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Report
Final Report by the Bogies Task Force of the Technical Innovation Circle for Rail Freight Transport (TIS)

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1. Summary

Bogies are a key cost factor in freight transport, not only because they have to be purchased and maintained, but also in terms of reliability and operating procedures. With total process optimisation in mind, the Bogies Task Force was requested by TIS, the Technical Innovation Circle for Rail Freight Transport, to look into the technical requirements for bogies, and these have been set out in the Final Report below.

The study focused on twin-axle bogies for freight wagons. The assumption throughout was a maximum load per axle of 25 tonnes. As requirements are extremely diverse and annual mileage, in particular, will continue to vary widely, a modular concept was devised to enable as many carry-over parts as possible while still providing flexibility when needed.

In using this modular approach to draw up concrete directives, the authors differentiated between two basic options, A and B. Option A allows for basic innovations to be implemented in the existing fleet and in retrofits, while Option B is designed for new vehicle generations and puts all five “L” criteria to their full innovative use.

The various modules and their combinations are to be analysed in the light of the target impacts of the 5L approach and assessed in terms of the beneficial effects they can generate for the main players in rail freight transport.

The requirements identified are intended, firstly, to assist the manufacturers of freight car bogies by offering a working platform for further implementation and, secondly, to facilitate the definition of a requirement profile for ordering a specific vehicle. The findings also provide a basis for ongoing discussion with the TIS cross-disciplinary group on an LCC/earnings-adjusted model.

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2. Introduction

In the process of writing the “White Paper Innovative Rail Freight Wagon 2030”, which met with a positive response when presented at InnoTrans 2012, TIS established the structure illustrated in Figure 1. As a consequence, TIS currently functions on two levels: the innovation platform, with the functions of identifying priorities for basic innovations, managing the process, and facilitating the vertical and horizontal integration of TIS in the political, industrial and academic landscape, and on the second level the task forces, where theme-specific exchange takes place and the basic work is carried out around the wagon, the sub-systems and the associated components. Unlike previous initiatives and working groups that have addressed the issue of rail freight transport, the decision-makers in TIS are the wagon keepers, i.e. those who invest in the wagons as a key group of players in rail freight transport.

