

FREIGHT RAIL TRANSPORT GOVERNANCE: AN INTERNATIONAL ISSUE

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Abstract

Since the economic deregulation of freight transport operations internationally, it has been necessary to have a workable knowledge and an understanding of the types of freight wagons that can help to be instrumental in the efficient and effective market participation of rail technology in the freight transport market. The article identifies and describes the most commonly used rail freight wagons for commercial purposes internationally. The investigation has indicated that subsequent to the economic deregulation of freight transport, there are nine rail wagon types manufactured and commonly used internationally. They are: (1) covered wagon/van; (2) refrigerated wagon/van; (3) flat wagon; (4) tank wagon; (5) container wagon; (6) open wagon; (7) hopper wagon; (8) side stanchion and centre partition wagon; and (9) motorcar wagon. The study revealed that the following three factors mainly dictate wagon design: (1) characteristics of the freight to be transported; (2) physical railway characteristics; and (3) the type of freight terminals and handling equipment necessary to efficiently and effectively accommodate and support rail freight transport.

Keywords: Break-Bulk Rail Terminals, Bulk Rail Terminals, Intermodal Terminals, Rail Freight Transport, Rail Wagon, Roll-On/Roll-Off Rail Terminals

1. INTRODUCTION

1.1. Research Need

Since the economic deregulation of freight transport operations internationally, it has been necessary to have a workable knowledge and an understanding of the types of freight wagons that can help to be instrumental in the efficient and effective market participation of rail technology in the freight transport market. Unfortunately the rail wagon classification of the International Union of Railways does not give sufficient guidance in this respect. In the light of this it was decided to conduct an investigation to determine which types of rail wagons are manufactured and operated most internationally, and to identify the main determinants of rail wagon design.

1.2. Research method

The investigation was performed through a literature¹⁷ and internet¹⁸ search, complemented with

detailed field visits to cities and freight rail terminals in the world where large-scale freight rail operations take place, and through interviews with representatives of major rail operators. Major rail operations and rail operators in the following places were visited: Atlanta, Baltimore, Boston, College Station, Chicago, Montreal, New York, San Francisco and Seattle in North America; Bremen, Frankfurt, Hamburg and Rotterdam in Europe; Auckland, Brisbane, Sydney and Wellington in Australasia; Cape Town, Casablanca, Durban, Johannesburg, Marrakesh, Richards Bay and Saldanha Bay in Africa; and Beijing, Busan, Hong Kong, Shanghai and Singapore in Asia.

2. WAGON DEVELOPMENT

Since rail transport was invented in the early part of the 19th century, specialised rail wagons have been developed to transport every type of freight. Although a variety of wagon types are in use to handle different types of freight, all wagons in a regional network typically have standardised width between the wheels, couplers and other fittings, such as hoses for air brakes, allowing different wagon types to be assembled into trains. For tracking and identification purposes, wagons are generally assigned a unique identifier, typically a *Union Internationale des Chemins de fer* (UIC) (English: International Union of Railways) wagon number, or in North America, a company reporting mark together with a company-specific serial number. Wagon numbers are key data for railway operations. They enable a railway wagon to be

17 The following published work dealing with rail transport governance, dictionaries, glossaries and catalogues have been consulted in the compilation of this paper: De Bod, Havenga and Pienaar, 2011; Havenga and Pienaar, 2011; Havenga and Pienaar, 2012; Hinkelman, 2013; Pienaar, De Bod and Havenga; South African Transport Services, 1982; South African Transport Services, 1985; RailNetEurope (RNE), 2014; Railway Technical Web Pages: 2014. Transnet Freight Rail (TFR), 2016; University of Birmingham and Network Rail: 2011

18 The following internet sites of rail wagon manufacturers have been consulted in the compilation of this paper: Astra Rail Industries: www.astrarail.com; DB Schenker: www.dbcargo.com; Indiamart: <http://dir.indiamart.com>; Kiruna Wagon: www.kirunawagon.com; NetworkRail: www.networkrail.co.za; Railteco: www.railteco.com; Railway Directory: Worldwide railway data: www.railwaydirectory.net; Surtees

Railway Supplies: www.surtees.co.za; The Greenbrier Companies: www.gbrx.com; Trinity Rail: www.trinityrail.com

positively identified, and form a common language between railway operators, infrastructure companies and state authorities. The complete wagon number comprises 12 digits. The individual digits have the following meaning: digits 1-2: type of vehicle and indication of the capacity to work on diverse systems (i.e. interoperability); digits 3-4: country code; digits 5-8: vehicle type information; digits 9-11: individual running number (serial number); and digit 12: self-check digit¹⁹.

The UIC list of rail wagons contains 13 wagon classes. Four of them, however, no longer exist for official classification purposes and lately the list distinguishes nine broad classes, within which many variations of each. The nine different UIC classes of wagons can be listed as follows²⁰.

