the costs of these upgrades.

Eight steps on the road to the digital automatic coupling

In 2018, to promote the introduction of a digital automatic coupling, TIS agreed on eight thematic areas that would provide a strategy for further action.

In Step 1, the companies involved in TIS produced a position paper which was published in October 2018. In it, they argue for the swiftest possible introduction of a digital automatic coupling in the European rail freight sector.[23]

Initial results are also available for Step 2 – "Basic principles of the DAC". The companies involved in TIS have discussed the basic requirements and considerations for the automatic coupling and already agreed many of the necessary standards.

TIS topics relating to digital automatic couplings

Source: TIS

1. Position paper for the DAC
2. Basic principles of the DAC
3. Functional requirements of the DAC
4. Dialogue forum with manufacturers
5. Energy and data management
6. Benefit transfer model
7. Migration concept / Milestone plan
8. Funding/Financing concept for the DAC

TIS is currently working to agree the functional requirements of the DAC – Step 3. Subsequently, the types of coupling currently available on the market will be evaluated to assess their fulfilment of these functional requirements. In the next step, TIS will initiate a forum for dialogue with manufacturers and potential manufacturers of automatic couplings. The aims of this forum will be to discuss with manufacturers the DAC functions required by the wagon owners and railway transport companies involved in TIS and agree the next steps of the process.

Parallel to this, TIS is already developing a design concept for future energy and data management in freight trains. The first results from Step 5 of the roadmap will be presented in the following chapter (cf. Chapter 1.3).

Interdisciplinary development of a realistic and fair cost sharing concept

TIS will also address the next steps in the very near future. The interdisciplinary working groups comprising wagon owners, railway companies, shippers, and supply industries, will enable TIS to develop and propose a realistic and fair cost sharing concept or benefit transfer model for the sector. Further concepts for migration and operating concepts, as well as financing and funding opportunities, are also on the agenda.

SBB Cargo AG and Deutsche Bahn AG have each initiated their own projects for the automatic coupling in the rail freight sector. These address various questions around the introduction of these systems. In 2019, SBB Cargo AG has already dispatched a small fleet of container wagons with the Type 2^{24} automatic coupling to participate in real operations and gather practical experience.

3.3 Energy and data management

Conventional freight trains have neither electrical power nor data communication capabilities. However, the development of high-performance batteries over recent years means that telematics devices can already be used in freight wagons. These could be supplemented by further autonomous power generating options, such as photovoltaic or wheelset generators. Data transfer between the telematics devices and servers is currently via mobile communications networks.

Reliable and secure data transmission – essential for the digitisation of RFT

Power consumption on board of innovative freight wagons will increase as more and more operations are automated. Future applications, such as a digital train integrity test, will also require reliable and secure data transmission within the train. This is beyond the capabilities of today's energy and data management systems using batteries and mobile communications networks. Technologies that work for current telematics devices will no longer be sufficient in the future.

New technologies must be upgradable to meet the requirements of tomorrow and beyond

TIS is therefore investigating possible designs for future-oriented energy and data management in freight trains. We must first answer two important questions: What electrical consumers will be used in the freight trains of the future? And how much power will they need? This information will enable TIS to derive the power line voltage required based on a future train length.

In addition, TIS is currently determining which data should be communicated between the freight wagons and the locomotive in future and the resulting requirements for data transmission.

Based on these results, TIS will derive a suitable technology for wired data transmission, such as CAN, Ethernet, power line etc. The latest studies indicate that a 110V power line and a CAN-bus for data communication will be recommended.

TIS also believes it is important that the new energy and data management concept should be expandable to cope with requirements that are as yet unknown. Moreover, the system must be robust, reliable and cost-effective – otherwise migration to the new design will be unfeasible if only for economic reasons.