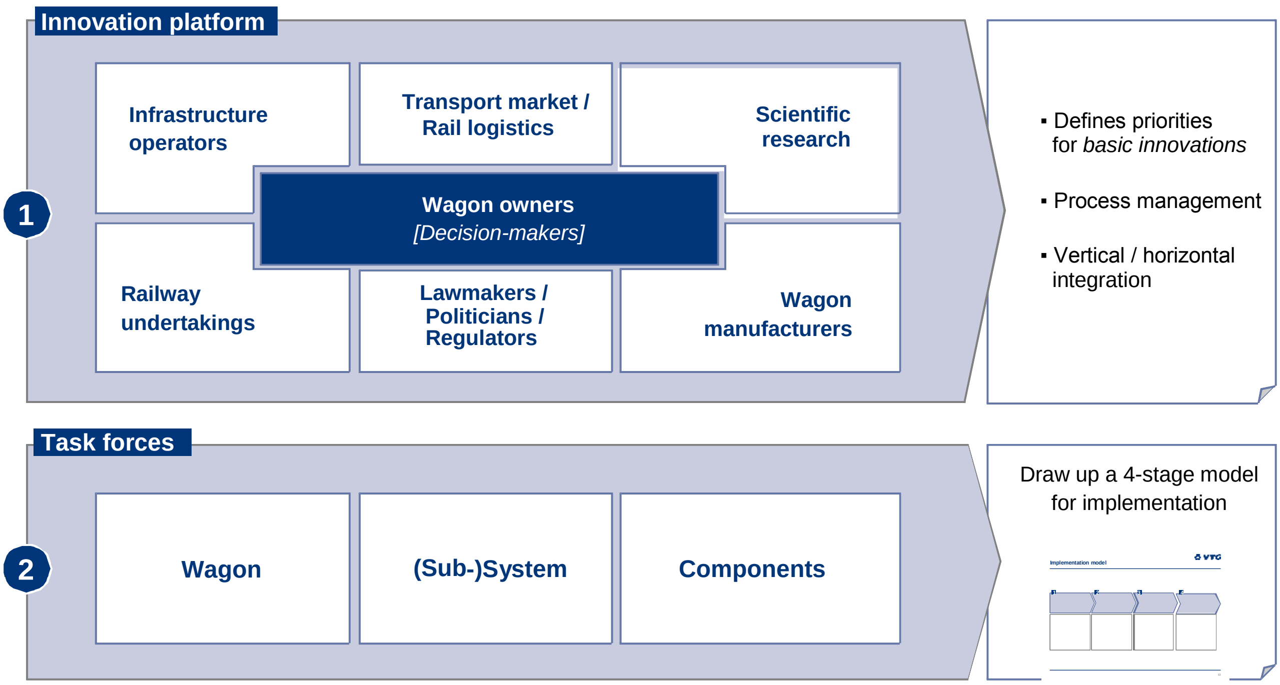

Figure 1: TIS Structure, [1]

The structure of the TIS task forces is visualised in

Figure 2, taking the Bogie Task Force as an example. This task force brings together companies which need or wish to address what the rail bogie of the future might deliver. They include infrastructure operators, who have an interest in reducing the wear on tracks, railway undertakings, who are seeking reliable, stable operation, wagon keepers, with a focus on the costs of investment and operation, and the wagon-building industry, who contribute their engineering and licensing experience. The objectives for the project are jointly determined: definition of the technical and operating requirements for the bogie of the future, formulation of the LCC, transfer and migration models, licensing issues such as costs, service life and risks, and a description of the financing options and potential to acquire third-party funding.

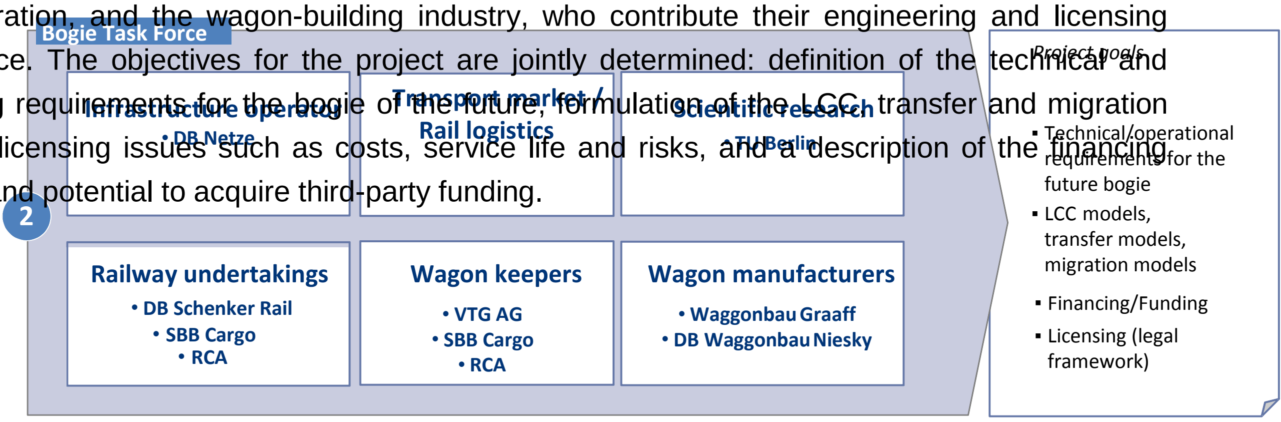

Figure 2: Structure of the Bogie Task Force

The table below lists the people most heavily involved in compiling this report.

Table 1: Authors of the Final Report

Name	Company/Institution	Remarks
Andreas Helm	DB Waggonbau Niesky	
Detlef Kappler	DB Waggonbau Niesky	
Hinrich Hempel	DB Schenker Rail	
Bastian Bisswanger	TU Berlin, ILS, FG SFZ[1]	temporarily
Patrick Eschweiler	TU Berlin, ILS, FG SFZ	temporarily
Markus Hecht	TU Berlin, ILS, FG SFZ	
Philipp Krause	TU Berlin, ILS, FG SFZ	temporarily
Klaus Schulner	Rail Cargo Austria	temporarily
Jens-Erik Galdiks	SBB Cargo	
Jürgen Hüllen	VTG AG	
Nico Helbig	Waggonbau Graaff	

[1] TU Berlin, Institute of Land and Sea Transport Systems, Rail Vehicles Department

3. Implementation model

The general approach underlying the way TIS works is visualised in Figure 3. The four core themes are demarcated as blocks, and by and large they are dealt with in sequence. The following Report devotes a chapter to each core theme.