(1) **Open wagons** are designed primarily for the transportation of bulk goods that are not weather-sensitive. The UIC divides open wagons into two subclasses: open wagons of ordinary design and open wagons of special design. **Open wagons of ordinary design** (UIC Class E) have a solid flat floor, with sides that are either solid or with doors on each side. **Open wagons of special design** (UIC Class F) are self-discharging hopper wagons that use unloading by gravity.

(2) **Covered wagons** (UIC Class G) are fully enclosed, with their sides and fixed roof forming a van, and are used mainly for the transportation of part-load consignments.

(3) **Refrigerated wagons** (UIC Class I) are insulated, fully enclosed wagons, which are either cooled by a cooling medium, or are equipped with their own cooling system.

(4) **Flat wagons** (UIC Classes K and R) either have no sides or low ones no higher than 60 cm. These include wagons with individual axles (Class K) and bogie wagons (Class R). Flat wagons have a flat, usually full-length, deck (or two decks in the case of motorcar wagons) and little or no superstructure.

(5) **Wagons with an opening roof** (UIC Class T) either have a sliding or rolling roof.

(6) **Special wagons are classified by** the UIC groups in a single group, namely Class U. These wagon types are as follows:

- Dual coupling wagons for joining wagons with different coupling systems;
- Trials (i.e. experimental) vehicles for intermodal transport;
- Self-discharging hopper wagons with loading hatches and bogies (which distinguishes them from wagons with an opening roof in UIC Class T); and

- Low-loading wagons.

(7) **Tank wagons** (UIC Class Z) are designed to transport liquid commodities, gas and powders/pellets in tanks that form an integral part of the underframe which supports the tank.

(8) **Spine wagons** (UIC Classes L and S) are designed to carry intermodal containers. These include wagons with individual axles (Class L) and bogie wagons (Class S).

(9) **Open wagons for special purposes** (UIC Class O) include (a) departmental wagons; (b) ferry wagons; (c) mixed open, flat wagons; and (d) mineral wagons. **Departmental wagons** are used by railway

administrations exclusively for their own internal utility purposes. They are special railway vehicles used to support the engineering functions of the railway, typically to maintain railway track and the overhead catenary (i.e. they are not applied commercially). **Ferry wagons** are covered goods wagons designed for goods services between the European continent and the United Kingdom. These wagons have to comply with the smaller loading gauge in the United Kingdom and therefore have less loading volume than the equivalent wagon for services on continental Europe. **Mixed open, flat wagons** are equipped with folding sides or stakes, and can be used either as flat wagons or as open goods wagons (to be distinguished from the wagons in Classes E and F). **Mineral wagons** are small open-topped wagons used in the United Kingdom to carry mine products, mainly coal, ores and minerals.

The nine wagon types incorporated in the UIC classification system listed above (a) are not all used internationally commercially; and (b) also include wagon types that are no longer manufactured but are still operated in certain UIC member countries because of their longevity. The UIC's instructions are sometimes interpreted differently by the various railway administrations, so that it could happen that almost identical wagons are grouped into different classes. In addition, wagons may occasionally have to be reclassified after slight modifications. For example, an E Class wagon could become an F Class simply by having a door welded onto it.

3. THE MOST IMPORTANT DETERMINANTS OF RAIL WAGON DESIGN

Rail transport competes with road transport for break-bulk and containerised freight. Because the unit cost decreases when output capacity increases, rail transport gains substantial economies of scale (mainly through advantages of density and distance) with high utilisation - and even more so in the case of a double-track operation with long trains. Economies of density exist when the total cost to transport units of freight from their points of departure to their intended destinations decreases by increasing utilisation of the existing vehicle fleet and infrastructure capacity within a market area of given size. Economies of density are enhanced by (1) using high-capacity technology to carry and handle large bulk loads; (2) minimising loading and unloading times; (3) utilising traffic consolidation; and (4) maximising the immediate and continuous utilisation of vehicles. Immediate utilisation refers to the measure to which the carrying capacity of vehicles is utilised, while continuous utilisation refers to the number of revenue-kilometres or revenue-trips covered per time period²¹.

This type of economy stems from the fact that one can serve the largest possible portion of a market with the same technology. The same volume of throughput occurs, but the movement is concentrated (or consolidated) into one process, permitting more intensive use of the capital involved.

To achieve economies of density, one usually needs specialised technology to handle large volumes of a specific or homogeneous type of

19 Pienaar, De Bod and Havenga, 2012: 16
20 Goods wagon, 2015

21 Pienaar, De Bod and Havenga, 2012: 16

goods. The inherent danger of this is the empty return trip. To reap the optimum rewards of specialisation, handling equipment at terminals should allow for rapid loading and unloading of freight in order to maximise the number of full vehicle load-kilometres per unit of time. Economies of density necessitate the maximum utilisation of large, durable equipment over as long a period as possible.