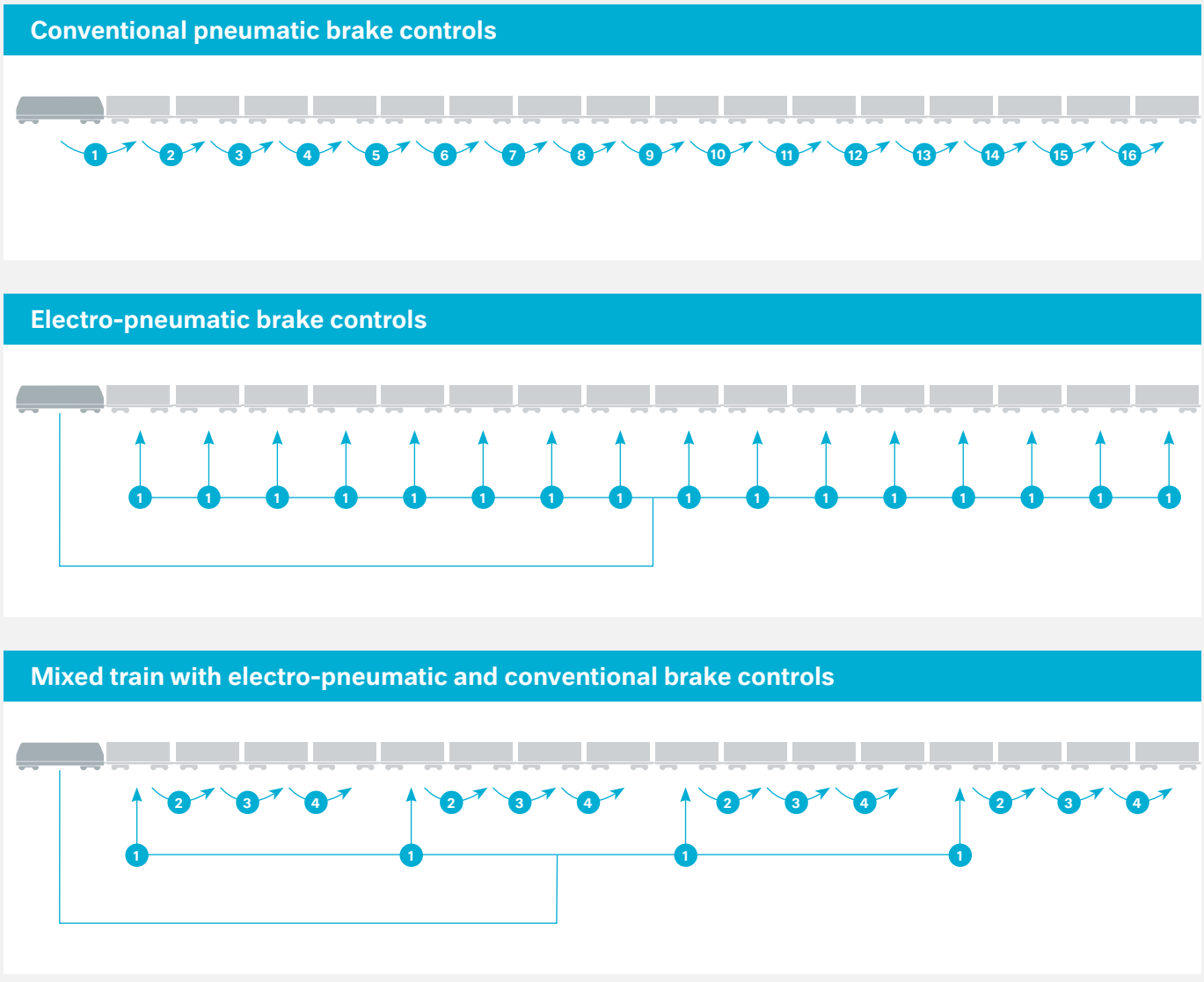
TIS is basing its work heavily on best practice examples from the automotive and aerospace industries where data bus systems have been established for many years and are produced in large quantities.

3.4 Electro-pneumatic brake

Electro-pneumatic brakes (EP brakes) have been used in rail passenger transport for many years. However, they are also used in rail freight transport on other continents, e.g. in North America, Australia, or South Africa.[25] Their key feature is that they simultaneously brake all the vehicles in the train regardless of its length. This is not possible with a standard air brake system due to its transmission speed which is limited to about 280 m/s.