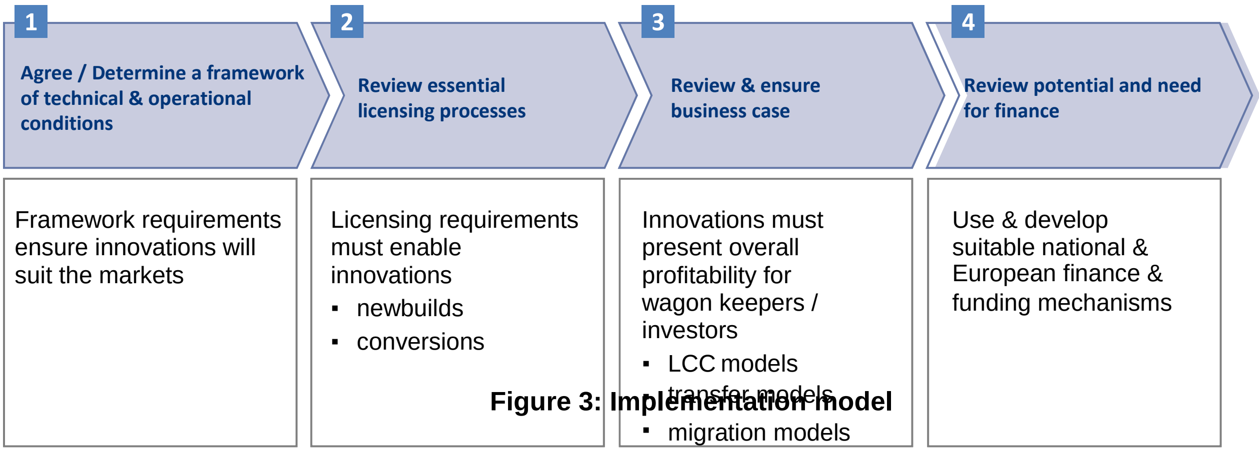

Figure 3: Implementation model

Before the relevant technical and operational requirements for the bogie of the future can be established, the interfaces, modules and components for the bogie must first of all be clearly defined. The interfaces derive from structural factors such as the transition from the body of the car to the bogie frame, from the bogie frame via the primary suspension to the wheelsets, from the wheelsets to the track, and from the wheelsets to the brake system module.

4. Technical and operational requirements

There is often a conflict of interest between technical and operational requirements. The solutions with the greatest potential in terms of noise reduction and lightweight design, for example, do not comply sufficiently with all railway standards, and in some cases they call for a new system, because future noise abatement targets in particular cannot be achieved by continuing along the same path of development. That explains why the technical requirements for basic innovations had to be broken down throughout into two options (A and B).

Option A:

- Basic innovations that can be incorporated into the existing fleet and new wagons based on the same designs
- Improvement to at least one of the five “L” factors

Option B:

- New bogie designs for a new generation of rolling stock, with improvements to more than one of the five “L” factors
- Must be compatible with the current operating system (CW identifier)

4.1 Technical requirements for the bogie system as a whole

The bogie system is composed of the modules specified in the sections below. In other words, it consists of a bogie frame, braking equipment, wheelsets, sensor technology and all the other components. The technical service life for the bogie system (excluding parts subject to wear) is set at 40 years.

		Criterion	Technical requirement		Comments
1	**Quality**	**Bogie system as a whole**	**Option A**	**Option B**	
1.1		**Key data**			
1.1.1		No. of axles	2	2	
1.1.2		Gauge	1,435 mm	1,435 mm	
1.1.3		Axle base	1,800 mm	≠ 1,800 mm ?	Check acoustic impacts (see Notes)
		Criterion	**Technical requirement**		**Comments**