Rail wagon manufacturers offer a variety of purpose-built models to best suit rail transport operators' specific operational needs. The investigation indicated that the three most important of these needs are (1) the characteristics of the freight conveyed; (2) physical railway characteristics; and (3) freight-handling technology at terminals.

3.1. Freight Characteristics

The characteristics of freight, for example, its mass, size, perishability, fragility and sensitivity to the elements, will dictate the physical characteristics and features of a rail wagon.

Goods can be grouped according to the stage they have reached in the series of processes within the supply chain of a product, extending from primary production to consumption, or end use. These groups are raw materials, semi-finished goods and finished goods:

- **Raw materials** are the primary output of agriculture (e.g. crop harvests and products stemming from livestock); forestry (e.g. timber); fishing; mining (dry products, e.g. coal and iron ore, and liquid products, mainly crude oil).

- **Semi-finished goods** are in the process of being converted from raw materials to finished goods, but are not yet in a form suitable for consumption or use.

- **Finished goods** have been processed (e.g. manufactured and assembled) into the form required for final consumption or intermediate use.

Any type of goods can be conveyed by rail transport and the variety of goods wagons available is adequately diverse and specialised to accommodate the different types of raw materials, semi-finished goods and finished physical products. Trains can carry large and high-density commodities and bulk consignments over long distances at low cost. Rail transport is well suited, therefore, to carrying raw materials and semi-finished goods. The introduction of containers has promoted the conveyance of high-value finished physical products. In the market for bulk, long-distance transport of raw materials throughput and price are more important to the client than short transit time and punctual delivery times. For example, as long as stockpiles of iron ore or coal at the destination point are sufficient, the arrival times of individual trains are not important. However, in many transport market segments, such as containers and parcels, rail transport is losing ground because road freight carriers offer regular, shorter and more consistent (reliable) transit times, and more accessible service.

Bulk freight constitutes the majority of tonnage carried by most freight railway operators. Bulk freight is transported unpacked in large quantities. Dry commodities are usually loaded into open wagons by being dropped from chutes

mounted at silos, by conveyor belts or with shovel buckets, while liquid commodities are poured with a spout or pumped through pipe connections into tank wagons. Gaseous and acidic commodities are loaded into tank wagons pneumatically through piping equipment.

Bulk dry commodities - mainly mining products such as coal, all types of metal ore, crushed stone, gravel and sand - are carried in (a) open self-discharging hopper wagons unloaded by gravity through funnel-shaped receptacles (hoppers) on the undercarriage of the wagon; (b) ordinary open wagons with solid sides that can be turned upside down at the unloading point; and (c) ordinary open wagons with securable sturdy side flaps and doors that can be tilted both ways at unloading points. Ordinary open wagons also carry bulk goods that are unloaded through shovelling. The latter commodities are mainly scrap metal and timber. Bulk freight commodities that must be protected from the elements, such as grain, sugar and fertiliser, are carried in closed hopper wagons and standard open wagons tightly covered with tarpaulins.

Bulk fluids (i.e. liquids and gases) are transported in tanks wagons. Common commodities carried in tank wagons include crude oil, refined petroleum products, heating oil, chemicals (mostly sulphuric acid, phosphoric acid, hydrochloric acid, ferric chloride and hydrofluosilic acid), slurried substances, liquid foodstuffs, alcohol, wine and, in exceptional circumstances, also potable water. Tank wagons are manufactured with commodity-specific linings and coatings to protect tank shell integrity and commodity purity.

Container freight transport is rapidly gaining market share over the traditional break-bulk method of wagon-load rail carriage. Semi-finished and finished items that can fit into standard intermodal containers on container wagons (flat wagons and well wagons) in unit trains and also as separate wagons in wagon-load trains have become the dominant type of non-bulk haulage. Rail transport operators internationally use standard-size containers that are 6,0 m or 12,0 m long, 2,4 m wide and 2,4 m or 2,6 m high, making them suitable for intermodal transport.

Various container types are available to meet the needs of the following freight types and packages:

- (1) General-purpose containers for boxes, cases, wrapped pallets, bags, drums, etc.;

- (2) High cube containers for bulk commodities and items taller than 2,4 metres;

- (3) Open-top containers for tall indivisible items exceeding a height of 2,6 metres;

- (4) Flat-rack containers for out-of-gauge cargo;

- (5) Refrigerated containers for perishable goods;

- (6) Ventilated containers for products requiring ventilation (e.g. to retard the ripening of fresh produce);

- (7) Tank containers for liquids and gas;

- (8) Insulated containers to avoid environmental contamination or impact;

- (9) Platform containers for barrels, drums, cable spools, machinery and processed timber;

- (10) Collapsible containers - for lower cost of returning containers to owners.