Conventional versus electro-pneumatic brake controls

Source: TIS



A convincing technical solution in many ways

Compared to a standard air brake system, EP brake technology generates lower longitudinal compressive forces in the train. This is especially interesting for the operation of long trains. A further advantage is the more homogeneous distribution of the load on the braking system and wheelsets. In addition, an EP brake offers more controlled braking than conventional brakes. This makes it easier to achieve a target speed accurately.

These advantages are counterbalanced by the high operating costs of EP brakes. In addition to a UIC-compliant 110 V power line, they usually also require a second air line in the train – the main air reservoir pipe. Nevertheless, TIS considers the EP brake to be an important technology that should be considered in the development of intelligent freight trains. The challenge is therefore to find ways to make a cost-effective EP brake that is suitable for the rail freight transport sector – if necessary, with limited functionalities.

Putting the brake on costs with the EP brake "light"

In order to benefit from the advantages of an EP brake when braking – while aiming for a cost-effective and economical solution – the TIS member companies DB Cargo AG and VTG AG have tested the concept of an EP brake "light".[26] This dispenses with the second main air reservoir pipe. After braking, the air reservoir is filled only via the main air pipe – just like a standard air brake. The brake release times are therefore longer than they would be if a main air reservoir pipe were available. The brake valves are controlled electrically via a 110 V power line.

3.5 Outlook: The intelligent freight train

The Roadmap to the Intelligent Freight Wagon is complete. Over recent months, TIS and its member companies have created a structure for the process and advanced their projects in all four of the defined fields. The first steps have been taken. But the various stakeholders in the sector face a long journey.

All agree that rapid progress is needed. Operations must be automated as a matter of urgency if the sector is to improve the efficiency of rail freight transportation – and find an answer to the significant shortage of skilled workers.

The intelligent freight train requires a digital automatic coupling

As a matter of principle – and on this all the companies involved in TIS agree – automation of the rail freight sector cannot be implemented satisfactorily without the introduction of a digital automatic coupling. This is the central challenge facing the sector. Without agreement on a Europe-wide, standardised coupling head for an automatic coupling, there can be no successful migration.

Standardisation of energy and data management

Future energy and data management systems for European freight trains must also be built according to a uniform concept. Otherwise, automation will never emerge from its infancy. Consequently, the intelligent freight train of the future should only use wagons which are coupled using the same still-to-be-defined technical standards, supply power for digital applications, transmit data in the same format, and process it using the same technology.

Sector and political authorities must pull in the same direction

It is already clear that the innovations yet to be developed for the intelligent freight train are much more complex, and require much greater coordination within the sector, than those for the innovative freight wagon. Considerable efforts are still needed to persuade important national and international stakeholders. In addition, the complexity and cost of the task puts it beyond the financial means of the sector alone. It urgently needs the support of political leaders and organisations.

A major challenge – but the first steps have been taken

The various development and testing projects already in progress show that the sector has taken up the challenge and is working hard to develop the intelligent freight train. This is demonstrated, for example, by the pilot testing of various applications for an automatic brake test. Progress is also being made in projects for the introduction of condition-based maintenance for freight wagons. In the digitisation of the technical wagon inspection, the sector still has a great deal of work to do before a roll out of the technology is possible. Here, the infrastructure companies, railway com-

panies, and wagon owners need to communicate much more intensively in order to find a solution that will benefit the entire sector. One problem they need to answer is whether the diagnostic equipment of the future should be “way-side” or “on-board”.
A TIS concept for a future energy and data management system is currently under development. Initially, it may well be advisable to maintain a two-pronged approach here. A power line will continue to be used alongside rechargeable batteries and a data line alongside wireless transmission methods. All stakeholders should keep in mind that the energy and data management concept must be implemented throughout Europe and closely linked to the introduction of a digital automatic coupling.

Working together for the success of the intelligent freight wagon

Individual companies are highly unlikely to enjoy any success in dealing with these complex issues alone – unless they are largely engaged in closed-system rail transports which require little interoperability of freight wagons. In this respect, it is essential that companies beyond those involved in TIS – such as shippers, wagon owners, rail transport and infrastructure companies, as well as railway and supply industries – contribute to the innovation process in order to put the intelligent freight train on the railroad to success.