	Quality	Bogie system as a whole	Option A	Option B	
1.2		**Axle load**			
1.2.1	R[2]	Admissible axle load	≥ 22.5 t[3]	25 t	
1.3		**Speed**			
1.3.1	R	Permissible running speed	120 km/h	120 km/h	
1.3.2	R	Permissible braking speed in standard version	100 km/h	100 km/h	
1.3.3	R	Permissible braking speed for SS class wagons	120 km/h	120 km/h	
1.3.4	P[4]	Permissible running speed[5]	160 km/h	160 km/h	
1.4		**Weight**			
1.4.1	R	Less weight than reference bogie Y25 1xBGU without end carriage with identical braking equipment (not counting wheelset weight)	x[6]	x	
1.5		**Compatibility / Installation**			
1.5.1	R	Joined to car body	Pivot acc. to UIC 510-1, Annexes 8 and 9	no spec	
1.5.2	R	Lateral support on body	Lateral support acc. to UIC 510-1, Annexes 8 and 9	no spec	
1.5.3	R	Envelope	Envelope acc. to UIC 510-1, Annex 11a	Envelope acc. to UIC 510-1, Annex 11a	
1.5.4	R	Vehicle gauge	Compliant with UIC 505-1	Compliant with UIC 505-1	
1.5.5	R	Compatible with automatic coupling	Envelope acc. to UIC 510-1, Annex 11a	Envelope acc. to UIC 510-1, Annex 11a	
		Criterion	**Technical requirement**		**Comments**
	Quality	**Bogie system as a whole**	**Option A**	**Option B**	

[2] F … Required

[3] 25 t. wheelset load also preferable for Option A depending on the implications for development and design costs.

[4] W … Preference

[5] Speed of 160 km/h depending on the implications for development and design costs.

[6] x … is a key criterion

1.6		**Noise**			
1.6.1	R	Wagon complies with TSI Noise Limits expected by 2016 (reference bogie Y25 1xBGU without end carriage with composite pads)	-2 dB comp. with current limit for new wagons[7]	-4 dB comp. with current limit for new wagons	
1.7		**Running characteristics**			
1.7.1	R	Improved running qualities with positive impact on maintenance[8]	x	x	Demonstrably less wear on wheels, better ride
1.7.2	R	Improved running qualities with positive impact on infrastructure	x	x	Measurement criteria to be defined by infrastructure operators
1.7.3	R	Standard for running characteristics is observed	EN 14363	EN 14363	
1.7.4	R	Minimum curve radius to be taken by the wagon	35 m[9]	75 m	
1.8		**Wear**			
1.8.1	R	Less wear on wheels/ flanges compared with Y25	x	x	Evidence required
1.9		**Certification**			
1.9.1	R	Requisite TSI Wagon component certification (valid from 1 January 2014)	x	x	
1.10		**Repair and maintenance**			
1.10.1	R	Service life for all components	At least 600,000 km, At least 6 years	At least 600,000 km, At least 6 years	
1.10.2	R	Maintenance of all components must be feasible independently of manufacturers	x	x	
1.11		**In-track operations**			
1.11.1	R	Full technical wagon inspection must be feasible under operating conditions (in track)	x	x	
1.12		**Other**			
1.12.1	R	Load indicator (total load, wheel load, load distribution)	x	x	Visible on the wagon without optical aid

4.1.1 Notes

Criterion 1.1.3: Axle base

Discussions were held about altering the axle base compared with the current Y25 bogie axle base of 1,800 mm.

[7] Only to be implemented in new rolling stock, not existing fleet.
[8] Resonance behaviour and its noise impacts taken into account.
[9] Similar envelope to Y25

The underlying idea was that in future the axle base should not be designed around a whole-number multiple of sleeper intervals (currently: 600mm to 1,800 mm), with a few to stimulating less vibration in the body of the car.

Altering the axle base would produce the following advantages

- smoother running (if the axles are placed further apart)
- less body vibration, although no concrete values have been demonstrated
- possibly also less in-track maintenance

This would be offset by the following disadvantages

- bumpier running (if the axles are placed closer together)
- The Y25 envelope and the installation space for the automatic central buffer coupling are no longer observed if the axle base is lengthened. If the envelope is exceeded, this measure cannot be combined with new bogies in existing vehicles or if tried and tested wagon superstructures remain in use.
- If wheelsets are spaced further apart, the bogie frame will be longer, increasing mass.

Criterion 1.7.2: Improved running qualities with positive impact on infrastructure

Detailed studies still need to be carried out on this point. Initial approaches are:
indirect determination of running properties and wear via measurement of traction energy requirement and systematic analysis of wheelset maintenance logs and measurement of track wear.

Criterion 1.7.4: Minimum wagon curve radius

If the minimum wagon radius (i.e. the smallest radius the wagon can negotiate) is increased, the bogie does not need to tilt so far. This permits a different kind of support for the body (similar to passenger railcars, railway engines) and substantially enhances flux. This saves considerable weight in the bogie and the body of the car.
However, these extensive changes means that the new bogie is incompatible with many well established wagon designs, so that cars would have to be redesigned and new approvals would be required.