Break-bulk freight:

Various freight types that are not suited for containerisation or bulk carriage are transported in special wagons custom-designed for the freight²². The most prominent of these are described below.

- Moisture-susceptible goods that have to be transported in fully enclosed wagons, commonly known as “covered wagons”. These wagons are designed to carry break-bulk, mostly boxed, crated, bagged, wrapped and palletised freight of all kinds. Common commodities transported are paper products, wooden products (e.g. furniture), canned goods and food products. The payload is typically made up of less-than-wagon-load and less-than-container-load shipments. Covered wagons are often equipped with various interior loading devices, for example belt rails and moveable bulkheads, to secure loads.

- Goods that require certain temperatures, ranging between freezing and normal room temperature, during transportation can be carried in refrigerated wagons/vans; however, refrigerated containers are becoming more dominant. Goods types that require refrigerated carriages are perishable items such as vegetables, fruit, juices, dairy products, red meat, poultry and fish. Some shipments of fruit and vegetables require only insulated and ventilated enclosure to retard the ripening process. Meat wagons are equipped with specialised rails for animal carcasses. Dairy and poultry products require specialised interior racks to ensure cooled air circulation.

- Heavy items that are not subject to damage by the elements (e.g. marble and granite blocks and uncontainerised indivisible oversized items) are carried on flat wagons.

- Uncontainerised oversized items, for example transformers, agricultural equipment, machinery and road vehicles, that would exceed height restrictions if carried on standard open wagons and flat wagons are often carried by well wagons.

- Extra-heavy and oversized loads are carried in Schnabel wagons. These wagons are used to move very large items that would exceed the loading gauge and heavy objects that would exceed mass carrying capacity if they were loaded onto any other type of goods wagon. Such loads typically include combine grain harvesters, industrial boilers, generators, large machinery, huge transformers, armoured military equipment and bulky rock items.

- Metal objects, for example steel ingots, metal sheets, coiled steel, pipes, bundled and compressed scrap, and palletised hardware and building material, are transported in standard open wagons.

- General goods that are packed in bags can be carried in open wagons with high sides. Weather-sensitive goods can be transported in waterproof bags, otherwise the wagons can be covered with tarpaulins if necessary.

- Baled goods are carried on open wagons equipped with stanchions on the sides and with the loads covered with tarpaulins.

- Long items, such as logs, poles and steel rods and rails, can be carried by long open wagons equipped with stanchions on the sides or along the middle of the deck, in which case the wagons are referred to as “centre partition wagons”.

- Light road vehicles, mostly motorcars, station-wagons, panel vans, minibuses and light trucks, are transported in open or closed motorcar wagons. After the vehicles are driven on, they are secured/fastened during transit and then driven off the wagons at the destination station, using a fold-up ramp attached to the wagon.

3.2. Physical Railway Characteristics

The results of the investigation indicate that the following physical railway characteristics influence wagon design: (a) quality and composition of railway beds; (b) curvature; (c) track; (d) railway gauge; and (e) bridges, tunnels and overhead traction wires.

- The quality and composition of railway beds affect the gross mass and operating speed of a rail wagon.

- Track curvature affects turning radius requirements and the maximum length and axle configuration of wagons. The length of wagons is limited by their structural robustness to withstand the pressure exerted by payload mass on those wagon sections not directly supported by sets of axles and wheels, and by the maximum axle mass loads that railway infrastructure can accommodate.

- Track type determines wheel requirements.

- Track gauge determines the width between wheels and therefore axle length. The width of rail wagons is limited by the gauge of the railway line. Efficiency requires that the same gauge be used throughout the system.

- Bridges, tunnels and overhead traction wires determine the loading gauge of the railway and therefore the maximum height and width of wagons (and their loads). The height of wagon loads is limited by overhead clearances along the way.

3.3. Type of Freight Terminal Handling Equipment

Freight-handling technology at terminals dictates the loading and unloading features of a wagon. Rail freight terminals can be divided functionally into four broad classes²³: (1) break-bulk rail terminals; (2) bulk rail terminals; (3) roll-on/roll-off rail terminals; and (4) intermodal terminals.

Break-bulk rail terminals: These terminals are used by trains that carry freight items packed in non-standard containers. Break-bulk terminals often have freight platforms beside their sidings for loading and unloading freight into/from rail wagons, which is mostly done by forklift trucks. On loading sidings there may be fixed facilities such as cranes, roller-bed conveyors and conventional conveyor belts, or mobile equipment such as forklift trucks, wheeled ramps, manoeuvrable roller-bed conveyors and conveyor belts, and truck-mounted cranes. Forklift trucks, wheeled ramps and manoeuvrable break-bulk conveyor belts are used to handle freight whenever vehicles are loaded and unloaded from the side, and cranes are used when (open) wagons are loaded from the top.