A strong rail freight sector needs a more competitive structure. This includes both an efficient infrastructure as well as financial and political support for research and the roll out of technology.

4.1 Making rail transportation more competitive

Low CO_2 emissions, an excellent energy balance, virtually no emissions of particulate matter: no other mode of transport is as safe and environmentally-friendly as rail freight. It offers answers to the transport and climate policy challenges of the future. However, rail freight is under considerable economic pressure and the reasons for this lie both within and outside the industry.

An integrated approach to growth in the rail sector

The sector and the political sphere must therefore address many other improvements that affect the entire rail freight transportation system beyond the innovative freight wagon and the intelligent freight train. The competitiveness of rail freight can only be increased significantly if the necessary innovations and agendas are introduced in all three fields.

In addition to promoting and implementing innovations, there is also an urgent need to improve the general conditions for rail freight as well as between modes of transport. These include:

- Efficient and reliable RFT infrastructure
- Integration of RFT into the future integrated German timetable ("Deutschland-Takt") and coordination with international timetables
- Elimination of administrative barriers in RFT, e.g. knowledge of the national language
- Digitisation of railway infrastructure incl. the introduction of ETCS
- Competitive track and facility pricing
- Limitation of charges and taxes
- Standardised data exchange between all participants in RFT
- Greater emphasis on multimodality
- Intensification of training and professional development in the RFT sector

The first steps have already been taken. In Germany, the sector and BMVI have jointly developed the Rail Freight Master Plan at round table discussions.[27] The transport policies agreed there have the backing of the companies involved in TIS – these are actively involved in the implementation and refinement of the master plan. As the sector's practice group, TIS will focus on the development, testing, and introduction of innovative freight wagons and intelligent freight trains in the railway operations.

However, TIS will continue to focus on the technical, operational, and economic challenges of rail freight transport.

4.2 Research and funding requirements

The companies involved in TIS have a clear view of the requirements of the future. Rail freight transportation must become more competitive – innovative freight wagons and intelligent freight trains are the way forward. However, TIS also takes a realistic view of current conditions. The development, testing, certification, and migration of these innovations will require a high level of commitment from the entire sector – both in terms of personnel and financial resources. Moreover, many innovations, such as the digital automatic coupling or energy and data management systems, can only be introduced as part of a pan-European strategy.

Innovation in the RFT sector needs targeted support

Without political and financial support, it cannot and will not achieve its goal: a significant increase in rail freight's market share. Taking these factors into account, the rail freight sector requires an intelligent mix of research and funding programmes to promote and accelerate the rate of innovation:

Practically-oriented research and development

Here, the areas requiring special attention from the rail freight sector include vehicle technology, digitisation, and automation – with all the innovations listed in the previous chapters.

Long-term operational testing

Mobile and digital test platforms, e.g. demonstrator trains, are needed to test the functionality of innovations and their impact on economic viability, noise, and energy. Applications for the digitisation and automation of operational procedures also require test runs.

Lighthouse projects

Examples of best practice send an important message to the sector. Positive practical experiences in real transports provide persuasive arguments and can make a key contribution to the advancement of important areas of innovation, such as the digital automatic coupling.

Migration of innovations

As a rule, the migration of innovations in rail freight transport is associated with a high level of initial investment. For companies operating in the sector, these costs are often not economically feasible. Additional costs incurred by the use of innovative components require funding to cushion the financial impact – with both existing and new wagons.

TIS will continue to work hard in order to pave the way for innovations in the rail freight sector.

The intelligent freight train: A milestone on the road to digital, automated rail freight transportation for the 21st century.

5.0 Summary
From the innovative freight wagon to the intelligent freight train

Over recent years, the Technical Innovation Circle for Rail Freight Transport (TIS) has made significant progress in advancing the development and implementation of basic innovations in the area of the freight wagon. There is now an industry-wide consensus that innovations for rail freight wagons are urgently needed and should be based on the 5L-criteria – low-noise, lightweight, long-running, logistics-enabled, life-cycle-cost-oriented. The intensification of innovation activities in the sector is now immediately obvious to any observer.