Criterion 1.11.1: Full technical wagon inspection must be feasible under operating conditions (in track)

Even wagons equipped with the new bogie will have to observe the future rules and be inspected by the technician before the train sets off. That means ensuring that all safety-relevant bogie components can be assessed. Conceptual design needs to factor in not only the traditional direct visual inspection, but also indirect checks using sensor technology, remote indicators, scale instruments, inspection glasses etc.

4.2 Technical requirements for the bogie frame module

The bogie frame module includes all parts serving to guide the wheelset and to absorb and transfer load. This section therefore includes the interfaces to the car body, suspension and damper, brake and sensor system.

		Criterion	Technical requirement		Comments
2	**Quality**	**Bogie frame module**	**Option A**	**Option B**	
2.1		**Design**			
2.1.1	F	Strength criteria observed	EN 13749	EN 13749	
2.1.2	F	Frame without end sills	x	x	needs little space
2.1.3	F	Endcarriage for mounting brakes as an option	x	x	
2.1.4	F	Net weight, including endcarriages, springs, dampers, sliders (but without wheelsets, axle box, brakes)	max. 1,250 kg	max. 1,250 kg	
2.1.5	F	Use of steels that can be heat straightened	x	x	
2.2		**Suspension / Damper**			
2.2.1	F	Full acoustic decoupling from wheelset to bogie	x	x	
2.2.2	F	Improved dampening for long-term reduction in vehicle damage	x	x	
2.3		**Interfaces to brake system**			
2.3.1	F	Option to include directional control valve	x	x	Bores and installation space in place
2.3.2	F	Able to incorporate axle-mounted brake discs	x	x	Bores and installation space in place
2.3.3	F	Able to incorporate unilateral compact brakes	x	x	Bores and installation space in place
2.3.4	F	Able to incorporate uni- and bilateral mechanical brake blocks	x	x	Bores and installation space in place
2.4		**Interfaces to wheelset**			
2.4.1	F	With more space for wheelsets of larger dimensions Wheelsets: axles - Ø 250 mm	x	x	cf. UIC SET 06
2.4.2	F	No unauthorised contact between wheelset and other bogie parts during operation whatever the state of wear	x	x	

		Criterion	Technical requirement		Comments
	Quality	Bogie frame module	Option A	Option B	
2.4.3	F	Overload indicator to fit on axle box	x	x	Gentler contact, no steel on steel
2.5		**Interfaces to sensor technology and power supply**			
2.5.1	F	Ability to incorporate sensor system for automatic brake test	x	x	Bores, space and cable duct in place
2.5.2	F	Ability to incorporate sensor system to record mileage	x	x	Bores, space and cable duct in place
2.5.3	F	Ability to incorporate sensor system to detect hot box/ bearing failure	x	x	Bores, space and cable duct in place
2.5.4	F	Ability to incorporate sensor system to determine axle load	x	x	Bores, space and cable duct in place
2.5.5	F	Ability to incorporate acceleration sensors	x	x	Bores, space and cable duct in place
2.5.6	F	Ability to incorporate independent bogie power supply	x	x	Bores, space and cable duct in place
2.5.7	F	Ability to incorporate a central junction box for all bogie sensor systems	x	x	Bores, space and cable duct in place Accessible from outside (Guide size from CargoCBM: 190 mm x 130 mm x 110 mm)

4.2.1 Notes

Criterion 2.5.7: Ability to incorporate a central junction box for all bogie sensor systems
The size of the junction box cannot yet be determined. However, it was considered helpful to specify dimensions. The example used is the junction box from the CargoCBM R&D project (source: TU Berlin).

4.3 Technical requirements for the brake system module

		Criterion	Technical requirement	Comments

3	Quality	Brake system module	Option A	Option B	
3.1	F	Basic option bogie without endcarriage for bilateral block brakes. Additional option permits incorporation of endcarriage.	X	x	
3.2	F	Must permit use of composite (K) blocks	x	x	
3.3	F	Must permit use of composite (LL) blocks	x		
3.4	F	Permits incorporation of axle-mounted brake discs	x	x	
3.5	F	Permits incorporation of compact block brakes	x	x	e.g. CFCB, BFCB
3.6	F	Permits incorporation of bilateral block brakes (additional)	x	x	
3.7	F	Permits incorporation of unilateral block brakes	x	x	
3.8	W	Permits incorporation of wheel-mounted brake discs		x	
3.9	F	Ability to adjust brake system for hybrid operation	x	x	
3.10	F	Calculation-based brake design for the freight car	x	x	
3.11	F	Service life of axle-mounted brake disc is adapted to service life of wheel disc	x	x	
3.12	W	Axle-mounted brake disc can be exchanged without disassembling wheel disc	x	x	

4.3.1 Notes

Criterion 3.10: Service life of axle-mounted brake disc is adapted to service life of wheel disc

Criterion 3.11: Axle-mounted brake disc can be exchanged without disassembling wheel disc

The purpose of both these criteria is to avoid unnecessary maintenance work. Replacing a worn brake disc should not, for example, mean having to remove a wheel disc.