Bulk rail terminals: These terminals are generally designed to be commodity-specific and designed either to receive loaded bulk commodity wagons (normally in unit trains) or to dispatch empty bulk commodity wagons/unit trains. Three

22 Symonds Group, 2001: 2

23 Rodrigue, 2013: 143–145

notable examples are: (1) ore departure terminals at mines designed and equipped to store raw material and load open wagons, and bulk ore destination stations equipped to receive loaded open wagons, unload the wagons, stockpile their payloads and to convey the stockpiled ore via belts to waiting ships or to beneficiation facilities; (2) oil refineries and chemical production plants designed and equipped to produce petroleum and chemical products, and store them in adjacent tank farms where rail tank wagons are loaded either pneumatically or by pouring through a top hatch; and (3) grain elevators used to store, mix and load grain into covered hoppers or other suitable wagons.

In the case of mining products, the development of (a) self-discharging wagons; (b) side-tipping open wagons; and (c) open wagons that could be turned upside down went along with the development of automated loading and unloading facilities and related materials-handling equipment, such as conveyor belts that remove the unloaded freight, at bulk rail terminals.

Self-discharging wagons: These wagons are unloaded by gravity. They are equipped with opening hatches on the underside or on the sides to discharge the load by gravity through funnel-shaped receptacles (hoppers) on the undercarriage of the wagon (commonly known as hopper wagons).

Side-tipping open wagons: These wagons have hydraulic, pneumatic or electronic tipping equipment that enables the wagon body to be lifted on one side. Side-tipping wagons are able to tip to both sides or to one side only. In order to prevent wagons from falling over during the tipping operation, they are equipped with track pinch bars with which they can be securely anchored to the rails.

Open wagons that could be turned upside down: At suitably equipped terminals, these wagons can be emptied by being turned about their longitudinal axis, which requires a very robust wagon underframe. Sometimes the wagons are fitted with rotatable couplings so that they do not have to be individually uncoupled. Wagon tippers simply tip the wagon upside down to unload it.

In the case of tank wagon unloading, the reception equipment at the arrival terminal must be able to handle (a) commodities that need to be unloaded pneumatically from the top of the wagon (such as the various types of acid, gas and volatile substances); (b) commodities that are unloaded pneumatically from the bottom of the wagon (such as slurrified substances, and powdered or pelletised material); (c) liquids that thicken when cooled down and need to be heated for decanting (such as oil, tallow, tar/bitumen and creosote); and (d) liquids that can flow freely from the bottom of the wagon without the necessity for pressurised pumping and being heated, for example white petroleum products and most potable liquids.

Roll-on/roll-off terminals: These terminals are used by unit trains transporting light road vehicles, mostly cars, where the vehicles are rolled (driven) into and out of motorcar wagons using a fold-up ramp attached to the wagons. Motorcar wagons are the only wagons that are loaded and unloaded through their ends.

Intermodal terminals: The implementation of standardised intermodal container transport has in

recent decades substantially enhanced the practice of transferring loads between rail wagons and road trucks, as well as promoting the close integration of freight rail transport and sea transport at port terminals.

Containerisation has significantly improved the productivity of rail terminals, since it permits quick loading, unloading and transloading of the containers, thus tying up less terminal rail capacity. This gain in productivity is achieved through good access to a port and/or the road system, supported through automated handling operations to meet the transshipment demands of modern intermodal rail operations. However, the gain in intermodal terminal productivity comes at the cost of fixed investment in terminal facilities and handling equipment. Firstly, intermodal operations require capital investments at the terminals in paved platforms and surfaces for container handling equipment and storage space for containers. Secondly, depending on the type of operation, specific intermodal handling equipment is used. The choice of equipment is dependent on (a) equipment-specific factors, namely: (i) capital investment required; (ii) equipment maintenance and upkeep; and (iii) the employment of specialised equipment operators; and (b) operational determinants: (i) mainly productivity objectives; (ii) traffic volume; (iii) the need to directly transload containers between vehicles (rail, road and water) or to store containers intermediately between reception; and (iv) and container stacking density during storage.

Container handling equipment can include side lifters, front-end container lifters, reach stackers, straddle carriers (including grappler lifts) and gantry cranes. These are discussed in turn²⁴.