The intelligent freight train: transferring the innovation philosophy to the entire train

However, generating tangible improvements in the competitiveness of rail freight transportation will require more than the promotion of isolated innovations in "freight wagon" design. Digitisation and automation strategies for the entire train must be devised in order to unlock its full potential. The project is now ready to take the next step: combining these innovative freight wagons into intelligent freight trains. In the past few months, TIS has structured and kick-started the necessary processes. The Roadmap to the Intelligent Freight Train is complete. The digital automatic coupling (DAC) with integrated power and data bus line is the heart of the intelligent freight train. It creates the necessary conditions for the comprehensive digitisation and automation of rail freight transport and will make railway operations significantly more efficient. The position of TIS is therefore clear: the Europe-wide introduction of a DAC must be made a top priority.

Innovation needs funding

The innovations being developed for the intelligent freight train require close coordination within the sector and are associated with high investment costs. Both are particularly relevant to the DAC since the migration to this standard will have to be a Europe-wide process. Considerable political and financial support will be required to put the intelligent freight train on the tracks. This also applies to the roll out of basic innovations which often involves high levels of initial investment.

Integrated approach for a competitive rail freight sector

Innovative freight wagons and the intelligent freight train are milestones on the way to a competitive rail freight transport sector. However, further improvements are needed to ensure that environmentally-friendly rail freight can compete with other modes of transport and expand its share of the market. The field ranges from the development of infrastructure to the introduction of ETCS signalling technology, and the creation of an even playing field between road and rail. The sector and political authorities throughout Europe must pull in the same direction. The measures agreed in the Rail Freight Master Plan will guide the sector over the coming months and years. Political authorities must now have the will to implement these measures promptly and provide the necessary financial resources. The companies involved in TIS will support them on this journey.

Comments

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[10] The current interface release V1.2 is available at http://www.innovative-freight-wagon.de/wp-content/uploads/ITSS_Standard_Specification_Interface1_V1-2_final.pdf.

[11] Cf. http://www.innovative-freight-wagon.de/wp-content/uploads/TIS-requirements-innovative-bogies-EN.pdf

[12] TVP2007 manufactured by Tatravagonka, RC25NT manufactured by Eisenbahnlaufwerke Halle, DRRS25L manufactured by WBN Waggonbau Niesky, GB25RS manufactured by Greenbrier.

[13] Both companies are members of the Technical Innovation Circle for Rail Freight Transport

[14] DRRS25L manufactured by WBN Waggonbau Niesky, RC25NT manufactured by Eisenbahnlaufwerke Halle

[15] Cf. https://uic.org/european-standard-freight-wagon-axle-for-25t-esfa-25-390
[16] Wheelsets manufactured by Bochumer Verein, Bonatrans, GuteHoffnungshütte Radsatz GmbH and Lucchini
[17] Wheelsets manufactured bx Bonatrans, GuteHoffnungshütte Radsatz GmbH and Lucchini
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[24] For this, SBB Cargo AG installed Voith CargoFlex Type Scharfenberg couplings which also provide automatic coupling of the air line.
[25] Cf. https://en.wikipedia.org/wiki/Electronically_controlled_pneumatic_brakes
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List of abbreviations

5L	Low-noise, lightweight, long-running, logistics-enabled, life-cycle-cost-oriented
AC	Automatic coupling (central buffer coupling)
FOEN	Swiss Federal Office for the Environment
FOT	Swiss Federal Office of Transport
DAC	Digital automatic coupling
BMVI	German Federal Ministry of Transport and Digital Infrastructure
ERP	Enterprise Resource Planning
ESFA	European Standard Freight Axle
IFW	Innovative freight wagon
ITSS	Industry platform for telematics and sensors
LCC	Life-cycle costs
TIS	Technical Innovation Circle for Rail Freight Transport
TSI	Technical Specifications for Interoperability
VPI	Association of Freight Wagon Owners in Germany
NDT	Non-destructive testing

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