4.4 Technical requirements for the wheelset module

The wheelset module is made up of the wheelset axle, axle box and bearings along with seals, wheel discs and mountings for wheelset guides. Wheel- or axle-based brake discs will, where appropriate, be components of the brake system module. The technical requirements for the wheelset module have been derived from the work of the TIS Bogie Task Force and the List of Requirements for low-maintenance wheelset axle design (status: 12 February 2013) compiled jointly by Deutsche Bahn, UIC, the Joint Sector Group (JSG) and VPI (Vereinigung der Privatgüterwagen-Interessenten). [2]

		Criterion	Technical requirement		Comments
4	**Quality**	**Wheelset module**	**Option A**	**Option B**	
4.1	**F**	**The latest EN standards must be observed including EURAXLES findings**	**x**	**x**	
4.2	**F**	**Strength of all components**	**Axle load ≥ 22.5 t**	**Axle load 25 t**	
4.3		**Wheelset bearings**			
4.3.1	F	Mounting dimensions for wheelset as for Y25	Seat as in UIC Leaflet 510-1, Section 4 and Annex 2	Not essential	
4.3.2	F	Dimensions of bearings	130 x 240 mm		see VPI/DB draft, [2]
			(130+x) x 240 mm		
	F			150 x 250 mm	
4.3.3	F	Diameter of sealing ring	160 mm; optimised sealing system preferable		
	F			Modified casing; optimised design	

		Criterion	Technical requirement		Comments
	Quality	Wheelset module	Option A	Option B	
4.3.4		Bearing system	Split cylindrical		As cartridges pose

			roller bearings (if necessary caulked or mounted in cartridge)		disadvantages for maintenance, split cylindrical roller bearings are preferable
4.3.5		Long shaft journal	191 mm		established
			217 mm		established
4.3.6	F	Centre-to-centre spacing on the axle	2000 mm	Check inner bearings	
4.3.7	F	No treatment for shaft journal (e.g. molybdenum coating)	x	x	uneconomic
4.4		**Locks**			
4.4.1	W	Axle bolts	Replace 3 x M20 by optimised option: 4 x M16 longer thread reach longer grip		Needs further examination
4.4.2	F	No locknuts	x	x	Less efficient, harder to perform NDT on shaft end
4.5	**F**	**Wheelset axle material**	**EA1N**		**established, widely used material**
4.6		**Wheel seating**			
4.6.1	F	Standardised diameter taking account of dimension specs	x	x	Compatibility of wheels from different manufacturers only ensured by standardised interface Simpler approval
4.6.2	F	Same position as for 25 t wheelset axle (BA 302): Distance reference plane – outer edge: 58 + 1 mm Distance reference plane – inner edge: 238 - 1mm	x	x	Compatibility of wheels from different manufacturers only ensured by standardised interface Simpler approval
4.6.3		Geometry must respect shorter length of seat in maintenance	x	x	
		Criterion	**Technical requirement**		**Comments**
	Quality	**Wheelset module**	**Option A**	**Option B**	
4.7		**Longitudinal bores**			
4.7.1		With 30 mm longitudinal boring	x	x	Easier to check Weight advantage Open: general NSA