• **Side lifters** are road-going vehicles with hydraulic powered cranes fitted at each end of their chassis to hoist and transport standard intermodal containers. The cranes are designed to lift containers from or place containers on the ground, as well as to move railway wagons, road vehicles, ro-ro vessels and low container stacks. Owing to their mobility, side lifters are able to move containers to and from any accessible location in a freight terminal and also to engage in the collection and delivery of containers at sites separated from the terminal. If side lifters are not available at terminals, containers can be moved around with the aid of vertical loading equipment; however, they move at a slower speed. Although side lifters require a special chassis, they are less expensive per twenty-foot-equivalent-unit (TEU) handled than other handling equipment because of their lower capital, infrastructure, maintenance and operating costs, which result from their relative ease of operation, lesser need for strong and smooth pavement service and higher handling speeds. Side lifters require a low level of skill to operate.

• **Front-end lifters** operate similarly to reach stackers, but they cannot lift containers from as tall container stacks as reach stackers can. Loading capabilities for front-end lifts are up to 40 tons. Because of poor mass distribution and torsional movements, rigid pavement surfaces are required at terminals that employ front-end container lifting equipment. They are therefore relatively inefficient

²⁴ Hinkelman, 2013: 100, 166, 185; Pienaar and Vogt, 2016: Chapter 13; Rickett, 2013: 26; Rushton, Croucher and Baker, 2014: 423–425

as far as land utilisation is concerned. Their capital and maintenance costs are comparatively moderate, and in view of their medium level of skills required to operate, so is their operational cost.

- **Reach stackers** are high-capacity container trucks fitted with a lifting arm and a spreader beam at the end of it to lift containers onto and from rail wagons or road vehicles. Reach stackers can stack containers up to six high, and can place a container in a rear stack by reaching over a low stack, resulting in high land utilisation. The spreader beam of a reach stacker lifts a container with twist-locking devices that attach to its top corners. Like gantry cranes and straddle carriers, reach stackers require a strong pavement foundation and a smooth surface for operation. They have moderate operating and maintenance costs, and require a medium level of skill to operate.

- **Straddle carriers** are special types of mobile cranes developed to straddle, lift, move, place and stack containers at intermodal terminals. By straddling the container, this device carries the container within the structure of the crane. The carrier lifts the container using a spreader and twist-locks, and then moves it to another location (it has wheels on each of the four corners of its frame). It is a versatile mover and stacker of containers, and can achieve quick turnaround times owing to its ability to hoist loads while moving. The straddling allows it to move and handle containers at higher speeds than the reach stacker, which has to balance the container against a counterweight while moving. The limitation of the straddle carrier is that containers need to be stacked in such a way that the frame of the carrier can move over the container stack, making an aisle necessary between every stack. Although the infrastructure cost of straddle carriers is lower than that of gantry cranes, it is higher than that of side lifters because they require stronger pavement structure than other smaller handling equipment. Although straddle carriers have relatively medium capital costs, their maintenance costs are high. The total cost of straddle carriers is substantially higher than that of reach stackers, but as a result of their versatility and swift operational ability, they are therefore only used in large, high-

volume container terminals. They require a high level of skill to operate. **Grappler lifts** are similar to straddle carriers except that they grip the bottom of the container rather than the top.

- **Gantry cranes** are used for directly transferring containers either (a) between sea-going vessels and rail wagons and, to a lesser extent, road vehicles; or (b) within intermodal rail terminals between rail wagons over a series of rails, or between rail wagons and road vehicles. Gantry cranes are equipped with a large boom bridging the distance between the ship's cargo hold and quayside freight vehicles, or bridging the distance between the land vehicles within the intermodal facility. The container-hoisting device moves back and forth along the spanning boom. When direct transloading is not possible at a particular time, the space below the crane can be utilised for track-side stacking of containers for later loading by rail wagons. Quayside container gantry cranes are mounted on rails and move parallel to the full length of a container vessel, while gantry cranes that transload containers between different rail wagons, or between rail wagons and road vehicles within intermodal rail terminals, are either mounted on rails or are rubber-tyred, moving alongside the full length of the terminal rail sidings and pathways for road vehicles. Rail-mounted gantries can operate over series of up to ten rails, while rubber-tyred gantries can operate over a series of up to four rail tracks. Both gantry types can stack containers in storage areas up to approximately 1 000 TEUs per hectare.

Of all the types of container-lifting equipment, gantry cranes achieve the highest land utilisation, because they can traverse several rows of containers, and can lift and place containers on tall stacks. Gantry cranes have a high equipment capital cost, and they require a strong pavement foundation, making the overall initial facility cost higher as well. Compared to straddle carriers and front-end loaders, gantry cranes have low unit maintenance costs but high capital costs, and require a high level of skill to operate. Table 1 contains a summary of salient operational aspects of container-handling equipment used in intermodal terminals.