					request for short test intervals => unlikely as axle has better dimensions Costs of longitudinal boring Corrosion in borings with long downtimes Availability of test equipment in European maintenance
4.7.2		Without longitudinal boring	x	x	Ability to check outer face or shaft end
4.8		**Axle geometry**			
4.8.1		Diameter taking account of dimension specs – cylindrical version	x	x	Simpler geometric contours Open: Spatial requirements for running and braking components
4.8.2		Diameter taking account of dimension specs – conical version	x	x	Can be fitted in existing gear Poss. need to modify mechanised ultrasonic test equipment Possible weight reduction Handling/ Transport of wheelsets
4.9		**Maintenance reserves**			
4.9.1	F	Seat diameter: 3 mm	x	x	Ensure maintenance procedures only 3 mm to define axle runtime (3 wheels at 1 mm less diameter per wheel swap)
4.9.2	F	Journal diameter: 3 mm	x	x	Ensure maintenance procedures
		Criterion	**Technical requirement**		**Comments**
	Quality	**Wheelset module**	**Option A**	**Option B**	
4.9.3	F	Collar diameter (outside seat of sealing ring): 2 mm	x	x	Ensure maintenance procedures
4.9.4	F	Journal diameter	x	x	Not applied to avoid different diameters within bearings
4.9.5	F	Maintenance acc. to IL, IS0, IS1,	x	x	

		IS2 or similar must be feasible with existing refurbishing equipment and processes			
4.10		**Anti-corrosion**			
4.10.1		With coating	x	x	Avoid as time-consuming (application, NDT) Open: Thickness of coating (thin or thick)
4.10.2		Without coating	x	x	Open: Bigger diameter than for coated wheelset axles
4.10.3		Service life of coating: versus service life of wheels	x	x	Meets ECCM criteria (MT – when fitting new discs)
4.11	**F**	**Suitable for use with hotbox detection or sensor system**	**x**	**x**	
4.12	**F**	**Optimum stock utilisation for parts subject to wear**	**Limit for TSI wheelsets 840 mm**	**Limit for TSI wheelsets ≤ 830 mm**	
4.13	**W**	**Service life of wheelset (excl. bearings)**	**At least 600,000 km At least 12 years**	**At least 600,000 km At least 12 years**	**with reprofiling**
4.14	**W**	**Additional wheelset weight compared with BA 004**		**Max. 50 kg**	**Exception: disc brake**

4.5 Technical requirements for the sensor system module

The sensor system module includes the IT from sensors and data transmission to relevant players.

		Criterion	Technical requirement		Comments
5	**Quality**	**Sensor technology**	**Option A**	**Option B**	
5.1		**IT installations as defined by Telematics Task Force**[10]			
5.1.1	F	Automatic brake test	x	x	
5.1.2	F	Recording mileage	x	x	
5.1.3	F	Detecting hotboxes	x	x	
5.1.4	F	Determining axle load	x	x	
5.1.5	F	Acceleration	x	x	Detect shunting impact, derailment, comfort …
5.1.6	F	Determining state of disc brake wear	x	x	

4.5.1 Notes

The sensor system requirements are designed to ensure that for every task of interest there is a well-functioning technical solution that has been approved for rail use and that the space and mountings are available. Whether every bogie needs to have the sensor system fitted is for the wagon keeper to decide. You may like to consult the detailed comments in the list of requirements compiled by the TIS Task Force on Telematics and Sensor Systems.

Criterion 5.3.3: Data transmission based on sector-specific transmission standard
There is currently no standard for the transmission of sensor data. The Bogie Task Force recommends describing the requirements soon, as otherwise it will not be possible to define a requirement.

[10] Required information on wagon

5. Approval processes required for a TSI bogie – Options A and B

Table 2: Certification for Bogie Option A in line with TSI WAG 08/57-ST17 Version EN03 of 27 June 2012

Item	Bogie-specific	Wagon-specific	Measure	TSI WAG	Applicable standards	Time required (estimate)	Risk
1	**X**		Bogie certification	§6.1.2 (Conformity assessment procedures)	Modules CB+CD	6 weeks	Incurred within respective tests
2	**X**		Static and fatigue tests	§4.2.3.6.1 (Structural design of bogie frame)	EN13749	16 weeks	Cracks in bogie frame. Design needs modifying. Operational tests must be repeated. → More time and greater cost
3		**X**	Assessment of running behaviour and stationary tests (Assumption: test vehicles are available)	§4.2.3.5 (Running safety) §4.2.3.5.1 (Safety against derailment running on twisted track) §4.2.3.5.2 (Running dynamic behaviour) §4.2.3.6 (Running gear)	EN14363 prEN15839	12 weeks	Running behaviour does not meet the requirements set out in the standards. Design needs modifying. Operational tests must be repeated. → More time and greater cost
4	**X**		Operational tests (on track)		EN13479	52 weeks	Damage or greater wear. Design needs modifying. Operational tests must be repeated. → More time and greater cost
5		**X**	Use of bogie in freight wagon certifications		PrEN16235	-	Comment, for exemption from test drives observe conditions in PrEN16235

Item	Bogie-specific	Wagon-specific	Measure	TSI WAG	Applicable standards	Time required (estimate)	Risk
			Modules				
6	X		Wheelset (Interoperability component subject to TSI)	§4.2.3.6.2 (Characteristics of wheelsets)	EN13260	-	No risk, wheelset is approved and meets the requirements of TSI WAG
7	X		Wheel disc/Monobloc Interoperability component subject to TSI)	§4.2.3.6.3 (Characteristics of wheels)	EN13979-1	-	No risk, wheel is approved and meets the requirements of TSI WAG
8	X		Wheelset axle (Interoperability component subject to TSI)	§4.2.3.6.4 (Characteristics of axles)	EN13103	-	No risk, axle is approved and meets the requirements of TSI WAG
9	X		Springs		EN13913	not clear[11]	
10	X		Damper		EN13802	not clear[7]	
11	X		Bearings		EN12080	not clear[7]	
12	X		Grease		EN12080	not clear[7]	
13	X		Housing	§4.2.3.6.5 (Axle boxes / bearings)	EN12082 + EN13749	not clear[7]	
14	X		Brake	§4.2.4 (Brake)		-	No risk, brake is approved and meets the requirements of TSI WAG
			Noise				
15		X	Nose measurement: Vehicles are available for testing)	TSI Noise		2 weeks	Bogie fails to meet desirable noise level.

Time required from full submission of documents and provision of test vehicles
(without operational testing under Item 4) **36 weeks**

[11] Data to be supplied by the manufacturer

6. Literature

[1] R. König and M. Hecht, White Paper Innovative Rail Freight Wagon 2030, Dresden, 2012.

[2] DB, UIC, JSG, VPI, "Anforderungskatalog an eine neue instandhaltungsarme Radsatzwellenkonstruktion," 2013.

[3] J. Hüllen, "Perspektiven des Schienengüterverkehrs aus Sicht eines Güterwagenhalters /-vermieters," *ZEV Rail,* pp. 50-54, 2013.

[4] M. Hecht, "Maßnahmen für ein gesundes wirtschaftliches Wachstum des Schienengüterverkehrs," Vienna, 2012.

[5] J. Hüllen, "Definition von Innovationsvarianten im Rahmen von TIS," slide, TIS meeting in Hamburg, status 13 March 2013.

[6] J. Hüllen, "Matrix für LCC-/Ertragswertmodelle," slide, TIS meeting in Hamburg, status 13 March 2013.

ANNEX A

Economic impact of the new standard bogie compared with the Y25 as the basis for an LCC model

a) One-off effects from implementing the design (regardless of material)

1. Development costs

a. Design
b. Approvals
c. Testing (commissioning)

2. Reorganising maintenance

d. Initial stocking
e. Purchase of special tools
f. Training staff (commissioning)

b) One-off effects per bogie

1. Purchase

2. Decommissioning: Disposal/Recovery

- Disassembly
- Sale
- Scrapping

c) Recurrent effects – Downtime

1. Recurrent wagon costs: Maintenance (keeper)

a. Provisioning
   - spare parts
   - consumables
b. Preventive maintenance (scheduled maintenance, condition-based maintenance)
c. Corrective maintenance (unplanned maintenance)
d. Maintenance – depending on failure rate
   - Repair with travel to workshop
   - Mobile maintenance – emergency repair in situ

2. Loss of use including upkeep of reserve

3. Productivity gain from technical measures

a. Greater payload possible because bogie weighs less
b. Greater payload due to higher permissible axle load

d) Recurrent effects – Operational time

1. Operating costs (RU)

a. Laying off wagon >> downtime?
b. Brake test
c. Technician's inspection
d. Any repairs arising

2. Track charges (Network / RU)

a. Basic charges
b. Path/product factor
c. Load component (wear-dependent)
d. Nose-dependent

3. Traction power (Energy / RU)

a. Basic charges for supply of rail power
b. Remuneration for power feedback
c. Discounts

Not factored in

Productivity gains from process enhancements: influences the entire logistics chain, advantages can only derive from improving the total process

- decisive cut in turnaround time (e.g. from 49 to 47 hours)

Methodology for LCC model

Definition and management of framework scenarios:

- reference route: track parameters (percentage of curves and gradients), associated track charge and time zone (defining charges for railway power)
- train formation (n wagons)
- travelling speed and profile (calculations of consumption + possibly feedback)