Table 1. Summary of container-handling equipment used in intermodal terminals²⁵

Type	Operating skill required	Total cost	Land utilisation	Highest container layer reach	Handling capability (tons)
Side lifter	Low	Low	Low	2	32
Front-end loader	Medium	Medium	Medium	3	42
Reach stacker	Medium	Medium	High	6	36
Straddle carrier	High	Medium	High	6	36
Gantry crane	High	High	High(est)	8	48

25 Hinkelman, 2013: 100, 166, 185; Pienaar and Vogt, 2016: Chapter 13; Rickett, 2013: 26; Rushton, Croucher and Baker, 2014: 423–425

4. RAIL WAGONS MOST COMMONLY USED INTERNATIONALLY

The research has indicated that there are nine contemporary rail wagon types manufactured and commonly used internationally. These are: (1) covered wagon/van; (2) refrigerated wagon/van; (3) flat wagon; (4) tank wagon; (5) container wagon; (6) open wagon; (7) hopper wagon; (8) side stanchion and centre partition wagon; and (9) motorcar wagon. The nine contemporary wagon types used most in rail freight transport internationally are discussed in turn.

- A **covered wagon/van** (UIC Class G) is designed for the transportation of moisture-susceptible goods and therefore has fully enclosed sides, with sliding doors on one or both sides, and a fixed roof. Covered wagons are designed to carry break-bulk, mostly boxed, crated, bagged and palletised freight of all kinds. The payload is typically made up of less-than-wagon-load shipments. Covered wagons are often equipped with various interior loading devices, for example belt rails and moveable bulkheads, to secure loads. Freight handling is conducted either manually or through the use of forklift trucks, wheeled ramps and manoeuvrable break-bulk roller-bed conveyors and conventional conveyor belts. Covered wagons are loaded and unloaded from the side.

- A **refrigerated wagon/van** (UIC Class I) is a completely enclosed, insulated wagon with mechanical cooling equipment or a cooling medium, such as carbon dioxide, designed to carry perishable freight at desired temperatures. Typical freight carried includes vegetables, fruit, juices, dairy products, red meat, poultry and fish. Some shipments of fruit and vegetables require only an insulated and ventilated enclosure to retard the ripening process. Meat wagons are equipped with specialised rails for animal carcasses. Dairy and poultry products require specialised interior racks to ensure cooled air circulation. Refrigerated wagons are loaded and unloaded from the side. Freight handling is conducted either manually or through the use of forklift trucks, wheeled ramps and manoeuvrable break-bulk conveyor belts.

- **Flat wagons** (UIC Classes K, L, R and S) consist of an open, fully accessible solid flat deck on four wheels (Class K) or a pair of bogies (Class R) or, instead of featuring a solid flat deck, flat wagons may have sturdy sills with lateral and diagonal connecting arms which form a "spine" chassis that supports the payload on four wheels (Class L) or a pair of bogies (Class S). Flat wagons are designed to transport goods items that must be loaded from the side or top because they are too large or cumbersome to load in enclosed wagons. The sides of the deck can include pockets for stakes or tie-down points to secure loads. Flat wagons are used (a) to carry standard intermodal containers or road trailers as part of intermodal freight transport shipping; and (b) non-containerised oversized items that are not vulnerable to damage from the elements.

- **Tank wagons** (UIC Class Z) are suitable for the carriage of a wide variety of bulk liquids, gas and powders/pellets in tanks integrated into wagons. Common commodities carried in tank wagons include refined petroleum products, chemicals,

heating oil, acids (mostly sulphuric acid, phosphoric acid, hydrochloric acid, ferric chloride and hydrofluosilic acid), slurrified substances and liquid foodstuffs, liquor, wine and alcohol. Tank wagons are manufactured with commodity-specific linings and coatings resistant to chemical reaction to protect the tank shell, equipment integrity and commodity purity. Commodity loading is performed pneumatically or by having commodities poured from the top. Unloading is done in several ways: (a) pneumatically from the top of the wagon (such as the various types of acid, gas and volatile substances); (b) pneumatically from the bottom of the wagon (such as slurrified substances and powdered/pelletised material); (c) heated with in-vehicle fitted heaters and decanted from the bottom (for liquids that thicken when cooled off, such as oil, tallow, tar and creosote); and (d) draining or pouring liquids that can flow freely from the bottom of the wagon without the necessity for pneumatic pumping and pre-heating (such as white petroleum products and most potable liquids).

- A **well wagon** (UIC Class U) is designed to carry intermodal containers on a depressed payload section (the "well"), mounted close to the rails between the wheel bogies of the wagon. This allows container stacking and high-cube containers to be carried lower than on a traditional flat wagon. Stability is enhanced as a result of the lower centre of gravity of the load, and sufficient vertical clearance is ensured. When stacked, the top container is held in place either by a bulkhead built into the wagon or through the use of inter-container connectors. The latter consist of a twist-lock and corner casting, which together form a standardised rotating connector for locking a container into place on a wagon and for lifting the containers by container cranes and side-lifts. Well wagons (also known as low-loading wagons) range from the relatively small two-axle to the largest low-loading 36-axle wagons (known as "Schnabel" wagons). Schnabel wagons consist of two separate sections. The load of the wagon is suspended between the two sections of the wagon by two carrying lifting arms. When a Schnabel wagon is empty, the lifting arms are connected and the wagon can operate as an ordinary low-floored wagon (well wagon) at normal freight train speeds. Schnabel wagons usually include hydraulic equipment able to reposition the load horizontally and vertically while travelling at very low speeds to avoid obstructions along the wagon's way. These wagons cannot operate safely on a narrow-gauge track and are only used on standard and broad-gauge tracks.

- **Open wagons** (UIC Class E) have open tops and are designed primarily for the transportation of bulk freight that is not moisture-retentive (mostly mining products), metal objects (like scrap metal, steel ingots, coiled steel, sheet steel and pipes) and lengthy items like wooden logs, poles and rods. Some of these wagons can either be partially tipped sideways to dump their payload (in which case the sides must have horizontally hinged or vertical flap doors), or be turned upside down to be emptied. This requires very robust and sturdy underframes and sides. Sometimes the wagons are fitted with rotatable couplings so that they do not have to be individually uncoupled, otherwise unloading is done by shovelling. Because bulk goods are often moved

in large quantities, these wagons are frequently used in unit trains.

- **Hopper wagons** are used to transport free-flowing, dry bulk commodities. The hopper wagon is distinguished from an open wagon in that it has opening hatches on the underside or on the sides to discharge its load. Hopper wagons are loaded from the top and unloaded by gravity through funnel-shaped receptacles (hoppers) on the undercarriage of the wagon. There are two main types of hopper wagons: open and covered. **Open hopper wagons** (UIC Class F) are used to transport commodities that may get wet and can dry out with few harmful effects, mostly mining products. **Covered hopper wagons** (UIC Class U) have sliding roofs for freight that must be protected from the elements, such as grain, sugar and fertiliser.

- **Side stanchion and centre partition wagons** (UIC Class O) feature stanchions on the sides of the deck or a longitudinal centre partition to which freight can be secured. Common goods items carried include logs, poles, masts, steel rods, steel rails and prefabricated lengthy building materials (e.g. roof trusses). **Side stanchion wagons** are also suitable to carry goods in baled form. In the case of **centre partition wagons**, the decks are canted towards the centre of the wagon with end-cushioning and floor risers suitable for packages without pre-attached dunnage. Centre partition wagons are designed to be loaded and unloaded from both sides; however, they must be loaded with half of the payload on one side of the partition and half on the other to avoid tipping over.

- A **motorcar wagon** (UIC Class S) is an enclosed or partly enclosed rail wagon designed to carry light road vehicles. Motorcar wagons feature adjustable decks that can be reconfigured as bi-level or tri-level to accommodate different vehicle shapes and sizes, onto which vehicles are driven at the departure terminal. They are secured/fastened during transit and then driven off the wagons at the destination station.

4. CONCLUSION

The study showed that it is necessary to have a workable knowledge and an understanding of the types of freight wagons that can help to be instrumental in the efficient and effective market participation of rail technology in the freight transport market. Rail wagon manufacturers offer a variety of purpose-built models to best suit rail transport operators' specific operational needs. The three most important of these needs are (1) the characteristics of the freight conveyed; (2) physical railway requirements; and (3) freight-handling technology at terminals. Freight-handling technology at terminals dictates the loading and unloading features of a wagon. Rail freight terminals can be divided functionally into four broad classes: (1) break-bulk rail terminals; (2) bulk rail terminals; (3) roll-on/roll-off rail terminals; and (4) intermodal terminals.

On land, rail transport has a competitive modal advantage in the market for bulk transport, and the mode competes with road transport for break-bulk and containerised freight. Because the unit cost decreases when output capacity increases, rail transport gains substantial economies of scale

(mainly through advantages of density and of distance) with high utilisation – and even more so in the case of a double-track operation with long trains. Economies of density are enhanced by (1) using high-capacity technology to carry and handle large bulk loads; (2) minimising loading and unloading times; (3) utilising traffic consolidation; and (4) maximising the immediate and continuous utilisation of vehicles. To achieve economies of density, one usually needs specialised technology to handle large volumes of a specific or homogeneous type of goods. The inherent danger of this is the empty return trip. To reap the optimum rewards of specialisation, handling equipment at terminals should allow for rapid loading and unloading of freight in order to maximise the number of full vehicle load-kilometres per unit of time. There are nine contemporary rail wagon types manufactured and commonly used internationally. These are identified in the paper.

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